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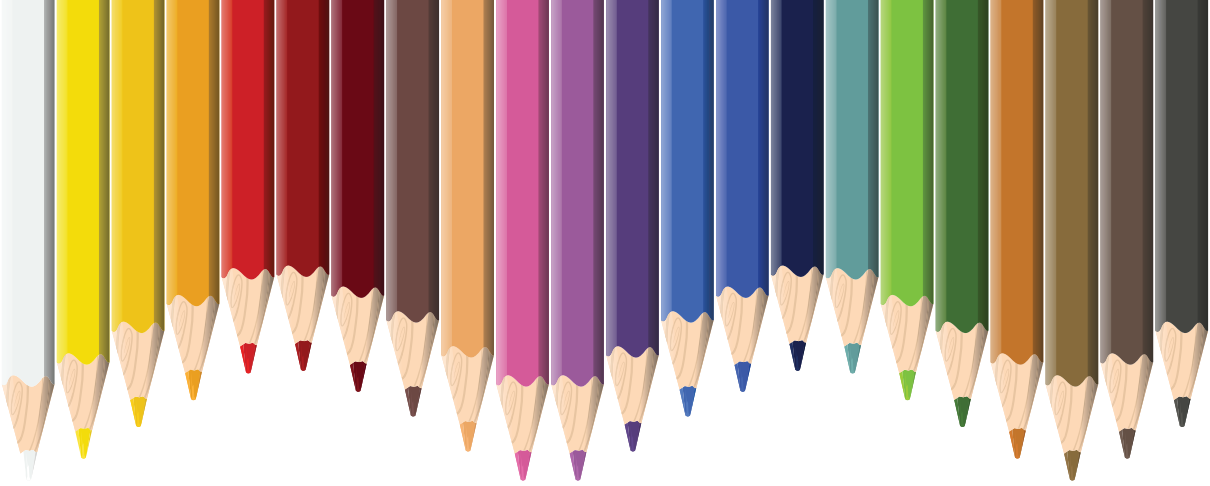

Chapter 1

PARASITE DIVERSITY OF FISHES IN TÜRKİYE – V. TREMATODA

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1. INTRODUCTION

Fish trematodes are a group of flatworms that are parasitic to fish. They belong to the class Trematoda, which is part of the phylum Platyhelminthes. They are heteroxenous parasites that have a multiple-host life cycle in which fish frequently serve as an intermediate or paratenic host (Ondračková et al. 2015). Mollusk serves as the first host while fish is the second intermediate host for the metacercarial stage of this group of parasites. In the complex life cycle strategy, the eggs of the trematodes are released into the water through the feces of infected fish. These eggs hatch into larvae, which are ingested by the mollusk. The larvae then develop into cercariae, which are released into the water and can infect fish that come into contact with them. The cercariae penetrate the skin of the fish and migrate to the internal organs, where they develop into adult trematodes (Paperna, 1996). Most trematodes are hermaphrodite, containing both male and female organs. They are dominant internal parasites of teleost fishes and the host specificity at the level of fish intermediate host is often low (Cribb et al. 2002). Infected small fish can readily be preyed upon by the definitive hosts of these parasites allowing the competition of the whole life cycle. The stable habitats in which both the free-living stages and intermediate hosts are capable of survival also favor this infection process. The complex multiple host-involved life cycle makes them sensitive to perturbed environments and this situation affects the level of infections by trematodes in their intermediate host fishes (Dzikowski et al. 2003).

In Türkiye, freshwater and marine environments are home to a total of 401 and 561 fish species, respectively, according to Faroese & Pauly (2022). Fish are a valuable source of food for human consumption. Due to the constant decrease in capture values in natural sources, some species, such as rainbow trout *Oncorhynchus mykiss*, European seabass *Dicentrarchus labrax*, and gilthead sea bream *Sparus aurata*, are now being cultured in either land-based culture facilities or net cages in lakes and seas to meet the increasing demand. Ornamental fish trade is another fast-growing industry in Türkiye, and either cultured individuals or imported ones are capturing more and more of the attention of hobbyists (Özer, 2022).

In the last few decades, researchers have investigated trematode parasites that infect fish in Türkiye. A large number of papers and checklists have been published on these parasites and their respective hosts in both freshwater and marine environments (Öktener, 2003, 2005, 2014, Özer, 2019, 2020, Özer & Öztürk, 2017, Öztürk & Özer, 2014). Recently, Özer (2021) published a comprehensive book that includes a host-parasite checklist based on all previous reports in Turkey. This chapter on trematode parasites of fish in Turkey is based on the data presented in this recent book, which includes individual publications on each trematode parasite species.

2. PARASITIC TREMATODE DIVERSITY OF FISHES IN TÜRKİYE

According to Özer (2021), a total of 144 trematode species were reported from all fish species from different environments in Türkiye and this was 19% of the whole parasite species reported from fishes in Türkiye (Figure 1). Among reported 144 trematode species, the highest number was from wild marine fishes (105), followed by wild freshwater fishes, cultured freshwater, and aquarium fishes (Figure 2).

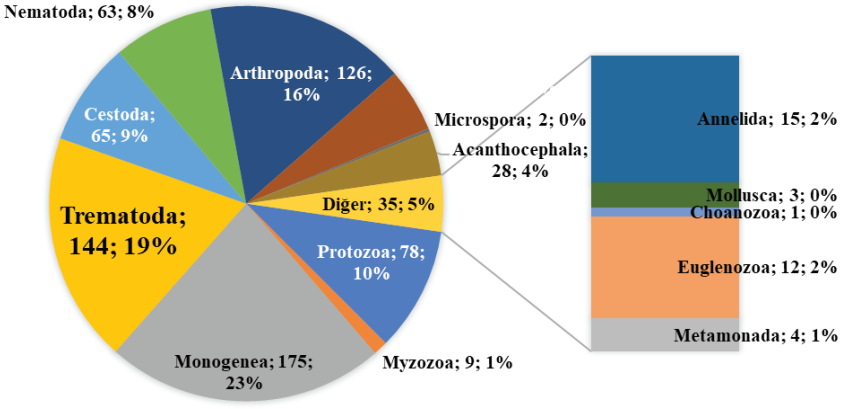


Figure 1. *Total number and percentage of trematode parasites reported from fishes in Türkiye.*

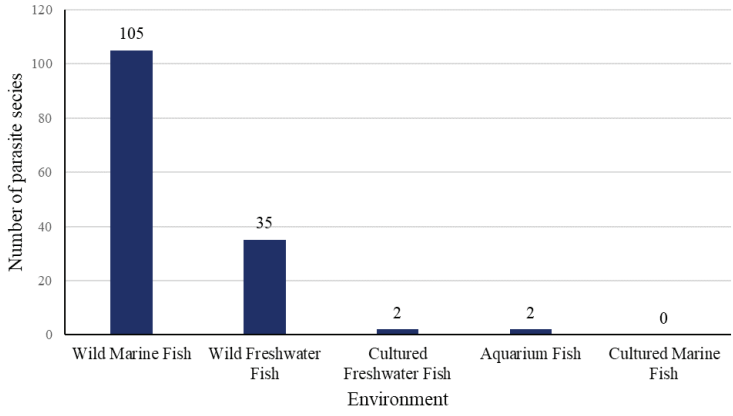


Figure 2. *The total number of trematode parasite species reported from marine, freshwater, and aquarium fishes in Türkiye.*

3. ParasitIC TREMATODE diversity of marine fishes

3.1. Wild marine fishes

Parasitic trematode diversity from wild marine fishes inhabiting the surrounding seas of Türkiye was very high and the highest number came from the Aegean Sea (55), followed by the Black Sea, the Sea of Marmara, and the Mediterranean Sea (Figure 3).

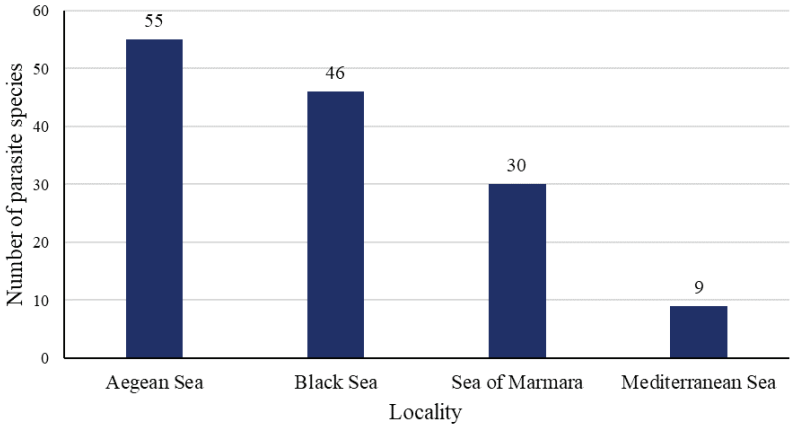


Figure 3. *The number of trematode species reported from wild marine fish species inhabited the surrounding seas of Türkiye.*

A very diverse wild marine fishes were reported to be the host for trematode parasites from the surrounding seas of Türkiye (Figure 4). The flathead grey mullet *Mugil cephalus* occupied 14 trematode species, followed by shore rockling *Gaidropsarus mediterraneus* (12), rusty blenny *Parablennius sanguinolentus* (9), golden grey mullet *Chelon auratus* (9) and the rest of fish species with different number of trematodes (Figure 4).

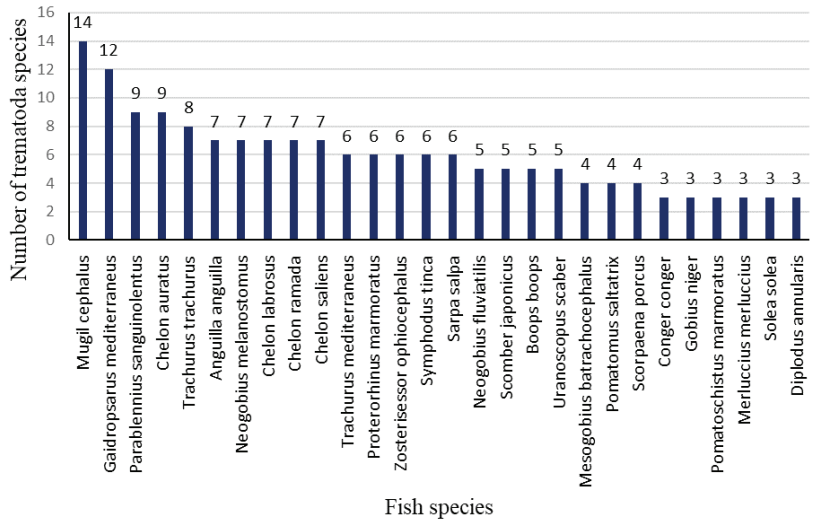


Figure 4. *The number of trematode species infesting the wild marine host fishes in Türkiye*

Parasitic trematodes reported from ≥3 wild marine fishes are illustrated in Figure 5 and it can be seen that *Helicometra fasciata* was the most occurred species infecting a total of 16 marine fish species, followed by *Lepocreadium album* (8 fish species), *Lecithochirium musculus* (6 fish species) and the rest had host numbers of between 3 and 5 (Figure 5). Other trematode species infecting a lesser number of fish hosts can be seen in Özer (2021).

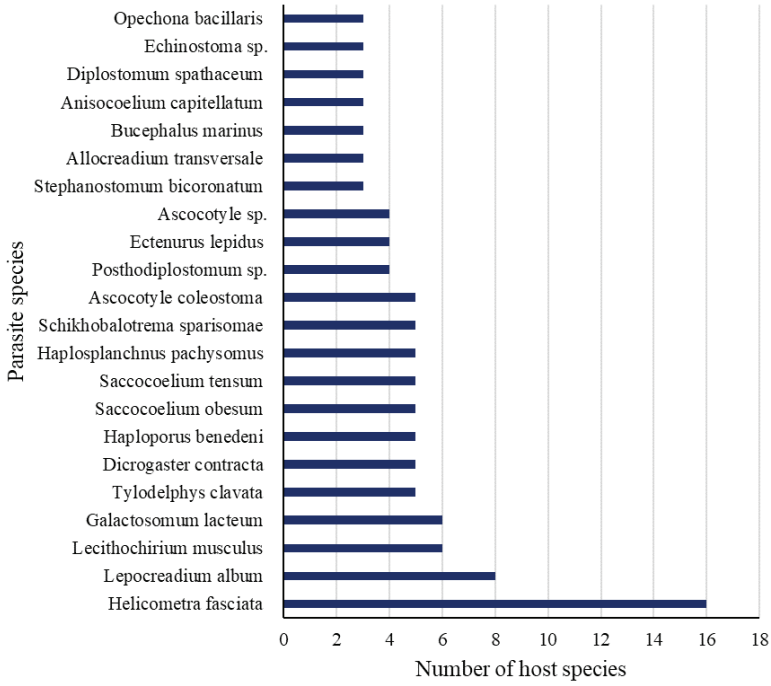


Figure 5. *The number of trematode species infecting ≥3 wild marine fish species in Türkiye*

3.2. Cultured marine fishes

Fish culture in marine environments in Türkiye is one of the main activities of fisheries. Seabass *Dicentrarchus labrax* and gilt-head sea bream *Sparus aurata* are the top cultured species in the Aegean and Black Sea and their total amounts of culture volumes are among the highest in Europe in the last decades. In recent years, Rainbow trout *Oncorhynchus mykiss* has been produced in the Black Sea during the last couple of years and some promising results are obtained throughout its culture. Surprisingly, there are no trematode species infecting any of either above-mentioned fish species or some other alternative ones. This situation may have arisen from the requirement for more hosts in their complete life cycle and it would be possible to encounter some trematodes in marine cultured fishes in Türkiye in the future.

4. ParasitIC TREMATODE diversity of freshwater fishes

4.1. Wild freshwater fish

Of the reported 35 trematode species in wild freshwater fishes, rudd *Scardinius erythrophthalmus* hosted the maximum number of species (12), followed by northern pike *Esox Lucius* (10), common carp *Cyprinus carpio* (9), vimba *Vimba vimba* (8) and white bream *Blicca bjoerkna* (8) (Figure 6). The rest of the fish species had a lesser number of trematode species (Figure 6).

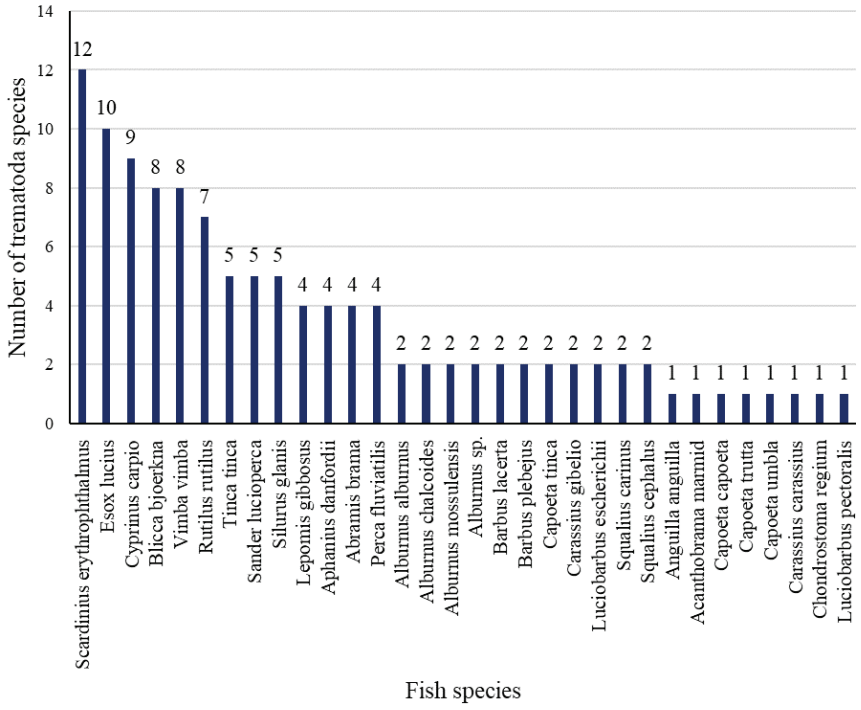


Figure 6. *The number of parasitic trematode species infecting the wild freshwater host fishes in Türkiye*

Trematode species reported from 4 and more wild freshwater fish host species in Türkiye are presented in Figure 7 and to see the lesser numbers of trematodes from different fish hosts, Özer (2021) can be consulted. *Diplostomum* sp was the most reported parasite from 34 fish host species, however, *Diplostomum* parasites allocated to *Diplostomum spathaceum* were also reported from 11 host species (Figure 7). As can be seen in Figure 7. *Thylodelphys clavata* and *Clinostomum complanatum* were also the other most reported trematode species in fishes in Türkiye. Lesser than 4 host species infecting parasites can be seen in Özer (2021).

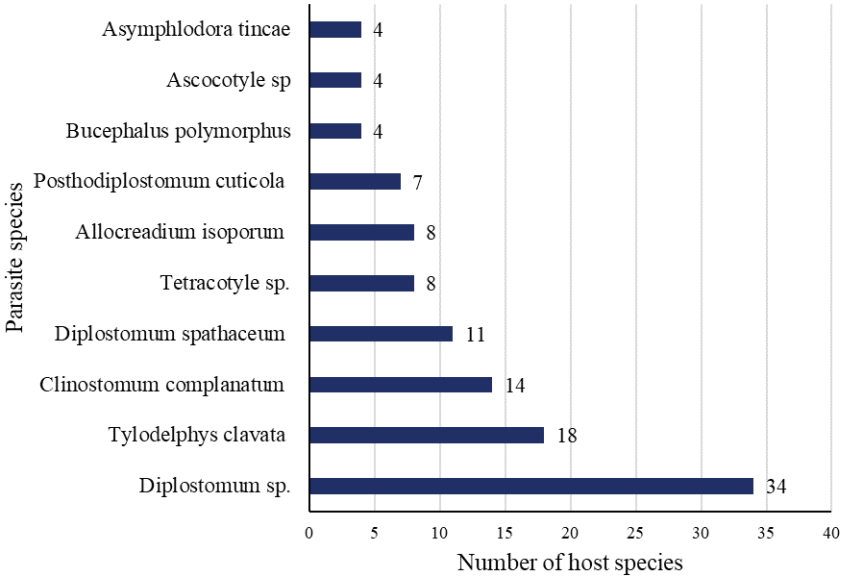


Figure 7. *The number of trematode species infecting wild freshwater fish species in Türkiye*

4.2. Cultured freshwater fish

In Türkiye, two commercially significant fish species, namely rainbow trout *Oncorhynchus mykiss* is the most intensively cultured species, and, common carp *Cyprinus carpio* is the other species cultured extensively. Thus far, only 2 trematode species, *Crepidostomum farionis* and a *Diplostomum* parasite not been assigned to a species, have been reported from *O. mykiss* (Özer, 2021).

5. PARASITIC TREMATODE DIVERSITY OF AQUARIUM FISHES

Ornamental fishes and aquarium fisheries are among the most popular sectors for hobbyists worldwide. Of the 32 ornamental fish species in Türkiye, a total of only 4 species, namely *Carassius auratus, Poecilia sphenops, Xiphophorus hellerii, Pangasius pangasius*, have been reported to be the host for trematode parasites (Özer, 2021). A member of *Centrocestus* not has been identified to species level has been reported from 3 host species while a member of *Transversotrema* was reported from only one host fish species (Özer, 2021).

6. PARASITIC TREMATODE INVESTIGATIONS ON FISHES IN TÜRKİYE AND RECOMMENDATIONS

This chapter about previously reported trematode parasites in wild and cultured host fishes in marine, freshwater, and aquariums in Türkiye provided up-to-date data based on the recent comprehensive work by Özer (2021). Trematode parasites of fishes are the second most specious group with 19% after monogenean parasites in Türkiye. Of the reported 144 trematode species, wild marine individuals dominated with 105 species and followed by another wild fishes in freshwater environments. The total 55 wild marine and 32 wild freshwater fish species reported to be the host for trematodes is very low when considering the reported 561 marine and 401 freshwater fish species in Türkiye by Froese & Pauly (2022). Thus, it is not known what the actual number of trematode species infecting host fishes in both surrounding seas and inland waters of Türkiye. In the future, however, more studies on trematode parasites of fishes will yield more results contributing to our current knowledge on this more host involving complex life cycle group of parasites.

References

Cribb, T.H., Chisholm, L.A., Bray, R.A. (2002). Diversity in the Monogenea and Digenea: does lifestyle matter? Int J Parasitol. 32: 321–8.

Dzikowski, R., Paperna, I., Diamant, A. (2003). Use of fish parasite species richness indices in analyzing anthropogenically impacted coastal marine ecosystems. Helgol Mar Res, 57: 220–227.

Froese, R., & Pauly, D. (2022). *FishBase.* World Wide Web electronic publication. www.fishbase.org, version (02/2022).

Ondračková, M., Hudcová, I., Dávidová, M., Adámek, Z., Kašný, M., Jurajda, P. (2015). Non-native gobies facilitate the transmission of *Bucephalus polymorphus* (Trematoda). Parasites & Vectors, 8: 382

Öktener, A. (2003). Checklist of metazoon parasites recorded in freshwater fish from Turkey, Zootaxa, 394: 1-28.

Öktener, A. (2005): A checklist of parasitic helminths reported from sixtyfive species of marine fish from Turkey including two new records of monogeneans. Zootaxa 1063: 33-52

Öktener, A. (2014). Revision of parasitic helminths reported in freshwater fish from Turkey with new records. Transylv. Rev. Syst. Ecol. Res. 16: 1–56.

Özer, A. (2019). *Invasive, Endemic Localized Fishes and Their Parasites*, 177 pp, İdeal Kültür Yayıncılık (In Turkish)

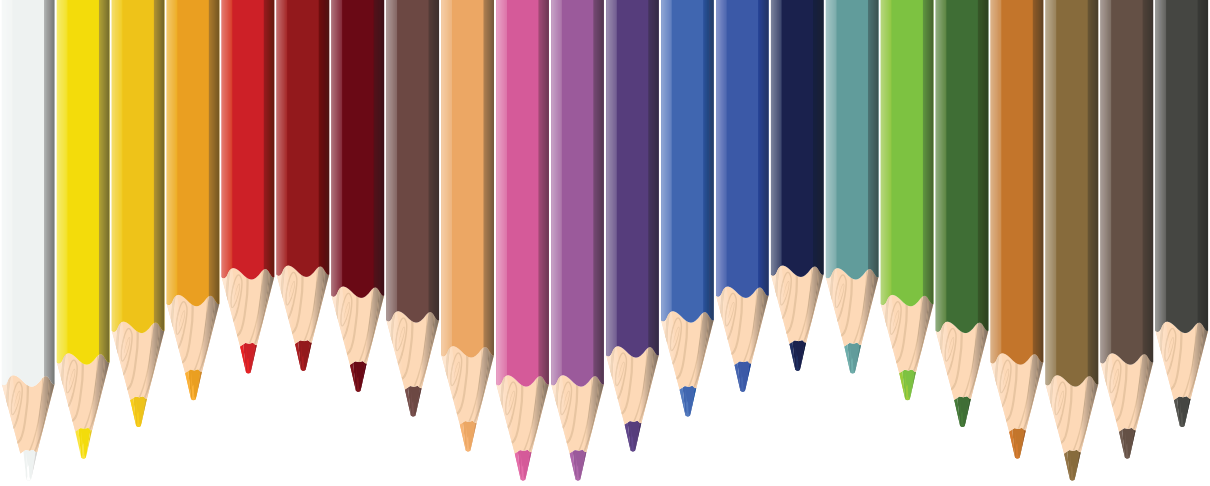
Özer, A. (2020). *Marine Fishes and Parasites*. İdeal Kültür Yayıncılık, 280 pp, (In Turkish)

Özer, A. (2021). *Checklist of Marine Freshwater and Aquarium Fish in Turkey*. Turkish Marine Research Foundation (TÜDAV), 311 pp, Publication No: 62.

Özer, A. (2022). Parasite Biodiversity of Marine, Freshwater and Aquarium Fishes in Turkey. (Editors; Akar, T., Daşdemir, İ., Cengizler, İ.), Current Research in Agriculture, Forestry and Aquaculture, Gece Kitaplığı, pp. 127-143.

Özer, A., & Öztürk T. (2017). Parasite Diversity of the Black Sea Fishes in Turkish Coastal Areas. (Eds: Sezgin, M., Bat, L., Ürkmez, D., Arıcı, E., Öztürk, B.), *In: Black Sea Marine Environment; The Turkish Shelf,* Turkish Marine Research Foundation (TÜDAV) Publication No: 46, pp. 289-309.

Paperna, l. (1996). Parasites, infections and diseases of fishes in Africa - An update CIFA Technical Paper. No.31. Rome, FAO. 220 p.



Chapter 2

MACHINE LEARNING APPLICATIONS IN SOIL QUALITY ASSESSMENT: A REVIEW.

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Introduction

With the increase in the world population, overuse of natural resources and the resulting increase in demand for food have made it inevitable to encounter problems such as climate change, deforestation and land degradation (Mouël and Forslund 2017). Systems' productivity capacity and the future of humanity is in big danger because of using the soil which is a non-renewable natural source to meet human needs (Costanza and Daly 1992).

The sustainability of the agricultural systems has become an international debate. For this reason, understanding and developing soil quality is a major step for considering these global issues (Lal, 2011). The sustainability of soil productivity functions, which is a crucial phenomenon for terrestrial ecosystems, is mostly related with understanding and monitoring the quality of soil properly. Organic matter, microbial activities, land use changes (Carter, 2002) and agricultural activities are so sensitive to any negative affect in soil functions (Emadi et al., 2009). In addition to this, soil properties are related to each other, but different agricultural management practices may cause different responses of soil in terms of productivity and quality (Raiesi, 2017).

Soil is a live, nonrenewable and natural resource for both human, plant, and animal life (Doran and Zeiss, 2000). By increasing world population, to get maximum yield from the per unit area has become a crucial factor for food security (Doran, 2002). In developing countries, towards economic development, lands are used inappropriately, so soil quality has become a serious issue as a result of this (Arshad and Martin, 2002). Increasing the amount of the land can be considered as a good idea for overcoming these problems, but, instead, focusing to heal the quality of soils is a better option (Rasheed et al., 1996; Yemefack et al., 2006).

Soil quality is expressed as sustainability of crop and animal production, providing an appropriate life area for human health and increasing the water and air quality in a soil where the natural and running ecosystem exists by the United States Department of Agriculture (USDA). It's crucial to assess the topsoil (0-20 cm) in terms of management applications because it represents the soil dynamic features (Karlen et al., 2003).

For sustainable agricultural management, it's crucial to determine the soil quality parameters. It's impossible to assess the quality of soil using all parameters, that's why choosing the best parameter in assessing the soil quality is important and needs to be studied carefully. For this reason, SQI (Soil Quality Index) assessment has become a critical approach to assess the quality of soil because having the flexible and basic use when assessing with different soil quality parameters (Fernandes et al., 2011; Larson and Pierce, 1994; Li et al., 2013; Liu et al., 2014; Lima et al., 2013; Marzaioli et al., 2010; Qi et al., 2009). When assessing the SQI, first the dataset is created, then diverse soil quality parameters are defined at different numerical scales and scoring functions used to normalize the data. After normalization processes, non-dimensional soil quality parameters are combined to be calculated through the different arithmetical operations (Andrews et al., 2002).

The SQI equation (Eq. 1) is presented below:

$$SQI = \sum_{i=1}^{n} W_i . X_i \quad (1)$$

where, SQI defines soil quality index, W_i is weighting of criterion i and X_i is sub-criteria value.

Thanks to developed technologic tools and software, comprehensive data analyses and forecasting forward looking have reached promising points. Especially in forecasting the soil quality, different machine learning models has become popular as random forest, support vector machine and linear regression (Kovacevic et al., 2010).

As an artificial intelligence subset, in machine learning diverse calculating methods are used to take out the knowledge. Learning data from computers and increasing the performance in obvious tasks without needing any open programming is the basis of machine learning. It's important to note that the accuracy of soil quality prediction mostly depends on the amount and the quality of the data and also comprehensive confirmation of the models to provide the reliability and applicability in the varied soil and environmental conditions. Besides, machine learning has the capability of fulfilling many complex problems such as computer games, natural language processing, handwriting robotics and brain-machine interface. In this chapter, general definitions of the machine learning applications used in predicting the soil quality index were given.

1. General Descriptions for the Machine Learning Applications

1.1. Linear Regression (LR)

Linear regression analysis aims to predict associating a specific variable with another specific variable. This analysis defines the prediction of a variable with the other certain variable with simple linear regression. In multiple linear regression, a certain variable is predicted using more than one variable. In these models the effect of independent variables is examined and the relationship between variables is represented by regression coefficients. The high R^2 values shows that the model is successful. But just because the model is statistically understandable doesn't express the causality relationship. In this analysis, it's important the variables have the normal distribution and take into consideration the extreme values.

1.2. Multiple Linear Regression (MLR)

In forecasting the dependent variable, linear regression statistical approach is used based on independent variables and its basic aim is to define the relationship between the predicted

output and independent variables. Because its simple use, suitable calculation and basic interpretation, MLR is used for the soil science practices (de Silva Chagas et al., 2016). To solve the problems between the diverse parameters related with linear relationships MLR is used which is the most conventional regression analyze.

The model used for the MLR is (Eq. 2):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_i x_i \quad (2)$$

where y is the dependent variable, β_0 is the regression constant, β_i is the coefficient of the independent variable, and x_i is the independent variable.

1.3. Random Forest (RF)

Random Forest is a statistical method which is defined as the community of tree species. It has become a generalized version of the bagging method with the addition of randomness specialization (Breiman, 2001).

Instead of separating each loop using the best branch, use the randomly selected in every loop and separate each loop to the branches. Each dataset is iteratively generated from the primary dataset. Subsequently, trees are constructed through the utilization of randomly selected features. Notably, these constructed trees remain unpruned, as suggested by Archer (2008) and Breiman (2001). This particular approach contributes to the distinctive accuracy of the random forest model. The strength of random forest lies in its rapidity, resilience against overfitting, and flexibility to operate with an extensive number of trees if necessary.

1.4. Support Vector Machine (SVM)

SVM is a supervised classification algorithm based on statistical ensemble model theory. Firstly, SVM basis mathematical algorithms were used for the binary classification, later, SVM was generalized for the multiclass nonlinear data classification.

In SVM, it is well known that a hyper-plane separates the two classes from each other, in other words, prediction of the most convenient decision function in separating the two different classes from each other is the principal of SVM (Vapnik, 1995; Vapnik, 1999). SVM, generally aims to find a hyper-plane which minimizes the distance between the closest points are called support vectors belonging to these two classes through many possible hyper-planes.

1.4.1. SVM for Linearly Separated Data

If training set accepted as with k samples as $\{x_i, y_i\}$, $i=1,\ldots,k$ in a classification problem which can be separated as linear, the equations belonging to hyper-plane can be showed as in the below section:

$$w.x_i + b \geq +1 \; for \; y = +1 \quad (3)$$

$$w.x_i + b \leq +1 \; for \; y = -1 \quad (4)$$

where $x \in R^n$ is a N-dimension space, $y \in \{-1, +1\}$ is a class label, w is weight vector (normalized hyper-plane), and b is a trend value.

Expression of w should be minimized to maximize the boundary of the optimum hyper-plane. In this case, solving the limited optimization problem as given below is required to determine the convenient hyper-plane:

$$min\left[\frac{1}{2}||w||^2\right] \quad (5)$$

Limitations related to this are expressed as (Vapnik, 1995):

$$y_i(w.x_i + b) - 1 \geq 0 \; and \; y_i \epsilon \{+1, -1\} \quad (6)$$

This optimization problem is solved using the Lagrange equations. After this operation the equation in the given below is obtained:

$$L(w, b, \alpha) = \frac{1}{2}||w||^2 - \sum_{i=1}^{k} \alpha_i y_i (w.x_i + b) + \sum_{i=1}^{k} \alpha_i \quad (7)$$

As a result, a decision equation for the binary classification which can be separated as linear can be expressed as given below (Osuna et al., 1997):

$$f(x) = sign\left(\sum_{i=1}^{k} \lambda_i y_i (x.x_i) + b\right) \quad (8)$$

1.4.2. SVM for Nonlinearly Separated Data

It's impossible to separate the data in most of the problems as it happens classifying the satellite images. In this case, the problem caused by some part of the training set staying out of the hyper-plane is solved by define a variable (ξ_i). The balance between maximizing the limit and minimizing the wrong classification mistakes can be controlled by the edit parameter expressed as C and taking positive values ($0 < C < \infty$). Optimization problem which is used as edit parameter and artificial variable can be expressed as:

$$min\left[\frac{||w||^2}{2} + C.\sum_{i=1}^{r} \xi_i\right] \quad (9)$$

The limitations related to this can be expressed as:

$$y_i(w.\varphi(x_i) + b) - 1 \geq 1 - \xi_i \quad (10)$$

$$\xi_i \geq 0 \; and \; i = 1, \ldots, N$$

SVM can make the nonlinear transformations with the help of kernel function express as $K(x_i, x_j) = \varphi(x).\varphi(x_j)$ and with this way linearly separation of data in a high dimension can be allowed. As a result, a decision rule related with solution of the cannot separated linearly binary data using the kernel function can be expressed as (Osuna et al., 1997):

$$f(x) = sign\left(\sum_i \alpha_i y_i \varphi(x).\varphi(x_i) + b\right) \quad (11)$$

The kernel function will be used for the SVM classification and determining the optimum parameters belonging to this function is crucial. The mostly used kernel functions and the parameters in literature were given in Table 1.

Table 1. Basic kernel functions and parameters used in support vector machines

Kernel Function	Mathematical Expression	Parameter
Polynomial Kernel	$K(x,y) = ((x.y)+1)^d$	The degree of polynomial (d)
Normalized Polynomial Kernel	$K(x,y) = \frac{((x.y)+1)^d}{\sqrt{((x.x)+1)^d((y.y)+1)^d}}$	The degree of polynomial (d)
Radial Basis Polynomial Kernel	$K(x,y) = e^{-\gamma\|\|(x-x_i)\|\|^2}$	Kernel size (γ)
Pearson VII (PUK) Kernel	$\frac{1}{\left[\left(\frac{2.\sqrt{\|\|x-y\|\|^2\sqrt{2^{(1/\omega)}-1}}}{\sigma}\right)^2\right]^{\omega}}$	Pearson width parameters (σ, ω)

2. Model Validation

Preparing data and comparing the success of the prediction models are two basis process of the prediction. After predict SOI values, determining the success of the different prediction models can be measured by the mostly used performance criteria as MAE (Mean Absolute Error), RMSE (Root Mean Square Error), MSE (Mean Square Error) and R^2 (Coefficient of Determination).

This metrics are considered as an important performance criteria for both artificial neural networks and machine learning methods. The closer the R^2 value is to zero, the more unsuccessful the model is, and the closer the model is to 1, the more successful the model is.

$$R^2 = \frac{\sum_{i=1}^{n}(P_i - \overline{O_i})^2}{\sum_{i=1}^{n}(O_i - \overline{O_i})^2} \quad (12)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(A_i - F_i)^2} \quad (13)$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|A_i - F_i| \quad (14)$$

$$MSE = \frac{\sum_{i=1}^{n}(Z_i - Z^i)^2}{n} \quad (15)$$

where P_i and O_i are the estimated and observed values at site i, respectively; $\bar{O}_i$ is the mean observed values; n is the number of samples; Z_i and Z^i are the measures and estimated value.

To assess the predictive capabilities of classification models such as support vector machine and random forest models, metrics such as Matthews Correlation Coefficient (MCC), accuracy rate, precision, recall, and F1-score are also preferred (Mahmood et al., 2020; Zhou et al., 2022).

The accuracy rate, assessing correctness by tallying accurate predictions, stands as the metric for gauging classification performance. It is formulated as the ratio of correct predictions to the overall number of samples (k).

$$Accuracy\ (Y, y) = \frac{1}{k_{samples}}\sum_{i=0}^{k_{samples}-1} 1(y_i = Y_i) \quad (16)$$

where y_i is the predicted value of the *i-th* sample, Y_i is the corresponding true value and 1*(x)* is the indicator function (Sokolova et al., 2006).

Precision represents the percentage of true positive cases among all instances identified as positive. The precision is defined as:

$$Precision = \frac{TP}{TP+FP} \quad (17)$$

Recall assesses the model's ability to correctly identify positive samples within the input variables. It is defined as:

$$Recall = \frac{TP}{TP+FN} \quad (18)$$

The F1-score serves as an indicator that combines both precision and recall. In situations where the input data is unbalanced, this metric is considered more reliable than the aforementioned three indicators. The F1-score is defined as:

$$F1 - score = 2.\frac{Precision.Recall}{Precision+Recall} \quad (19)$$

where TP is true positive (positive class is predicted as positive class); FP is false positive (negative class is predicted as positive class); FN is false positive (positive class is predicted as negative class).

The Matthews correlation coefficient (MCC), introduced by Matthews in 1975, is a metric that encompasses both sensitivity and specificity in assessing the prediction algorithm. The MCC is defined as:

$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP+FN)\times(TP+FP)\times(TN+FN)\times(TN+FP)}} \quad (20)$$

Moreover, for assessing model performance, a confusion matrix, and the Receiver Operating Characteristic curve (ROC curve), as introduced by Fawcett (2006), were utilized. The ROC curve adeptly portrays the correlation between the false-positive rate (FPR) and the true-positive rate (TPR), graphically represented from the initial point at (0,0) to the terminal point at (1,1) on the ROC curve chart.

The confusion matrix compares actual values with the model's predicted values, offering insights into the usefulness and types of errors made by the current classification models. Specifically, the matrix was generated for two classes, positive and negative, yielding four potential outcomes: True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN) (Chawgien and Kiattisin, 2021).

3. Conclusion

The increasing global population and the resulting demand for food have led to challenges such as climate change, deforestation, and soil degradation. The use of soil, a non-renewable resource, poses a threat to the sustainability of agricultural systems. Soil quality, determined by various parameters, is crucial for sustainable productivity. The Soil

Quality Index (SQI) is a critical approach for assessing soil quality, utilizing different parameters. Machine learning models, including Linear Regression, Multiple Linear Regression, Random Forest, and Support Vector Machine, play a key role in predicting SQI. Validation metrics such as MAE, RMSE, MSE, and R^2 are used to evaluate model performance. Classification models are assessed using metrics like MCC, accuracy rate, precision, recall, and F1-score, along with the confusion matrix and ROC curve.

References

Andrews, S. S., Karlen, D. L., & Mitchell, J. P. (2002). A comparison of soil quality indexing methods for vegetable production systems in Northern California. *Agriculture, ecosystems & environment*, *90*(1), 25-45.

Archer, K. J., & Kimes, R. V. (2008). Empirical characterization of random forest variable importance measures. *Computational statistics & data analysis*, *52*(4), 2249-2260.

Arshad, M. A., & Martin, S. (2002). Identifying critical limits for soil quality indicators in agro-ecosystems. *Agriculture, ecosystems & environment*, *88*(2), 153-160.

Breiman, L. (2001). Random forests. *Machine learning*, *45*, 5-32.

Carter, M. R. (2002). Soil quality for sustainable land management: organic matter and aggregation interactions that maintain soil functions. *Agronomy journal*, *94*(1), 38-47.

Chawgien, K., & Kiattisin, S. (2021). Machine learning techniques for classifying the sweetness of watermelon using acoustic signal and image processing. *Computers and Electronics in Agriculture*, *181*, 105938.

Costanza, R., & Daly, H. E. (1992). Natural capital and sustainable development. *Conservation biology*, *6*(1), 37-46.

da Silva Chagas, C., de Carvalho Junior, W., Bhering, S. B., & Calderano Filho, B. (2016). Spatial prediction of soil surface texture in a semiarid region using random forest and multiple linear regressions. *Catena*, *139*, 232-240.

Doran, J. W. (2002). Soil health and global sustainability: translating science into practice. *Agriculture, ecosystems & environment*, *88*(2), 119-127.

Doran, J. W., & Zeiss, M. R. (2000). Soil health and sustainability: managing the biotic component of soil quality. *Applied soil ecology*, *15*(1), 3-11.

Emadi, M., Baghernejad, M., & Memarian, H. R. (2009). Effect of land-use change on soil fertility characteristics within water-stable aggregates of two cultivated soils in northern Iran. *Land Use Policy*, *26*(2), 452-457.

Fernandes, J. C., Gamero, C. A., Rodrigues, J. G. L., & Mirás-Avalos, J. M. (2011). Determination of the quality index of a Paleudult under sunflower culture and different management systems. *Soil and Tillage Research*, *112*(2), 167-174.

Karlen, D. L., Ditzler, C. A., & Andrews, S. S. (2003). Soil quality: why and how?. *Geoderma*, *114*(3-4), 145-156.

Kovačević, M., Bajat, B., & Gajić, B. (2010). Soil type classification and estimation of soil properties using support vector machines. *Geoderma*, *154*(3-4), 340-347.

Lal, R. (2011). Sequestering carbon in soils of agro-ecosystems. *Food policy*, *36*, S33-S39.

Larson, W. E., & Pierce, F. J. (1994). The dynamics of soil quality as a measure of sustainable management. *Defining soil quality for a sustainable environment*, *35*, 37-51.

Le Mouël, C., & Forslund, A. (2017). How can we feed the world in 2050? A review of the responses from global scenario studies. *European Review of Agricultural Economics*, *44*(4), 541-591.

Li, P., Zhang, T., Wang, X., & Yu, D. (2013). Development of biological soil quality indicator system for subtropical China. *Soil and tillage research*, *126*, 112-118.

Lima, A. C. R., Brussaard, L., Totola, M. R., Hoogmoed, W. B., & De Goede, R. G. M. (2013). A functional evaluation of three indicator sets for assessing soil quality. *Applied Soil Ecology*, *64*, 194-200.

Mahmoud, A. M., Swilem, S. M., Alqarni, A. S., & Haron, F. (2020, December). Infant Cry Classification Using Semi-supervised K-Nearest Neighbor Approach. In *2020 13th International Conference on Developments in eSystems Engineering (DeSE)* (pp. 305-310). IEEE.

Marzaioli, R., D'Ascoli, R., De Pascale, R. A., & Rutigliano, F. A. (2010). Soil quality in a Mediterranean area of Southern Italy as related to different land use types. *Applied Soil Ecology*, *44*(3), 205-212.

Matthews, B. W. (1975). Comparison of the predicted and observed secondary structure of T4 phage lysozyme. *Biochimica et Biophysica Acta (BBA)-Protein Structure*, *405*(2), 442-451.

Osuna, E. E. (1998). *Support vector machines: Training and applications* (Doctoral dissertation, Massachusetts Institute of Technology).

Qi, Y., Darilek, J. L., Huang, B., Zhao, Y., Sun, W., & Gu, Z. (2009). Evaluating soil quality indices in an agricultural region of Jiangsu Province, China. *Geoderma*, *149*(3-4), 325-334.

Raiesi, F. (2017). A minimum data set and soil quality index to quantify the effect of land use conversion on soil quality and degradation in native rangelands of upland arid and semiarid regions. *Ecological indicators*, *75*, 307-320.

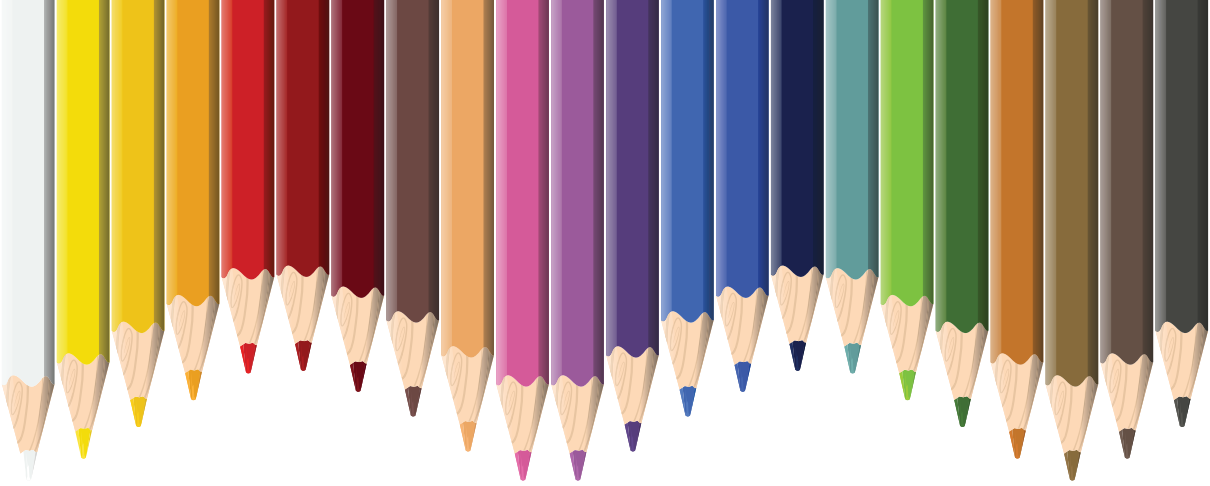
Rasheed, S. A., Prabhu, N. T., & Munshi, A. K. (1996). Electromyographic and ultrasonographic observations of masseter and anterior

temporalis muscles in children. *The Journal of Clinical Pediatric Dentistry*, *20*(2), 127-132.

Vapnik, V. (1999). *The nature of statistical learning theory*. Springer science & business media.

Yemefack, M., Jetten, V. G., & Rossiter, D. G. (2006). Developing a minimum data set for characterizing soil dynamics in shifting cultivation systems. *Soil and Tillage Research*, *86*(1), 84-98.

Zhou, X., Ampatzidis, Y., Lee, W. S., Zhou, C., Agehara, S., & Schueller, J. K. (2022). Deep learning-based postharvest strawberry bruise detection under UV and incandescent light. *Computers and Electronics in Agriculture*, *202*, 107389.



Chapter 3

DEVELOPMENTS IN THE AQUACULTURE SECTOR IN THE WORLD AND TURKEY

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INTRODUCTION

Nowadays, developed countries pay attention to their nutrition and choose foods that are suitable for their health. Fish, which has an important place among these foods, is in the first place because it contains rich protein and unsaturated fatty acids, meets the main nutritional needs of the body, and plays a role in metabolic and physiological functions in humans (Kaya et al., 2004). Aquaculture is the largest animal proteins in the world and as a sector, it provides continuous input to the world economy (Çöteli, 2022).

The aquaculture sector is an important source of economy for our country and is also very important in terms of animal protein. The World Health Organization (WHO) recommends especially seafood and fish to combat obesity. According to per capita fish and seafood consumption data, our country is behind the undeveloped countries. This situation is of great importance for the healthy nutrition of people and the development of the sector. In this context, it is very important to increase consumption by carrying out promotional activities and encouraging consumption. In addition, many factors such as unconscious and excessive fishing, global warming and environmental pollution negatively affect fisheries production in the world and in Turkey. Protection of the seas and inland waters against all kinds of pollution and degradation should be considered as the first priority while formulating the fishing policy. In addition, the impo[1]rtance of aquaculture is increasing every year. According to FAO, aquaculture is the food sector that has developed the most in the last 10 years. Aquaculture is recognized as an important alternative potential for today's future food supply. In this review, developments in the aquaculture sector in the world and Turkey are described (Arslan and Yıldız, 2021).

As a result of the increasing world population, the efficient and effective use of available resources is becoming more and more necessary. Food production from aquatic ecosystems, which make up three quarters of the world's land area, is seen as one of the most important resources. In the last 10 years, there has been no significant increase in the world's capture fisheries production and it is assumed that sustainable production will not exceed 100 million tons. On the other hand, there has been a steady increase in aquaculture and aquaculture production (Çakmak et al., 2011). There are generally two types of aquaculture production: capture and aquaculture. In recent years, the share of capture fish in total production has decreased, while aquaculture production has increased rapidly. The main reason for this is that it is no longer possible to increase the amount of product that can be obtained from the seas through fishing (Gün and Kızak, 2019).

Although aquaculture production through capture fisheries has not shown a significant increase in the world and Turkey in recent years, it has

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been determined that there has been a significant increase in aquaculture production. Aquaculture is the fastest growing food production sector in the world and continues to grow in almost every region of the world (Subasinghe et al., 2009). Globally, aquaculture production is growing at an average rate of 8.8% per year, which is the highest among livestock sectors. The People's Republic of China is the world's largest aquaculture producer and, together with Asian countries, accounts for approximately 90% of aquaculture production. According to FAO, developing countries accounted for 59% of aquaculture since 1970, rising to 90% in 2002. Aquaculture production is estimated to be 85 million tons in 2030 (Tatlıdil et al., 2009). According to FAO, according to the amounts of aquaculture and fishing production in 2020, the Asian continent leads in both fishing and aquaculture in aquaculture production (FAO, 2022; Gün and Kızak, 2019).

AQUACULTURE AND FISHERIES IN THE WORLD

According to the biological developmental stages of aquatic organisms, it is a field of production and science that has connections with different sectors that take into account many scientific and economic principles such as the protection of the natural environment and resources, reducing the fishing pressure on natural stocks, without disturbing the controlled optimal environmental conditions, ecological structures and water resources balances. Scientific and technological developments and innovations in applications in the last 50 years have contributed significantly to the development of the sector. Technological and scientific developments in the last 50 years have contributed greatly to the development of the industry (Bostock 2011; Şahinöz et al., 2017).

According to the United Nations, the world population, which is increasing by an average of 78 million per year, will reach 12-13 billion in the 2050s and the demand for animal products will double in the next 20 years. It is stated that approximately 20% of your animal protein needs will be met from fish (FAO, 2022). According to FAO reports in 2010, humans consume 81% of the world's seafood production as food. The remainder is used for fish oil, fish meal and other purposes. With 100 kg of compound feed, chicken yields 20 kg and salmon 65 kg of edible meat (Sabaut, 2007). This has further increased the importance of the aquaculture industry. From 1970 to 2015, the average annual growth rate of aquaculture in the world was 1.6%. As a result, the amount of fish consumed per capita through aquaculture increased 10-fold, from 0.7 kg to 7.8 kg in 2008 (FAO, 2010; Şahinöz et al., 2017).

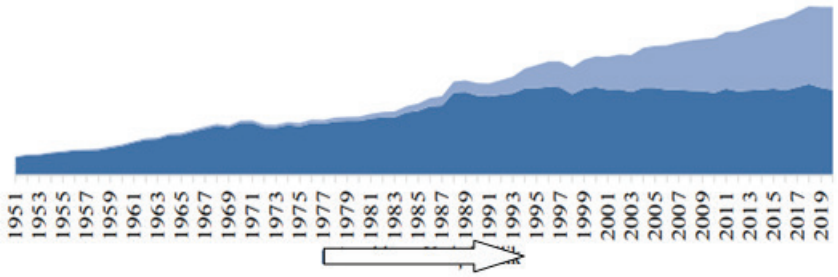


Figure 1. World Aquaculture – Fisheries- Production Amount (tons) (FAO, 2022).

The aquaculture sector has shown a significant development in the last 50 years and has an important share in international trade. Fish and fish products are important for the economy of many countries (FAO,2022).

Table 1. *World aquaculture production (tons) (FAO, 2022).*

	Pearson VII (PUK) Kernel		
Years	Fisheries	Productive	Total
2016	89.600	76.600	166.200
2017	93.200	79.600	172.800
2018	96.500	82.120	178.620
2019	92.500	81.360	173.860
2020	90.300	87.500	177.800

Covid-19, which has been affecting the whole world since the first months of 2019, has affected aquaculture production. and has a key position in the global trade of aquaculture products. It is seen to have a negative impact on importers and exporters. Recent worldwide, when the data of the years are analyzed, the acceleration in the direction of increase in aquaculture production has been the same for two years. level of consumer behavior and trade. The impact on consumer behavior and trade globally is similar with the unprecedented COVID-19 pandemic, the global fisheries and aquaculture value chain has been impacted by as a result of the pandemic. In summary, the pandemic has affected both the demand and also revealed their vulnerability in terms of supply.

When we look at the total aquaculture production in the world by years (Table 2).

Table 2. *World Aquaculture Production by Countries (tons) (FAO, 2022).*

COUNTRIES	2016	2017	2018	2019	2020
Chına	61.605.135	62198086	62207599	62242310	62846808
Indıa	11.495.213	12307666	12668063	13455205	14140699
Indonesıa	10.876.369	11711313	12386253	13253701	12151946
Vıetnam	6.648.243	7136167	7481039	7871286	8022708
Peru	3.796.978	4157414	7169817	4968902	5770371
Russıa	4.759.392	4864504	5108858	5211894	5342456
Abd	5.348.349	5473700	5212754	5290541	4694411
Bangledesh	3.878.324	4134436	4276641	4384219	4503371
Norway	3.359.975	3686996	3843920	3762008	3940977
Japan	3.876.920	3821112	3773800	3762008	3751228
Turkey	585.657	637797	625776	834662	**785.822**
Other	49.956.110	52608231	53796421	52820072	51817746
World	166.186.665	172.727.422	178.550.941	177.857.045	177.768.543

We can see that overfishing and pollution have led to a decrease in the species and amount of catch, and even since the 1980s, catches have stabilized. On the other hand, aquaculture production is increasing every year and it is thought that aquaculture is replacing fishing in the supply of aquaculture products. In 2020, global aquaculture production was 177.8 million tons, of which 87.5 million tons (49%) was aquaculture. Of the aquaculture production, 33 million tons was obtained from the seas and 54 million tons from inland waters. China, the largest aquaculture producer, produced 49.6 million tons in 2020, accounting for 57% of the world total. The largest aquaculture producer in Continental Europe was Turkey with 785,822 tons in 2020.

FISHERIES AND AQUACULTURE IN TURKEY

Our seas surrounding our country from three sides and numerous rivers, lakes, ponds Our lakes and reservoirs offer wide opportunities for aquaculture and aquaculture offers. Compared to other countries, our water resources remain relatively clean are available. The biodiversity of our water resources is also rich.

Institutional organization responsible for the management of our water resources, education and research institutions and sectoral organizations exist.

There are sufficient number of fishermen, fishing vessels and fishing vessels to fish from our water resources. technology is available in our country. In

fact, in fisheries, it is even possible to fish outside the country's waters. hardware is available. The best examples of this are in the Georgian waters of the Black Sea and Fishing by Turkish fishing vessels in Mauritania. Aquaculture facility suitable for development for aquaculture production, technology and human resources are also available in our country. Our country, in its geography, The leader in aquaculture in the Middle East, Caucasus and European Union countries countries.

It is a country that can produce quality production in terms of food safety and export to various countries of the world, especially Our fishermen and breeders who can export products to EU countries, processing-evaluation facilities and manpower. In parallel with the development in aquaculture production, aquaculture is important in the export of aquaculture products. developments have been experienced.

In general terms, three quarters of our exports in recent years aquaculture products. However, the development of technology and industry, increasing population and developing needs cause natural resources to be used more, resources to be worn out and polluted. Our water resources are negatively affected by industrial and domestic pollution and construction. Fisheries production fluctuates from year to year depending on the production of migratory small pelagic species such as anchovy, sprat and sardine. Since catch estimates of these species cannot be made, production planning cannot be made. Both pelagic and demersal fish stocks are decreasing due to fishing, ecological, climatic and pollution pressures and annual production amounts cannot exceed certain levels according to species. There is no possibility to increase the fishery production in the sea and inland waters of our country more than certain levels according to species. The increase in the number of fishing vessels in our fleet was stopped in 2002, then it showed a constant and decreasing trend and the number of vessels was reduced with the buy-back program implemented between 2012-2022.

However, the engine power and volumes of the existing vessels in the fleet are increasing, the capacities of the fishing gear and technological equipment they use are increasing. The fishing power of our fishing fleet continues to create fishing pressure on fish stocks mostly in the country's waters.

Tablo 3. *Aquaculture production of Turkey (tons) (Tuık, 2023).*

Year	Total	Sea Product	Aquaculture	Indlandwater
2012	644.852	396.327	212.410	36.120
2013	607.515	339.047	233.394	35.074
2014	537.345	266.078	235.133	36.134
2015	672.241	397.731	240.334	34.176
2016	588.715	301.464	253.395	33.856
2017	630.820	322.173	276.502	32.145
2018	628.631	283.955	314.537	30.139
2019	836.524	431.572	373.356	31.596
2020	785.811	331.281	421.411	33.119
2021	799.844	295.018	471.686	33.140
2022	849.808	301.747	514.805	33.256

When we evaluate the last 10 years of aquaculture in Turkey, total production, which was approximately 645 thousand tons in 2012, was approximately 850 thousand in 2022. The increase in total production was 31%. 35.30% of the 2022 production is sea fish, 60.57% is aquaculture products and 3.91% is inland water products. The decrease in the amount of products based on aquaculture due to overfishing, poaching and the increase in the amount of products from aquaculture shows that production globally is moving in the right direction (Table 3)

Table 4. Aquaculture production in Turkey (tons) (TUIK, 2023)

Year	Fishing	Aquaculture	Total
2012	432.442	212.410	644.852
2013	374.121	233.394	675.15
2014	302. 212	235.133	537.345
2015	431.907	240.334	672.241
2016	335.320	253.395	588.715
2017	354.318	276.502	630.820
2018	314.094	314.537	628.631
2019	463.168	373.356	836.524
2020	364.400	421.411	785.811
2021	328.165	471.686	799.851
2022	335 003	514 805	849 808

In the last 10 years, while the amount of fish obtained by fishing has decreased by 24.11%, this rate in aquaculture has increased to 54.96%. Aquaculture is carried out in inland waters, rivers, natural lakes, dam lakes, other water resources and seas. Until 2013, aquaculture production in inland waters was higher than in the seas, while in 2021, aquaculture production in the seas was higher than inland waters (Table 4). Quotas imposed on countries, climatic factors, regulations and bans, and restrictions on tools and equipment have all contributed to the decline in fisheries. Production of Covid-19 in aquaculture in Turkey, which continues in 2021.

The effect of the pandemic on the amount of aquaculture products was in the direction of a decrease in the rate of increase when the previous years were taken into consideration. During the pandemic, there was a shortage and even cancelations in seafood trade around the world. Due to this reason, while a contraction was observed in the exports of aquaculture products in 2021 in our country, in 2022 has started to increase again.

Table 5. *Aquaculture by provinces (tons) (TUIK, 2023)*

PROVINCE	2017	2018	2019	2020	2021
Mugla	99.734	115088	128706	141459	144295
Izmır	67585	75084	85975	99640	111547
Aydın	11351	20523	25779	23571	30238
Elazıg	**17620**	**18000**	**21550**	**23000**	**26500**
Mersın	2642	2788	17843	19418	26299
Samsun	8277	6666	6341	12569	14721
Trabzon	4207	5541	7702	8315	11040
Sanlıutrfa	3920	4000	5025	7004	7658
Antalya	2733	5694	6063	7103	7407
Sınop	1900	3229	5353	6638	6638
Other	56533	57924	63019	72.694	85343
Turkey	276.502	314.537	373356	421.411	471.686

Of the fish produced through aquaculture in the seas, 33% is sea product, 28% is sea bream, 28% is sea bream trout. Fish produced from inland waters through aquaculture. Trout production accounts for 98.6% of the total. While 36.4% of marine aquaculture production is realized in Muğla, 36.4% of inland aquaculture production is realized in inland waters. 16.6% of the production was realized in Elazığ. Almost all marine aquaculture production. While all of them are sea bass and sea bream, only trout is used in inland waters (Table 5).

Table 6. Amount of fish caught in Turkish seas (tons)(TUIK,2023)

Years	Mediterranen	Western Black sea	Eastern Black sea	Aegean	Marmara	Toplam
2018	13.811	77.900	157.952	47.676	24.832	322.172
2019	12.726	86.922	89.355	42.612	52.338	283.954
2020	13.802	76.557	270.197	41.216	29.797	431.572
2021	15.336	113.425	136.268	42.106	24.146	331.281
2022	14.922	79.523	149.103	37.076	14 .400	301.747

The most important share in marine fishing is 77 % and the Black Sea Region. In the last 5 years, the amount of fishing in our seas has decreased, with the Marmara sea having the lowest share.

Excessive mucilage formation in the Marmara Sea in 2021 due to increased seawater temperature, stagnation and increase in nitrogen-phosphorus load due to the effect of climate change damaged the aquatic ecosystem. Due

to its dense structure, mucilage clogged the net eyes, prevented fishing, and damaged species diversity or biodiversity, especially species that lack mobility or move very slowly on the bottom. This situation has a negative impact on aquaculture The reflection on the catch was determined as a 40% decrease in the amount of catch in the Marmara Sea compared to the previous year (Anonim 2022).

Table 7. *Amount of fish species captured (tons) (Tuik, 2023)*

FISH SPECIES	2018	2019	2020	2021	2022
Anchovy	158.094	96.452	262.544	151.598	125 980
Sprat	33.950	20.057	38.078	28.041	11161
Horse Mack.	8.066	14.222	13.180	19.590	981
Pılchard	23.426	18.854	19.119	5.800	729
Whıtıng	8.248	6.814	8.941	0.380	7 690
Blue Fısh	1.935	5.767	1.213	5.804	5 495
Scad	4.919	6.456	6.325	4.416	3 948
Striped Red	2.074	2.915	2.342	3.072	1 303
Twaıte Shad	1.576	1.605	1.965	3.065	3 146
Bogue	3.559	2.865	2.599	2.601	2 310

Anchovy is the most important species fished from the seas in Turkey and has a significant impact on fishing statistics in Turkey. Anchovy determines both the Black Sea productivity and the catch data for Turkey. Catch data. When analyzed, anchovy, which was 151,598 tons in 2021, decreased to 125 980 tons in 2022. In 2022, the most fished species after anchovy is sprat. Sprat is among the fish that are not consumed by humans. sprat fish meal is used as fish feed Table 7).

Table.8. Consumption ofseafood products

Years	2017	2018	2019	2020	2021
Consumption	572.490	546.737	514.640	559.932	554.291
Per person consumption (kg)	5.5	6.1	6.3	6.7	6.5

While fish consumption per person in Turkey was 5.5 kg in 2017, it was 6.5 kg in 2021. The average fish consumption per capita in the world is 16 kg, while this figure is 22 kg in the European Union.

CONCLUSION

As in the rest of the world, the catchable stock size has been reached in Turkey and it is not possible to increase production through hunting. The protection of seas and inland waters from all kinds of pollution and degradation should be considered as the first priority when formulating fishing policies. Aquaculture is an indispensable nutrient in a healthy diet. Especially in the fight against obesity, the World Health Organization(WHO) emphasizes fish and seafood as a good source of animal protein.

However, when the per capita consumption data are analyzed, it is seen that the consumption habits of seafood in Turkey are behind even the undeveloped countries. In this context, it is necessary to carry out extension activities to increase consumption. In the world and in Turkey, aquaculture is negatively affected by many factors such as excessive and unconscious fishing methods, global warming and environmental pollution.

Aquaculture will play a very important role in the future in meeting the need for abundant and cheap protein. Worldwide, the amount of aquaculture products obtained by aquaculture is increasing rapidly. While this increase is quite high, different species. Concerning the billions of people around the world whose lives and livelihoods depend on traditional fisheries and aquaculture, the United Nations General Assembly has declared 2022 the International Year of Traditional Fisheries and Aquaculture.

REFERENCES

Anomim 2022. Agriculture and Forestry Journal January-February Issue, http://www.turktarim.gov.tr/Haber/735/Aquaculture -cultivation-increasing-every-year

Arslan. G., Yıldız. P. O. 2021. Overview of the Turkish aquaculture sector. Menba Kastamonu University Journal of Faculty of Fisheries, 7(1), 46-57

Bilgüven M., Can G. 2018. Possibilities of Using Chicken Meal Instead of Fish Meal in Fish Feeds, Bursa Uludag University Journal of Faculty of Agriculture, Volume: 32 Issue: 2 Page: 189-200

Bostock, J. 2011. Foresight Projeck on Global food and Farming Futurs. The Application of Science and Technology Development in Shapping Curent and Future Aquaculture Production Systems, Journal of Aqricultural Science, 149, 133-141.

Çakmak, E., Aksungur, N., Firidin, Ş., Aksungur, M., Çavdar, Y., Kurtoğlu, İ.Z., Başçınar, N.S., Akbulut, B., Savaş, H., Üstündağ, E., Alkan, A., Ergün, H., Ertekin, A., Zengin, B., Serdar, S., Fidan, D. ve Özkan, B. 2011. The Acquisition of Black Sea Trout (Salmo trutta labrax Pallas, 1811) to the Private Sector, Project Final Report Book, TAGEM/HAYSÜD/2006/ 09/03/02, Trabzon, 147 pp.

Çöteli, F.T. 2022. Product Report Aquaculture, Institute of Agricultural Economics and Policy Development (TEPGE), 29s.

Demir, O. 2008. Overview of Turkey Aquaculture and Feed Sector, Journal of Fisheries Sciences 2 (5): 704-710

FAO, 2010. Status of Fisheries and Aquaculture in the World.. http://www.fao.org/3/CA0191TR/ca0191tr.pdf. Subasinghe, R., Soto, D., Jia, J., 2009. Global aquaculture and its role in sustainable development. Aquaculture, 1: 2-9.

FAO, 2022. FishStat Plus-Universal software for fishery statistical time series http://www.fao.org/fishery/statistics/software/fishstat/en (Erişim tarihi: 01.10.2023)

Gün A., Kızak V. 2019. Statistical status of aquaculture production in the world and in Turkey. Menba Kastamonu University Journal of Faculty of Fisheries, 5(2), 25-36.

Kaya Y., Duyar H.A., Erdem M.E. 2004. The Importance of Fish Fatty Acids for Human Health, Ege University Journal of Fisheries, Volume: 21 Number: 3-4 Page: 365-370

Özden, O., Fırat, K., Büke, E., Saka. Ş. 2005. Fangri Fish (Pagrus pagrus) Breeding, T.C. Ministry of Agriculture and Rural Affairs General Directorate of Agricultural Production and Development. 239s. Öziş Matba-Ankara

Sabaut J.J. 2007. Feeding Farmed Fish. 1-9. http://www.feap.info/produktion/feeds/sabatcipaen.asp. 13/3/2007.

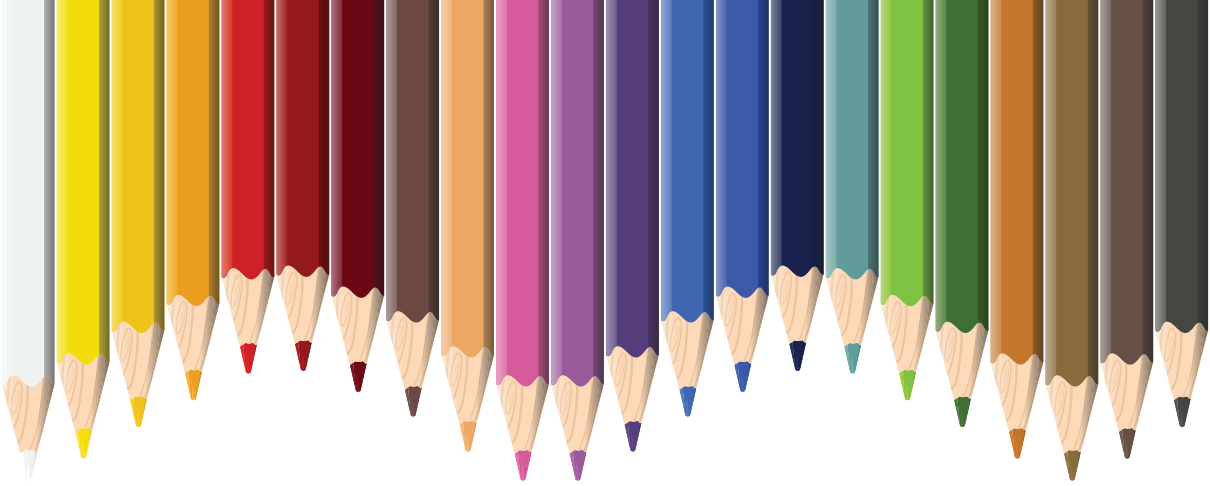
Subasinghe, R., Soto, D., Jia, J. 2009. Global aquaculture and its role in sustainable development. Aquaculture, 1: 2-9.

Şahinöz, E., Doğru, Z., Aral, F. 2017. Journal of Urban Academy, 10;4, 446-476

Tatlıdil, F., Aktürk, D., Batramoglu, Z., Fidan, H. 2009. Development Trends of Aquaculture in the World. Journal of Animal and Veterinary Advances, 8 (11): 2291-2298.

TÜİK, 2022. Fisheries statistics, TUİK www.tuik.gov.tr

TÜİK, 2023. Fisheries statistics, TUİK www.tuik.gov.tr



Chapter 4

A RESEARCH ON THE PHYSICAL CONDITIONS AND PROBLEMS OF BURSA-YENIŞEHIR DISTRICT DAIRY CATTLE FARMS REGARDING BUSINESS BUILDINGS[1]

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Introduction

Turkey also made livestock production in the agribusinesses, and there are many problems related to business buildings and operating conditions. One of these problems is that agricultural businesses are small family agribusinesses. Apart from this problem, although animal products have a significant place in human nutrition, the amount of animal food per capita is lower than in developed countries. In addition, despite the high animal existence, the total agricultural production is low. Another significant problems are that the production per animal is below a certain standard. The business buildings are not of sufficient size and equipment and can not market the animal products. Apart from the above-mentioned structural problems in the agribusiness, there are problems such as the difficulty of accessing technical information by animal businesses, the inadequacy of modern tools and machines, unwillingness to cooperate, and inadequate animal improvement activities.

Foodstuffs of animal origin in human life are crucial in balanced nutrition. Annual meat consumption is 39 kg per capita globally, and this value is around 20 kg in Turkey. These values are 123 kg and 91 kg in developed countries such as the USA and the EU. The protein value of red meat consumption should be considered, and this value should be 33 kg. The annual per capita red meat consumption in the world was 14.5 kg in 2019. While this value is 46 kg in the USA, 26 kg in the EU, it is at a low value such as 8.5 kg in Turkey (**TUİK, 2020**). The annual per capita consumption of red meat in Turkey was 8.6 kg in 2019, while this value dropped to 7 kg in 2010. When these values are compared with the values in the USA and EU countries, there is an animal protein deficit in Turkey. The amount of milk per capita in Turkey are low compared with the US and EU countries. The annual per capita consumption of 12.5 liters of milk, yoğurt consumption is 41.1 kg, cheese consumption is 14.2 kg in Turkey (**TUİK, 2020**). Animal barns were made several mistakes in planning in Turkey. As a result, animal health and productivity are negatively affected since the functions expected from barns are not fully achieved. One of the main mistakes made in planning is not considering the region's climate conditions. However, increasing animal productivity is achieved by establishing the most appropriate and economic balance for animals. In our country, the structuring of building elements and selecting materials are made in the same way and with the same type of barns, even in climatic regions that differ from each other. This situation unnecessarily increases the building cost (**Olgun and Öneş, 1989**). For the barns to fulfill their functions properly, they must prepare plans by the special conditions of various climatic and agricultural regions. It can be achieved by examining the barns in the different areas on-site, examining the detected problems under the light of the basic principles of barn planning technique, and developing suitable plan types for other conditions. In this study, the structural conditions and difficulties of the

barns in the dairy cattle farming businesses of Yenişehir vicinity, which has an essential place in Bursa region's dairy cattle farming and which has the feature of an exemplary vicinity in this regard, were investigated and searched the possibilities of developing them. In addition, it was aimed to help the preparation of suitable barn types in a particular agribusiness courtyard layout by determining the general principles in the planning of the barns planned to be built in the future in this region.

Materials and Methods

This research was carried out in 1997 to determine the circumstance, competence, and improvement possibilities of the barns in the farmyard layout of dairy cattle farming businesses in the Bursa-Yenişehir district. For this purpose, 17 barns in 9 dairy cattle agribusinesses representing the agribusinesses in the district were selected as research materials. There are 2 barns in one of the established agribusinesses. In the research, 3 different barn types were examined, and it was determined that 13 of the barns with tied-stall barns, 3 of them were free-loose barns and 1 of them were free-stall barns. Yenişehir district, together with its villages, covers an area of 772 km^2. The Yenişehir plain is 240 m above sea level. Kocasu, which crosses the plain and mingles with Sakarya, is the lifeblood of the local agriculture. All the climatic characteristics of the Marmara region are seen in the Yenişehir vicinity. Summers are generally dry and hot. The rain mainly falls in spring and autumn, and winters are intermittent with snow. The distribution of precipitation to the seasons is 184.6 mm in the spring, 74.0 mm in the summer, 174.1 mm in the autumn and, 271 mm in the winter. The annual average temperature in Bursa is 14.4 °C. The highest average temperature was 30.9 °C in August, and the average minimum temperature was 1.7 °C in January (**Anonymous, 1997**). The climate data of Bursa province are given in **Table 1**. To research by its purpose, paying attention to selecting barns that could represent the district and the region by obtaining the information of "Yenişehir District Directorate of Agriculture" and the "Yenişehir Milk Businesses Association". In the selected agribusinesses, completed the data file of the agribusiness by adding the measurements, sketches, and photographs made within the agribusiness along with the previously prepared questionnaires. The building materials used in the barns were determined, the dimensions related to the interior layout of the barns were measured and cross-section-details were derived. In addition, information on ventilation and lighting in the barns was collected. Detailed information about the problems encountered in practice was obtained by interviewing the owners and workers in the business. The issues in the barns were tried to be determined by observations. The settlement and direction status of the barns and utilities in the agribusinesses were evaluated using the drawn sketch, plan, and examination information. Questionnaire studies, photographs, sketches, and plans drawn during the examination stage were

used. In addition, the courtyard layout of the agribusinesses, the location of the barns and utilities, and the floor plans and details of these structures were drawn in scale. In the light of the measurement results and the plans drawn in the research, the barn systems, the arrangement of the stalls in closed barns, the manger way, the linkage arrangements, urine channels, service, and passageways, evaluated barn dimensions, building materials, and the dimensions of the various building elements, and determined problems. It has been investigated whether they are sufficient in various aspects in free loose and free-stall barns. According to the conditions of Bursa-Yenişehir district and the priciples in the literature, appropriate barn plans were prepared for the region and the most suitable barn types were tried to be determined.

Results

In the study, measurements, sketches, questionnaires, and observations were made in 17 barns in 9 agribusinesses as research material, and data on barns in the agribusiness were generated. The main occupation of all agribusinesses was dairy cattle farming.

Tablo 1. *1997 year Bursa province climate data*

Meteorological Data	MOUNTS												
	1	2	3	4	5	6	7	8	9	10	11	12	Av.
Ave. Temp. (°C)	5.2	6.0	8.0	12.6	17.4	21.6	24.2	23.9	19.7	15.4	11.3	7.5	14.4
Ave. High Temp. (°C)	9.2	10.5	13.4	18.7	23.6	28.0	30.6	30.9	26.9	22.1	16.7	11.7	20.2
Ave. Low Temp. (°C)	1.7	2.1	3.4	7.0	11.2	14.4	16.7	16.7	13.3	10.0	7.0	3.9	9.0
Highest Temp. (°C)	23.8	26.1	32.5	36.2	37.0	40.5	41.3	42.6	40.1	35.4	31.0	26.5	42.6
Lowest Temp. (°C)	-20.5	-25.7	-8.7	-4.2	0.8	4.0	8.3	7.6	3.3	-1.0	-8.4	-17.9	-25.7
Ave. Rel. Hum (%)	76	74	72	70	70	63	59	60	66	72	76	75	69.0
Highest Rel. Humidity (%)	81	80	82	82	82	76	72	75	82	86	85	81	80.0
Ave. Precip. (mm)	96.5	83.9	73.0	59.0	52.6	30.2	26.8	17.0	41.7	57.1	75.3	99.7	713.1
Ave Wind Velocity (m/s)	3.4	3.3	2.9	2.4	2.0	2.3	2.9	2.8	2.4	2.0	2.3	3.2	2.7
Ave. Snowy Days	3.1	2.5	0.9	0.2	-	-	-	-	-	-	0.1	0.9	7.7
Depth of Snow Cover	0.8	0.5	0.19	0.1	-	-	-	-	-	-	0.33	0.35	0.8

Water supplied from the city network was used as a water resource in agribusinesses. The electricity needed in the agribusinesses was provided from the main transformers, and all agribusinesses benefit from electricity. The barns were built within the courtyard of the agribusinesses and separately from the homes, except for 3 agribusinesses within the agribusinesses examined. Most of the buildings that agribusinesses need were located in the courtyard. An example of courtyard arrangement was given in **Figure 1**. The sketch of an agribusiness where all the structures were collected in a courtyard was given in **Figure 2**. When examined the constructional dimensions, arrangement types, temperature, and relative humidity values in tied-stall barns, differences emerged compared to the standard values. This situation caused damage to the building elements of the barn, and the workers and animals in the barn to be negatively affected. The amount of heat lost from the building elements was high due to the insufficiency of the materials used for insulation in some barns. The floor plan and the cross-sectional area of a tied-stall barn were as given in **Figure 3**. Ventilation areas and ventilation windows in the barns were given in **Figure 4** and **5**. Natural ventilation system has been applied in all of the barns. Due to the insufficiency of the air inlet and outlet

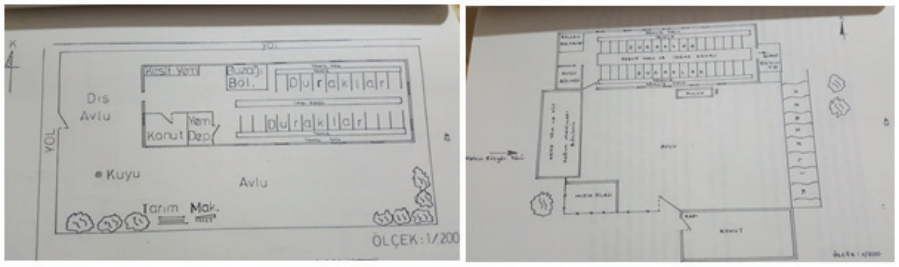


Figure 1. *An example of the arrangement of a agribusiness courtyard*

Figure 2. *The sketch of an agribusiness where all the structures are collected in a courtyard.*

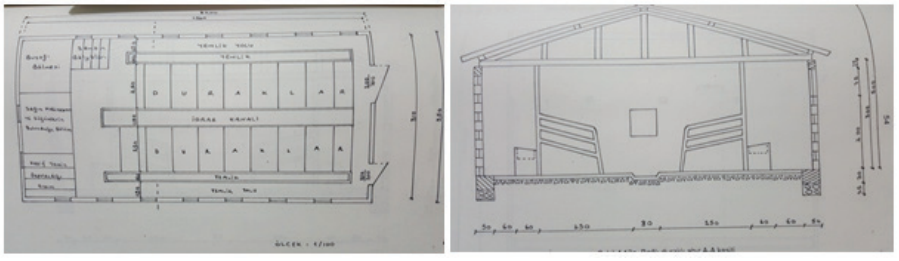


Figure 3. *The floor plan and the cross sectional area of a stall barn*

areas required for natural ventilation could not achieve the desired amount of air exchange the barn. The ventilation areas and windows in the barns examined were given in **Figures 4** and **5**. While only **4** of the barns had natural

lighting systems, the others had natural and artificial lighting systems together. Natural lighting was made from windows, translucent plastic covers on the roof, and air outlet areas. The shortage of the total window area in the 11 barns examined led to the failure to provide the desired natural lighting. In the artificial lighting applied in the barns, the distribution of the desired light in the barn had been reduced due to the insufficiency of the lamps and the fact that they could not be appropriately placed. The natural lighting and insufficient lighting systems used in the barns examined were shown in **Figures 6 and 7.**

Figure 4. and Figure 5. *Ventilation areas and ventilation windows in the barns*

Figures 6 and 7. *The natural lighting and insufficient lighting systems applied in the barns where the research was conducted are shown.*

The research was carried out in 17 barns in 9 dairy cattle agribusinesses and it was determined that 13 (76.5%) of the barns had tied-stall barns, 1 (17.6%) free-loose barn and 3 (5.9%) free-stall barns. The number of milk cows in the barns mainly was between 1-10 heads. The grouping of the barns according to the number of milch cows was given in **Table 2.**

Table2. *Grouping barns according to the number of milch cows*

Groups by the number of dairy cows	Number of barns	%
1-10	10	58.8
11-20	6	35.3
21-30	1	5.9
Total	19	100.0

Findings of the physical conditions of the barns

Most of the barns in the study were in the east-west direction. The front of the 12 (70.6%) barns was towards the south. The barn widths varied between 7.0-24.0 meters, and the average was measured as 9.9 meters. The usable length of the barn floors varied between 12.0-31.0 m. The length of the barn mostly varied between 13.0-16.0 m. Values for barn floor area dimensions were given in **Table 3**.

Table 3. *Values for barn floor area dimensions*

Barn width (mm)	Number of barns	%	Barn length (m)	Number of barns	%
6-9	11	64.7	13-15	4	23.5
9-12	5	29.0	16-19	1	5.9
12-15	-	-	19-22	3	17.6
15-18	-	-	22-25	1	5.9
18-21	-	-	25-28	3	17.6
21 and upper	1	5.9	28 and upper	5	29.5
Total	17	100		17	100

In only 2 (15.4%) of the stall barns, there had been made stalls by the rules. Although the others do not had a stall platform, found stall partitions separating the cattles from each other. The widths of the barns have been measured between 1.10-1.85 m, and the lengths of the barns between 1.6-2.0 m. In the barns without stall partitions, animals of 0.80-1.85 m width were tied. The animals were chained to the stalls. The manger widths of the barns varied between 0.50-0.70 m and the average were measured 0.63 m. The height of the mangers from the stall varied between 0.20-0.85 m and their depth between 0.10-0.45 m. Droppings canal widths of barns were measured between 0.60-1.70 m, and were found to be high. Droppings canal slopes are generally inadequate and measured between 0-1.5%. It did not find the manger path in 2 barns. In addition, the manger road widths of 0.5-1.7 m were found in the barns in the partitions connected to the service road. The height of the barns from the bottom to the ridge piece had been measured between 2.5 and 3.0 m. The values of barn heights in stall barns were given in **Table 4**.

Table 4. *Barn heights in stall barns*

Barn heights	Number of barns	%
2.0-2.5	2	15.4
2.5-3.0	8	61.5
3.0-3.5	2	15.4
3.5-4.0	1	7.7

The air volume per cattle in the barns varied between 5.57-29.46 m^3, and an average of 20.89 m^3 was calculated. It has been calculated that the resting places of the free-loose barns varied between 128-300 m^2, and the areas per cattle varied between 8.4-30.0 m^2. It has been observed that the floors of the resting places of all barns were concrete. While the floor of the promenade of the barns was concrete in 2 barns, the others had soil. In the free-stall barn, which has 53 stalls along the length of the barn and out from the long side, stall lengths were measured as 2 m and stall widths as 1.0 m. The width of the service path was 2 m, and cleaned the service path and manger path during milking. In addition, partitions prepared for milking were allocated behind the stalls and between the service path and the mangers. The promenade area per cattle has been calculated as 16.7 m^2. Except for 7 (41.2%) of the barns examined in the research, there were no partitions reserved for calves and steers. The group partitions contained 2-7 cattles. The area of the partitions was calculated as 10.35 m^2 on average. In the free-stall barn, the style of the arrangement inside the barn was given in **Figure 8**. While some of the barns have partitions reserved for birth, no space is left for sick animals on any agribusiness. The birth and calf partition in a tied-stall barn was shown in **Figure 9**.

Figure 8. *The style of the arrangement inside the barn in the free stall barn*
Figure 9. *Birth and calf compartment in a barn*

The data on the manger, stall, and manure canal dimensions and service road widths in the barns were given in **Table 5**. In addition, the information on the number of milch cattles, width, length and height, and window and door dimensions of the barns were given in **Table 6.** Established ditches silos in the courtyard for 7 (41.2%) of the business for silage feed storage. Drinkers with a length of 2.5-20 m and a width of 04-0.8 m were planned in the barns to meet the water needs of the cattles. It was determined that threw of the manure collected in the barn out of the manure evacuation openings opened on the barn walls and accumulated during daily cleaning. A manure discharge opening in a barn was shown in **Figure 10**.

Figure 10. *Manure discharge opening in a barn*

While stone was used as the basic building material in 6 (35.3%) barns, concrete material was used in 11 (64.7%) barns. The barn floor consisted of compacted soil in 6 (35.3%) of the barns and concrete poured on stone blockage in 11 (64.7%) of the barns. It was determined that the walls of 4 (23.5%) of the barns were made of briquettes material, 7 (41.2%) of the walls of briquette and plaster material, and the walls of 6 (35.3%) of them were made of brick material. While 9 (64.3%) of the barns had wooden doors, 5 (35.7%) had doors made of iron or sheet metal. Door widths varied between 1.0-4.0 m, and heights varied between 2.30-3.10 m. It has been determined that window widths in barns varied between 0.8-3.0 m and heights varied between 0.45-0.90 m.

Discussion

Most of the barns surveyed had 1-10 head cattles. There should be cattles between 20-30 heads (**Kaygısız and Tümer, 2009**). Natural ventilation was used in all of the barns. Fresh air entered the barn through windows, doors, manure openings, or windows that opened for some reason. However, the insufficiency of the air intake holes and exit openings required for natural ventilation in most barns could not provide the barn's desired level of air exchange. **Arıcı et al. (2001)** reported that the insulation of the walls was an important precaution when roof insulation was not sufficient. It is also possible to reduce the barn volume by reducing door and window areas and building ceilings as other measures. Large openings for summer ventilation and small openings for winter ventilation are used as air entry windows (**Ekmekyapar, 2001**). **Yüksel et al. (2004)** determined that the dimensions of the sections to be used as air intake holes (0.05x0.75 m and 0.15x0.75 m) are the most appropriate. These results are consistent with the problems related to natural ventilation in barns found in previous studies (**Avcı, 2009; Alkan et al., 2011; Alkan, 2015**). While it was determined that sufficient lighting was done in only 4 barns, natural lighting couldn't be done at a sufficient level due to the small window area in 9 barns. **Alkan (2015)** stated that the ratio of the window area to the barn floor area should be between 1/15-1/20 for the animals in the barn to benefit from natural light. **Yaslıoğlu and Arıcı (2005)** specified that should

use 4-6 W/m^2 electric bulbs or 1.5-2.0 W/m^2 fluorescent lamps in the manger way to provide the required lighting intensity. These results were consistent with natural and artificial lighting problems in barns found in previous studies (**Özhan et al., 2009; Alkan et al., 2011; Alkan, 2015; Şirin and Kocaman, 2016; Bilgili and Aybek, 2019**). The long side of most of its barns is located in an east-west direction. The façade of 12 (70.6%) of the barns opens to the south. **Şimşek (1996)** and **Kayar (2011)** indicated the importance of placing in a north-south direction to benefit from natural lighting in double stall barns. In addition, in 3 free barns, the direction where the walls are open is the south direction. **Büyüktaş et al. (2016)** and **Uğurlu and Şahin (2010)** were suitable for the directions previously reported. While the average width of the mangers in the barns was 0.63 m, the heights of the mangers varied between 0.20-0.85 m. In the tied-stall barns, the manger path left in front of the wall was at most 1.0 m wide. **Arıcı et al. (2010)** previously stated 1.0 m manger path width was encountered in only 3 (23%) of the stall barns examined. The stall lengths in the barns varied between 1.5-2.5 m. **Yüksel and Şişman (2015)** reported that the mangers varied between 0.6-0.8 m depending on the structure. The width of the urinary canal in the barns was measured between 0.35-0.55 m and the average was calculated as 0.42 m. **Usta (2011)** and **Çayır et al. (2012)** stated that the width of the urinary canal varied between 0.30-0.40 m. However, it has been reported that these values were taken as 0.45-0.50 m in conditions where the cleaning was done mechanically. Service road widths in the barns varied between 0.60-2.00 m, and **Büyüktaş et al. (2016)** and **Olgun (2011)** are less than the recommended value of 1.5-2.0 m. Free loose stall barns are suitable for businesses with 60 or more cattle (**Anonymous 2016**). Service path widths in the barns varied between 0.60-2.00 m, and **Büyüktaş et al. (2016)** and **Olgun (2011)** were less than the recommended value of 1.5-2.0 m. Free stall barns are suitable for businesses with 60 or more cattle (**Anonymous 2016**). The average stall width of free stall barns was 1.00 m, and the average stall length was calculated as 2.0 m. **Olgun (2011)** specified that the optimum stall width was 1.15 m and stall length was 2.15 m. Previous studies were consistent with the results obtained in the research (**Öztürk et al., 2007; Arıcı et al., 2010; Yılmaz and Yardımcı, 2014**). Newborn calves were taken into individual calf partitions 2-3 days after birth in case of disease reinfection. Only 1 of the agribusiness had an calf partition. The area reserved as a calf partitions in this agribusiness was only wide enough for 4 calves to coexist. **Arıcı et al. (2010)** stated that usually 50% of dairy cattles should have been kept in the barns. The milking house must separate a clean and well-drained part and provide adequate lighting, ventilation, and water. The window area in the milking place should be 1/10 of the floor area, and it is appropriate to plan one milking stall for every ten cattles (**Arıcı et al., 2010; Yüksel and Şişman, 2015)**.

Barn Building Elements

All of the barns had foundations, but the basic wall width was insufficient. İf the width of the foundation wall is taken 0.5-0.6 m, it is possible to carry the load on the foundation **(Alkan, 2015; Güğercin et al., 2017).** The height of 61.5% of the barns varied between 2.5-3.0 m. The distance between the service road and the ceiling complied with the values recommended in previous studies. It was essential to plan barn wall heights between 2.0-3.5 m in tied-stall barns and 2.5-3.0 m in free loose barns to constitute the desired air volume. **Kılıç et al. (2020)** reported that barn height ranges between 2.50-2.75 for warm regions. It has been observed that the widths of single winged doors in the barns examined are wider than the 1.00-1.25 m dimensions given in **Şirin and Kocaman (2016)**. The door width recommended for double-wing doors should be between 1.50-1.65 m (**Balaban and Şen, 1988**). Door heights are kept low in some barns. It can suggest that the door heights to be 2.0-2.4 m higher than the barn floor (**Göncü and Gökçe, 2017; Güler et al., 2017**). Barn window widths varied between 0.8-3.0 m, window heights 0.45-0.90 m, and the height of the windows from the ground varied between 1.00-1.25 m. The windows could not provide a homogeneous light distribution in the barn. **Özkütük et al. (2007)** and **Alkan (2015)** stated that window widths and heights should be planned 1.00-1.25 m in size, and the windows in a rectangular shape, adequate lighting and homogeneous distribution of light in the barn.

Choosing the Suitable Barn Type

The research results showed that the barns could not provide the environmental conditions desired by the animals due to various planning faults and lack of information. In terms of economic management, planning of dairy cattle barns of 30 heads and above will be appropriate considering factors such as the economic situation of the business manager, instability in milk prices, rapid increases in feed prices, high feed loan interest rates, and the obligation to employ workers. In determining the barn type, environmental conditions, regional habits, and opportunities to provide building materials are essential. When these factors are evaluated together, free-stall and free-loose barns are more suitable than tied-stall barns for the region. Tied-stall barns are not recommended than the other two barn types due to both the construction cost and the difficulties in management, considering the region's environmental conditions. Although free-loose barns constitute the most suitable barn type for the region, they are preferred in tied-stall barns due to the habits of those engaged in animal husbandry in the region. The recommendations made in the study were consistent with previous studies (**Çaylı, 2006; Karabacak and Topak, 2007; Kocaman, 2008; Alkan 2015; Şirin ve Kocaman, 2016; Kurç ve Kocaman, 2016; Kılıç ve ark., 2020**).

Table 5. *Measurements of manger, stall and urinary canal sizes and service road widths in barns*

Business No	Barn Type	Feeder Dimension (m)				Stall Dimension (m)			Manure Channel Dimension (m)				Service Road (m)	Feeder Road (m)
		Width (m)	Feeder Height (m)	Feeder Height (m)	Feeder Thickness (m)	Width (m)	Length (m)	Base Materials	Width (m)	Depth to the Stall Side	Service Road (m)	Slope (%)		
1	Stall Barn	0.75	0.62	0.30	0.10	1.85	1.90	Concrete	0.95	0.05	0.95	0.5	0.95	0.95
2	Stall Barn	0.50	0.40	0.35	0.10	1.85	1.80	Concrete	0.50	0.10	-	0.0	-	1.00
3	Stall Barn	0.50	0.50	0.25	0.10	1.65	2.10	Concrete	-	-	0.80	1.0	0.80	-
4	Stall Barn	0.65	0.70	0.40	0.15	1.10	2.00	Concrete	0.60	0.05	0.60	0.5	0.60	1.00
5	Free Loose Barn	0.50	0.50	0.30	0.03	-	-	Concrete	0.60	0.05	0.60	0.5	0.60	0.60
6	Stall Barn	0.60	0.75	0.25	0.10	1.50	2.50	Concrete	1.00	0.15	3.00	0.5	2.00	1.70
7	Stall Barn	0.60	0.60	0.45	0.10	2.00	1.50	Concrete	1.00	0.05	1.00	1.5	1.00	0.95
8	Stall Barn	0.60	0.20	0.10	0.10	1.20	1.50	Concrete	0.35	0.05	1.35	0.5	1.35	0.95
9	Free Loose Barn	0.70	0.80	0.30	0.15	-	-	Soil	1.10	0.10	1.10	0.7	1.10	0.90
10	Stall Barn	0.60	0.65	0.35	0.10	1.70	1.80	Concrete	0.90	0.10	0.90	0.5	0.90	0.50
11	Free Loose Barn	0.50	0.90	0.60	0.15	-	-	Soil	0.80	0.15	0.80	1.5	0.80	-
12	Stall Barn	0.75	0.70	0.45	0.10	1.50	2.50	Concrete	0.55	0.05	0.60	0.5	0.60	0.90
13	Stall Barn	0.60	0.85	0.25	0.10	2.00	2.20	Concrete	0.40	0.08	-	0.0	-	-
14	Stall Barn	0.70	0.50	0.25	0.15	1.20	2.00	Concrete	0.80	0.10	0.80	1.0	0.80	0.90
15	Free Stall Barn	0.60	0.10	0.10	-	1.00	2.00	Concrete	1.70	0.05	1.70	0.6	1.70	0.90
16	Stall Barn	0.70	0.85	0.25	0.10	1.10	2.00	Concrete	0.36	0.10	2.00	1.5	2.00	1.00
17	Stall Barn	0.60	0.80	0.35	0.10	1.20	1.60	Concrete	-	-	-	0.0	-	-

Table 6. *Measurements of the number of milking cows, width, length and height of the barns and the dimensions of windows and doors*

Business No	Barn Type	Number of Milch Cows	Barn Width (m)	Barn Length (m)	Barn Height (m)	Window Dimension (mm)		The height of Windows form the Ground	Door Dimensions (mm)		Local
						Width (m)	Height (m)		Width (m)	Height (m)	
1	Stall Barn	11	8.0	13	3.5	0.8	0.40	1.45	1.20	1.85	Ayaz
2	Stall Barn	10	7.0	13	4.0	0.9	0.45	1.70	1.40	2.10	Osmaniye
3	Stall Barn	14	6.5	20	4.0	0.9	0.65	1.00	1.00	1.70	Karaköy
4	Stall Barn	13	8.5	24	5.0	1.6	0.60	2.00	2.00	2.00	Karaköy
5	Free Loose Barn	7	9.0	17	4.0	-	-	-	-	-	Karacaali
6	Stall Barn	10	9.5	20	5.0	0.9	0.75	2.00	2.00	3.00	Hayriye
7	Stall Barn	11	8.5	30	4.0	0.8	0.50	1.65	2.60	1.90	Avşar
8	Stall Barn	10	10.0	30	5.5	1.5	0.45	1.70	2.50	2.10	Karasıl
9	Free Loose Barn	20	10.0	30	5.5	-	-	-	-	-	Karasıl
10	Stall Barn	10	7.5	20	4.0	1.0	0.60	1.75	2.50	2.75	Karasıl
11	Free Loose Barn	9	8.0	16	4.0	-	-	-	-	-	Merkez
12	Stall Barn	9	8.5	25	4.5	0.9	0.90	2.50	1.50	2.00	Osmaniye
13	Stall Barn	14	9.5	32	4.5	3.0	0.50	2.00	1.60	2.00	Merkez
14	Stall Barn	8	7.7	15	3.5	1.1	0.80	1.20	1.10	2.00	Merkez
15	Free Stall Barn	26	24.0	26	6.0	-	-	-	4.00	3.00	Çardakköy
16	Stall Barn	10	8.0	26	4.3	1.0	0.50	0.50	3.30	2.00	Cihadiye
17	Stall Barn	9	8.5	15	4.5	0.9	0.50	0.50	1.50	2.00	Menteşe

Conclusions

This research, in 1997, investigated the structural condition and problems of dairy cattle farms in the Bursa-Yenişehir district. It was tried to determine the development possibilities and the selection of dairy cattle barns suitable for the region. According to the results, various faults have been identified in the arrangement of the buildings in the business courtyards. Most of the barns are far from providing suitable environmental conditions and modern barns required by the animals. It has been determined that the barns planned as free-loose barn types were not used during the whole production period due to traditional habits and various inadequacies. The barn capacity suitable for the region has been determined as 30 heads considering the physical conditions of the agribusinesses and environmental conditions. Free-loose barn and free-stall barn types are more suitable than tied-stall barns considering the regional requirements, and these barn types are recommended to be selected in planning.

References

Alkan, S., Karslı, T., Karabağ, K. (2011). Basic principles of planning dairy barns in organic agriculture. I. Ali Numan Kıraç Agriculture Congress and Fair with International Participation, 27-30 April, Eskişehir, Turkey.

Alkan, S. (2015). Major problems encountered in dairy cattle barns in Turkey. Academic Journal of Agriculture 4 (1): 43-48.

Anonymous, (1997). The Annual report of Meteorological Station, Bursa, Turkey. www.mgm.gov.tr/verideğerlendirme/il-ve-ilçeler-statistic.aspx?k

Anonymous, (2016). http://www.agriculture.gov.tr/agriculture/livestock/cattle

Arıcı, İ., Şimşek, E., Yaslıoğlu, E. (2001). Planning of dairy cattle barns. Sütaş Dairy Training Center Publications, Bursa, 26p.

Arıcı, İ., Şimşek, E., Yaslıoğlu, E. (2010). Planning of dairy Cattle barns. Sütaş Education Center Publications, Livestock Series. 4, Bursa.

Avcı, M.O. (2009). A research on climatic environmental conditions in barns of dairy farm in Aydın province. Adnan Menderes Üniversity Graduate of Natural and Applied Sciences Department of Farm Structure and Irrigation, MSc. Thesis, Aydın, Turkey.

Balaban, A and Şen, E. (1988). Agricultural structures, Publications of Ankara University Faculty of Agriculture, No: 721, Ankara, Turkey.

Bilgili, M.E. and Aybek, A. (2019). Evaluation in terms of requirements in application of carried out scientific studies for structural and mechanization properties of dairy cattle farms in Turkey. Çukurova 2. International Multidisciplinary Studies Congress. https://www.researchgate.net/ publication/333752

Büyüktaş, K., Atılgan, A., Tezcan, A. (2016). Agricultural production structures. Süleyman Demirel University Faculty of Agriculture Publication No: 101, Isparta.

Çayır, M., Atılgan, A., Öz, H. (2012). Manure and water in cattle shelters. Süleyman Demirel University Faculty of Agriculture Journal 7 (2): 1-9, ISSN 1304-9984.

Çaylı, A. (2006). A Research on environmental conditions control and solution proposals in dairy cattle shelters and a case of Kahramanmaras-Dereköy. KSU Institute of Science, Department of Agricultural Structures and Irrigation, Master Thesis, 59 p.

Ekmekyapar, T. (2001). Agricultural structures. Atatürk University Faculty of Agriculture Textbook. Publications No: 204, Erzurum.

Göncü, S., Gökçe, G. (2017). Technological applications for profitable and sustainable production in cattle breeding enterprises in Turkey. Çukurova J. Agric. Food Sci. 32: 29-34, 2017.

Güğercin, Ö., Koç, D.L., Büyüktaş, K., Baytorun, N., Polat, B., Polat, Ö.D. (2017). Determining of current situation of some animal barns in dairy cattle barns in Adana Province. Çukurova J. Agric. Food Sci. 32: 19-28.

Güler, O., Aydın, R., Diler, A., Yanar, M., Koçyiğit, R., Maraşlı, A. (2017). A Research on barn features of cattle farms; Example of Narman district of Erzurum province. Yüzüncü Yıl University Journal of Agricultural Sciences, 27 (3), 396-405.

Karabacak, A., and Topak, R. (2007). Structural conditions and problems of dairy cattle barns in Ereğli vicinity. Selçuk University Faculty of Agriculture Journal 21 (42): (2007) 55-58.

Kayar, Y. (2011). Evaluation of structural properties of housing in dairy cattle farm in Denizli region. Master Thesis, Depatment of Agricultural Structures and Irrigation, Denizli, Turkey.

Kaygısız, A. ve Tümer, R. (2009). The structural features of farms of dairy cattle in Kahramanmaraş Provınce: 2. Barns Traits. KSU J. Nat. 40 Sci., 12(1): 40-47.

Kılıç, İ., Yaylı, B., Alakberov, A. (2020). Structural status and evaluation of dairy cattle operations in Bakû. Journal of Agricultural Faculty of Bursa Uludag University, 34(2): 237-253.

Kocaman, İ. (2008). A Research on the development of different capacity tied stall dairy cattle barn projects for Kırklareli region. Tekirdağ Faculty of Agriculture Journal 5 (2), Tekirdağ.

Kurç, H. C., Kocaman, İ. (2016). A Structural examination of cattle breeding agribusinesses in Tekirdağ-Malkara region. Tekirdağ Agriculture Faculty Journal 2016: 13 (04).

Olgun, M. and Öneş, A. (1989). Problems and suggestions in animal agribusinesss in TİGEM agribusinesses. (Unpublished research), Ankara.

Olgun, M. (2011). Agricultural structures. Ankara University Faculty of Agriculture Textbook. Publication No. 529, Ankara.

Özhan, M., Tüzemen, N., Yanar, M. (2009). Cattle breeding. Atatürk University Faculty of Agriculture, Offset House, Erzurum.

Özkütük, K., Göncü Karakök, S., Gökçe, G. (2007). Cattle welfare in dairy cow barn design. HASAD Journal 2007, Year: 23, Issue: 32; 32-37s.

Şimşek, E. (1996). Great breeding dairy cattle agribusiness optimum design. Uludağ University Institute of Science (Ph.D Thesis). Bursa.

Şirin, Ü. and Kocaman, B. (2016). Optimum design of dairy cattle barns in Erzurum province. Journal of Agricultural Faculty of Gaziosmanpasa University, 33 (3): 28-38.

TUİK, (2020). http://www.tuik.gov.tr//PruTablo.do?alt_id=1001

Uğurlu, N., and Şahin, S. (2010). The structural properties of dairy cattle barns in Kayseri. Selçuk University Journal of Selçuk Agriculture and Food Sciences, 24 (2): (2010) 23-26.

Usta, S. (2011). Principles of creating architectural layouts in free-stall dairy cattle farms and development of type layout plans as suggestions for producers.

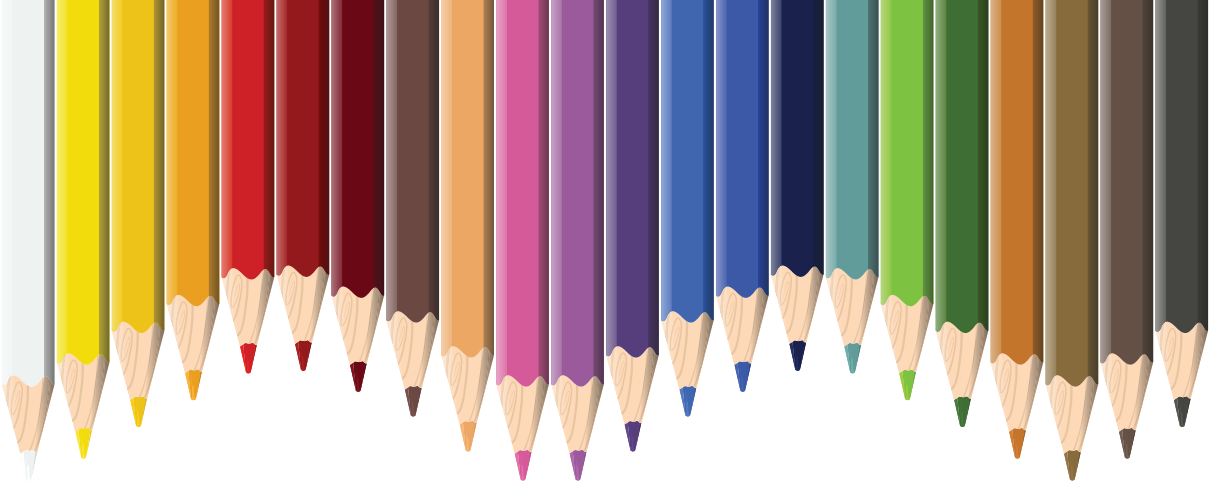
Süleyman Demirel University Journal of Technical Sciences Vol: 1, Issue: 2, Page: 29-42, Isparta.

Yaslıoğlu, E., Arıcı, İ. (2005). A Research on the development of suitable cold barn types for dairy cattle in Bursa Region. Journal of Tekirdag Agricultural Faculty, 2/2: 1-13.

Yılmaz, H. İ., Yardımcı, N. (2014). Evaluation of agribusinesses in dairy cattle farms in terms of animal welfare in Isparta region. Harran Journal of Agricultural and Food Sciences, 18 (4), 27-34.

Yüksel, A.N., Soysal, M.İ., Kocaman, İ. and Soysal, S.İ. (2004). Dairy cattle basic book (Planning Dairy Cattle agribusiness/Dairy Cattle Breeding). Hasad Publishing, Istanbul.

Yüksel, A.N. and Şişman, C. B. (2015). Planning animal agribusiness. Hasad Publishing, Istanbul, Turkey.



Chapter 5

APPLICATIONS OF DEEP LEARNING IN FOREST ROADS

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INTRODUCTION

One of the most important natural resources of economic value in the world is undoubtedly the forest ecosystem. A forest ecosystem is a homogeneous piece of forest in terms of the composition, characteristics and interrelationships of the elements that manifest themselves in a specific location. Forests play a vital role in maintaining Earth's biodiversity and mitigating climate change by sequestering huge amounts of carbon in their vegetation and soil. In addition, forests regulate rainfall, ensuring essential water resources for agriculture, industry and drinking water. Forests serve as a significant source of sustenance, medicine, drinking water, and provide unlimited recreational and aesthetic benefits for millions of people. They also play a crucial role in the global economy, emphasizing the need for careful and effective forest management in today's context. With the transfer of production processes to digital platforms in the modern age, making them transparent and tangible, the importance of forest maintenance and conservation remains as relevant as ever. Forest roads are vital for facilitating transportation, forest management, preserving natural resources, preventing forest fires, and afforestation operations in steep terrain regions (Çalışkan, 2013). To ensure successful forest management and conservation of natural resources, a well-planned, designed, constructed and maintained forest road system is essential (Çalışkan, 2017). Continuous monitoring of forest road infrastructure and tracking of changes is critical not just for navigation service quality, but also for public institutions' service planning. Furthermore, operators carry out the digitization of forest roads manually, resulting in potential topological errors and inconsistencies arising from varying levels of digitization experience. There are many applications for integrating feature extraction from satellite images and aerial photographs into Geographic Information Systems (GIS). Essential steps in this integration process include object detection in high-resolution satellite images, route finding in high-resolution image data, identifying landforms, and accessing land cover information.

Use of image classification techniques for road extraction has been an area of study for more than twenty years in spatial data research (Gruen L. 1997, Heipke et al., 1997; Narwade Musande 2014; Kiss et al., 2016). There are numerous uses for integrating feature extraction from satellite imagery and aerial photos into Geographic Information Systems (GIS). Key steps in this integration process consist of high-resolution satellite image object detection, high-resolution image data route discovery, landform identification, and access to land cover information.

Image classification techniques have been studied for over two decades in the field of spatial data research for road extraction (Gruen L. 1997, Heipke et al. 1997; Narwade Musande 2014; Kiss et al. 2016).Artificial intelligence (AI) has emerged as a highly researched and developed field in recent years, owing

to the growing utilization of AI technologies in software and products created by both academic and industrial scientists and developers. These technologies have enabled people to lead simpler lives. Machine learning, specifically deep learning techniques, is frequently employed in AI applications. Cutting-edge information technologies are essential to support the advancement of forestry. Currently, numerous next-generation information technologies have been successfully implemented in forestry activities. Deep learning (DL) methods serve as a typical AI algorithm, and they are widely utilized in multiple industries, including forestry (Hittave 2015; Afonso et al., 2017; Ye et al. 2019; Ma et al., 2019; Haque et al., 2020; Yuan et al. 2020; Çalışkan et al., 2022a).

This study aims to investigate the detection of forest roads through the implementation of artificial intelligence and deep learning applications. The second section outlines the concepts of artificial intelligence, machine learning, and deep learning. The third segment concentrates on the application of deep learning methods in the detection of forest roads. Finally, the last section presents the study's findings.

ARTIFICIAL INTELLIGENCE AND DEEP LEARNING

Artificial intelligence (AI) aims to equip machines with human-like abilities such as self-learning, reasoning, and logical decision-making (Charniak, 1985). The term AI refers to a computer or machine's ability to perform high-level logical tasks, which may be unique to humans, such as problem-solving, understanding, meaning extraction, generalization, or learning from past experiences (Andrew, 1991). AI technology emerged in the 1950s, enabling machines to perform certain tasks with human-like skill. Weak AI is limited to performing only programmed tasks, while strong AI systems can enhance the original programming through algorithmic calculations and learn from errors (Andrew, 1991).

Machine learning, which originated in the 1980s and gained widespread popularity through the use of data mining, utilizes systems capable of generating simulations based on provided data and parameters. These systems can make more accurate detections than humans, revealing previously undiscovered trends and patterns through their self-training capabilities (Ratner, 2000).Deep learning, introduced in the 2010s, operates across multiple layers, simultaneously performing calculations used in machine learning. It can aid in identifying parameters that require definition in machine learning, thereby offering improved evaluations with refined parameters (LeCun et al., 2015). Machine learning is a subspace of artificial intelligence, and deep learning is a subspace of machine learning (Figure 1).

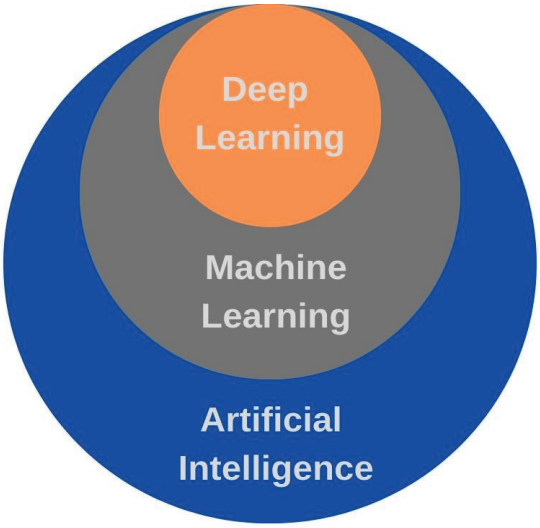


Figure 1. Relationship between Artificial Intelligence, Machine Learning and Deep Learning (Goodfellow et al., 2016)

A novel technique that bolsters the precision and clarity of artificial intelligence (AI) is Deep Learning. The method, created to emulate how the human brain retains data, intends to decode the intricate data representation approach employed by humans in AI research (LeCun et al., 2015). In standard machine learning algorithms, the training stage requires the calculation of pre-established human-generated features. In contrast, Deep Learning learns distinctive features independently of human intervention during the training phase. Artificial neural networks, which predate deep learning algorithms in AI and are widely used, have a structured arrangement of layers, comprising input, hidden, and output layers. In contrast, deep learning entails a notably intricate configuration with numerous layers, frequently ranging from 5 to 10 or even dozens of layers. The utilization of Graphics Processing Units (GPUs) in computers enhances the execution of training processes in deep learning algorithms due to their multi-layered and complex structures (Şeker et al., 2017; Kayaalp et al., 2018; Arı, 2019).Obtaining predictions with the Deep Learning Algorithm involves a learning process of the relationships between data, specifically the input and output variables, requiring intensive mathematical operations. Deciding on algorithm parameters, such as layer count, neuron count, and transfer function type, is crucial for achieving successful prediction results. Additionally, identifying various features, particularly the one predicted through Deep Learning and known as the output variable, in addition to the input variables applied in prediction, constitutes another set of parameters that impact the predictive efficacy of the network. Various deep learning architectures have been proposed to achieve high performance rates

in different situations. Each of these architectures is designed to provide successful processes for specific types of circumstances. Deep learning architectures are influenced by the type, structure, and amount of data. The choice of architecture can significantly impact the performance and efficiency of the model. It is crucial to consider the input size, the complexity of the task, and the available resources when selecting an architecture. Additionally, the training process and optimization techniques are also key factors to achieve the best results. Many deep learning architectures are currently employed, and the selection is based on the structure of the issues being tackled. Various deep learning architectures are utilized to produce outcomes like data classification, recognition, detection, and prediction. Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), Restricted Boltzmann Machines (RBM), Recurrent Neural Networks (RNN), Autoencoders (AE), and Deep Belief Networks are among the most preferred deep learning architectures. The selection of the neural network model depends on the problem at hand. Each architecture has its unique benefits and limitations (Mosavi et al., 2019). Deep learning studies are used when researchers cannot determine all features in problem-solving, or when the features cannot be obtained as numerical data through existing methods, even if all features are determinable. Today, deep learning is in an advanced state and is one of the most active research areas.

As GIS experience a constant rise in data density, computer-aided systems for analyzing and storing this data are becoming increasingly necessary. In GIS, deep learning algorithms serve various purposes such as map drawing over extended periods, adding new roads to maps, and analyzing data. High-resolution remote sensing for Earth observation has played a vital role in multiple areas, and one of the primary techniques it has focused on is road extraction (Samadzadegan et al., 2009).Compared to road extraction in urban areas, extracting roads in mountainous regions presents more difficulties due to the presence of tree shadows and topographical complexity. Several techniques have been proposed to extract roads from remote sensing images. Recently, the use of deep learning and technology-based applications in forestry areas has increased significantly. Recently, the use of deep learning and technology-based applications in forestry areas has increased significantly. Nowadays, deep learning is the leading technological advancement in forestry applications. The advances in image processing and deep learning have impacted research in forestry, with successful detection of forest roads through deep learning methods.

DEEP LEARNING APPLICATIONS IN FOREST ROADS

Funds are assigned for the upkeep and repair of forest transportation routes, which are vital channels for navigation within wooded areas. The detection and resolution of road deficiencies, including but not limited to partial

collapses, potholes, and cracks in these thoroughfares, are essential in curbing accidents linked to these particular issues. Maintaining roads in good condition is crucial for safe driving, a responsibility shared by both highway authorities and local forest management units. Among the vital tasks for forest roads is the monitoring of deterioration, which necessitates specialized knowledge. Over time, improper construction methods during the building phase, pressure from heavy vehicles, and weather conditions can cause deformations on road surfaces.

In recent years, deep learning methods have gained importance in various disciplines that require remote sensing, such as defense, medicine, agriculture and aviation. These methods continue to provide highly successful results compared to traditional approaches. The main difference between deep learning and classical image recognition techniques is that deep learning methods automatically learn features from existing data. As a result, deep learning has emerged as a widely discussed research topic. Especially in recent years, with deep learning methods emerging as the dominant trend, various approaches have been proposed for forest road extraction (Çalışkan, 2022a).

Lee et al. (2004) introduced an integrated neural network-based system for detecting cracks on roads by using digital surface images to classify types of cracks. Bacher and Mayer (2005) proposed an automated technique for extracting roads from high-resolution multispectral satellite images. The images were initially classified into a "road class image" that includes membership values for each pixel. Wang et al. (2005) discussed road extraction methods from multispectral images, emphasizing that such methods involve separation of roads from other ground features based on the spectral characteristics of individual pixels. Miao et al. (2014) proposed a semi-automatic method to detect road networks from high-resolution satellite images. Tapan et al. (2015) sought to identify roads in forested regions automatically using a trained classification approach on 30 cm resolution infrared digital aerial photos.

Alshehhi et al. (2017) introduced a novel hierarchical graph-based approach for extracting roads from high-resolution images. Meanwhile, Tian and co-authors (2017) utilized images captured by vehicle cameras to classify highways and employed a deep learning with the Faster R-CNN architecture.

Lu et al. (2018) put forth a new method for road detection that adeptly extracts road networks by utilizing both local and global information in conjunction with remote sensing images. Ale et al. (2018) recommended a procedure for efficiently detecting road damage through the analysis of road images. They conducted training employing the RetinaNet model on images obtained from smartphones to discern the presence of road damage, presenting an augmented classification rate for road damage detection.

Wang et al. (2018) presented a straightforward and useful model for

detecting objects in road damage assessment. The authors employed Faster-RCNN and SSD models to detect road damage, achieving favorable outcomes in various IEEE big data studies.In 2018, Buslaev et al. proposed an approach for automatic road extraction utilizing an evolutionary neural network. The dataset comprised 6,226 images with a resolution of 1024x1024 and RGB input, and was trained using ResNet-34 and U-Net models.

In a 2018 study, Horita et al. proposed an alternative approach for road marking detection and segmentation. The approach was based on a Fully Convolutional Neural Network (FCNN) with an encoder-decoder architecture. In another study, Zhang et al. suggested a segmentation method using a semantic segmentation neural network that combines the strengths of U-Net, a convolutional neural network, for extracting roads from aerial images.Hoang (2018) developed an AI algorithm for identifying damages on asphalt road surfaces. The algorithm extracts features from digital images using image processing methods, including a Gaussian filter, directional filter, and integrated projection.Gao et al. (2019) proposed a deep residual convolutional neural network (RDRCNN) for the improved detection of road areas. Meanwhile, Singh et al. (2019) suggested a deep convolutional neural network for extracting roads from aerial imagery. Their model was trained on the Massachusetts road dataset, utilizing the U-Net architecture.

Abdollahi et al. (2019) introduced a novel mixed approach for extracting roads from Unmanned Aerial Vehicles (UAV) imagery. Zhang et al. (2018) implemented a semantic segmentation model to extract roads from aerial photographs by merging U-net with three ResBlocks for both contracting and expanding roads.Mandal and et al. (2019) proposed a method for crack detection and classification in autonomous roads based on deep learning using YOLO v2, a convolutional neural network method used for object detection.

In a study conducted by Çalışkan et al. (2022a), the extraction of forest road networks from high-resolution orthophoto images using deep learning was explored. The study utilized four distinct deep learning models, specifically AlexNet, ResNet-50, InceptionResNet-V2, and U-Net.In a recent study (Çalışkan et al., 2022b), three distinct deep learning architectures using semantic segmentation, including MobileNet-V2, ResNet-18 and Xception, were assessed for their effectiveness in extracting forest road networks from high-resolution orthophoto images. The results were analyzed for their accuracy and efficiency.

DISCUSSION AND CONCLUSIONS

The study analyzed the efficacy and efficiency of the models.Artificial intelligence (AI) and deep learning are utilized in forestry to bring an intelligent and data-driven approach to forest management and decision-making

processes. Deep learning architectures have evolved for various fields, revealing their versatility. These architectures are believed to become omnipresent in everyday life, indicating the opening of a pathway to an autonomous world. Efforts are underway to achieve self-driving vehicles, safer roads, and unmanned aerial and ground vehicles, leading to a transformation in the transportation industry.

When reviewing the literature, it is observed that methods developed using deep learning demonstrate a high success rate. Due to rapid changes in both artificial and natural features, regular updates of spatial data, especially related to road networks, are essential. Traditional methods for providing road data are ineffective due to their costliness and time-consuming nature. In contrast, using advanced remote sensing and Unmanned Aerial Vehicle (UAV) technologies for extracting road types can be economically and practically efficient.

The training time for deep learning algorithms is higher than that of classical algorithms. The performance of deep learning is dependant on numerous parameters, which are often determined through trial and error. Some of these parameters include the number of hidden layers, optimization techniques, error functions, and activation functions. The selection of these functions significantly impacts the network's performance.

In conclusion, deep learning is a rapidly expanding, multidisciplinary research area that focuses on novel challenges, including the detection and monitoring of forest roads. Collaborative efforts between deep learning experts and forestry scientists are likely to produce substantial gains in addressing these challenges.

REFERENCES

Abdollahi, A., Pradhan, B., and Shukla, N. (2019) Extraction of road features from UAV images using a novel level set segmentation approach. International Journal of Urban Sciences,Volume 23, Issue 3, 1 -15.

Afonso, C., Rossi, ALD., Vieira, FHA., and Leon, F. (2017). Deep learning for biological image classifcation. Expert Syst. Appl. 85:114–122. https://doi.org/10.1016/j.eswa.2017.05.039.

Ale, L., Ning, Z,,and Longzhuang, L.(2018). Road Damage Detection Using RetinaNet. IEEE International Conference on Big Data (Big Data). IEEE, 10-13 December 2018, Seattle, WA, USA.

Alshehhi, R., and Prashanth, R.M.(2017). Hierarchical graph-based segmentation for extracting road networks from high-resolution satellite images. ISPRS. journal of photogrammetry and remote sensing 126 : 245-260.

Andrew, A. M.(1991). Artificial Intelligence , Boston: AddisonWesley Company.

Arı, A. (2019). Beyin Mr Görüntülerinden Tümörlerin Tespit Edilerek Sınıflandırılması, Doktora Tezi, Inönü Üniversitesi, Malatya, Turkey.

Bacher, U. and Mayer, H.(2005). Automatic road extraction from multispectral high resolution satellite images, inProc. Int. Archives Photogramm. Remote Sens. Spatial Inf. Sci., vol. 36, pp. 29–34.

Buslaev, A., Seferbekov, S., Iglovikov, V., Shvets, A.(2018). Fully convolutional network for automatic road extraction from satellite imagery. The IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops. 18-22 June 2018. Salt Lake City, UT, USA.

Copeland, J. (1993). Artificial Intelligence: A Philosophical, Blackwell: Oxford.

Charniak, E., McDermot, D.(1985). Introduction to Artifical Intelligence, Boston: Addison-Wesley Company.

Çalışkan, E. (2013). Planning of Forest Road Network and Analysis in Mountainous Area, Life Science Journal, 10(2),2456-2465.

Çalışkan, E.(2017). Planning of environmentally sound forest road route using GIS & S- MCDM. Šumarski list, 141 (11- 12), 583.

Çalışkan, E., Sevim, Y.(2022a). Forest road detection using deep learning models,-Geocarto International Journal , Vol..37, sa.20, ss.5875-5890.

Çalışkan, E., Sevim Y.(2022b). Forest road extraction from orthophoto images by convolutional neural networks, Geocarto International Journal ,Vol.37, sa.26, ss.11671-11685.

Gao, L., Song,W., Dai, J., Chen, Y. (2019). Road Extraction from High-Resolution Remote Sensing Imagery Using Refined Deep Residual Convolutional Neural Network. Remote Sens., 11, 552.

Goodfellow, I., Bengio, Y., Courville, A., Bengio, Y. (2016). Deep learning (Vol. 1, No.2). Cambridge: MIT press.

Gruen, A., Li H.H.(1997). Semi-automatic linear feature extraction by dynamic programming and LSB-Snakes, Photogrammetric Engineering and Remote Sensing, 63(8): 985-995.

Haque, IR., Neubert, J. (2020). Deep learning approaches to biomedical image segmentation. Inform Med Unlocked 18:1–12. https://doi.org/10.1016/j.imu.2020.100297

Heipke, C., Mayer, H., Wiedemann, C., Jamet, O.(1997). Evaluation of automatic road extraction . Int. Arch. Photogramm. Remote Sens., 32, 151–160.

Hittawe, MM., Muddamsetty, SM., Sidibé, D., Mériaudeau, F. (2015). Multiple features extraction for timber defects detection and classifcation using SVM. In: IEEE International Conference on Image Processing. IEEE. https://doi.org/10.1109/ICIP.2015.7350834

Hoang, N.D. (2018). An Artificial Intelligence Method for Asphalt Pavement Pothole Detection Using Least Squares Support Vector Machine and Neural Network with Steerable Filter-Based Feature Extraction. Advances in Civil Engineering, 1–12. doi:10.1155/2018/7419058

Horita, L.R.T and Grassi, V.(2017). Employing a fully convolutional neural network for road marking detection. Robotics Symposium (LARS) and 2017 Brazilian Symposium on Robotics (SBR), Latin American. IEEE, 2017.

Kayaalp, K., and Süzen, A.A., (2018). Derin Öğrenme ve Türkiye'deki Uygulamaları. Institution of Economic Development and Social Researches Publications, , p. 1-93. Türkiye.

Kiss, K., Malinen, J., Tokola, T. (2016). Comparison of high and low density airborne LiDAR data for forest road quality assessment. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences III-8: 167-172. - doi:10.519 4/isprsannals-III-8-167-2016

Kizrak, M.A and Bolat B. (2018). Derin Öğrenme ile Kalabalık Analizi Üzerine Detaylı Bir Araştırma, Bilişim Teknolojileri Dergisi**,** 11:3,263-286,Turkey.

Lee, B. J. and Lee, H. (2004). Position-Invariant Neural Network for Digital Pavement Crack Analysis. Computer-Aided Civil and Infrastructure Engineering, 19(2), 105–118. doi:10.1111/j.1467-8667.2004.00341.x

LeCun, Y., Bengio, Y. and Hinton, G.,(2015). Deep learning. Nature, 521, 436-444. Congress, 25 August – 01 September, Melbourne, Australia.

Lu, Y., Gao, K., Zhang, T., and Xu, T. (2018). A novel image registration approach via combining local features and geometric invariants. PLoS ONE 13(1), https://doi.org/10.1371/journal. pone.0190383

Ma, L., Liu, Y., Zhang, X., Ye, Y., Yin, G., Johnson, BA. (2019). Deep learning in remote sensing applications: A meta-analysis and review. ISPRS J Photogramm 152:166–177. https://doi.org/10. 1016/j.isprsjprs.2019.04.015

Mandal, V., Uong, L. and Adu-Gyamfi, Y. (2019). Automated Road Crack Detection Using Deep Convolutional Neural Networks. Proceedings - 2018 IEEE International Conference on Big Data, Big Data 2018, 5212–5215. doi:10.1109/BigData.2018.8622327

Miao, Z., Wang, B., Shi, W., and Zhang, H.(2014). A semi-automatic method for road centerline extraction from VHR images. IEEE Geoscience and Remote Sensing Letters, 11(11), 1856 1860.

Mnih, V., and Hinton, G.E.(2010). Learning to detect roads in high-resolution aerial images, in Proc. ECCV, Sep, pp. 210–223.

Mosavi, A., Ardabili, S., Varkonyi-Koczy, A.R. (2019). List of Deep Learning Models, International Conference on Global Research and Education, Budapest, 202-214.

Narwade, R., Musande, V. (2014). Automatic road extraction from airborne LiDAR: a review. International Journal of Engineering Research and Applications 4: 12, 54-62.

Polat, N., and Uysal, M. (2020). An investigation of tree extraction from UAV-based photogrammetric dense point cloud. Arabian Journal of Geosciences, 13(17): 1-8.

Ratner, B.,(2000). A comparison of two popular machine learning methods, DM STAT-1 Online Newsletter about Quantitative Methods in Direct Marketing, 4.

Redmon, J., Divvala, S., Girshick, R. ve Farhadi, A. (2016). You only look once: Unified, real-time object detection. Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2016-Decem, 779–788. doi:10.1109/CVPR.2016.91

Singh, P., and Dash, R.(2019). A Two-Step Deep Convolution Neural Network for Road Extraction from Aerial Images. 2019 6th International Conference on Signal Processing and Integrated Networks (SPIN). IEEE.

Samadzadegan, F., Hahn, M,.(2009). Automatic road extraction from LIDAR data based on classifier fusion, Urban Remote Sensing Event, pp.1-6. doi: 10.1109/URS.2009.5137739.

Şeker, A., Diri, B. and Balık, H.H.(2017). Derin Öğrenme Yöntemleri ve Uygulamaları Hakkında Bir İnceleme, Gazi Mühendislik Bilimleri Dergisi (GMBD), 3:3, 47-64.

Tapan, K.S., Bölme, M., Eker, O. (2015). Görüntülerden sınıflandırma yöntemlerini kullanarak detayların otomatik olarak belirlenmesi: renkli kızılötesi hava fotoğraflarından ormanlık alanlarda yolların belirlenmesi için bir sınıflandırma uygulaması, TUFUAB VIII. Teknik Sempozyumu, Konya,Türkiye.

Tian, Y., Gelernter, J., Wang, X., Chen, W., Gao, J., Zhang, Y. and Li, X. (2017). Lane marking detection via deep convolutional neural network, Neurocomputing, vol. 280, pp. 46–55

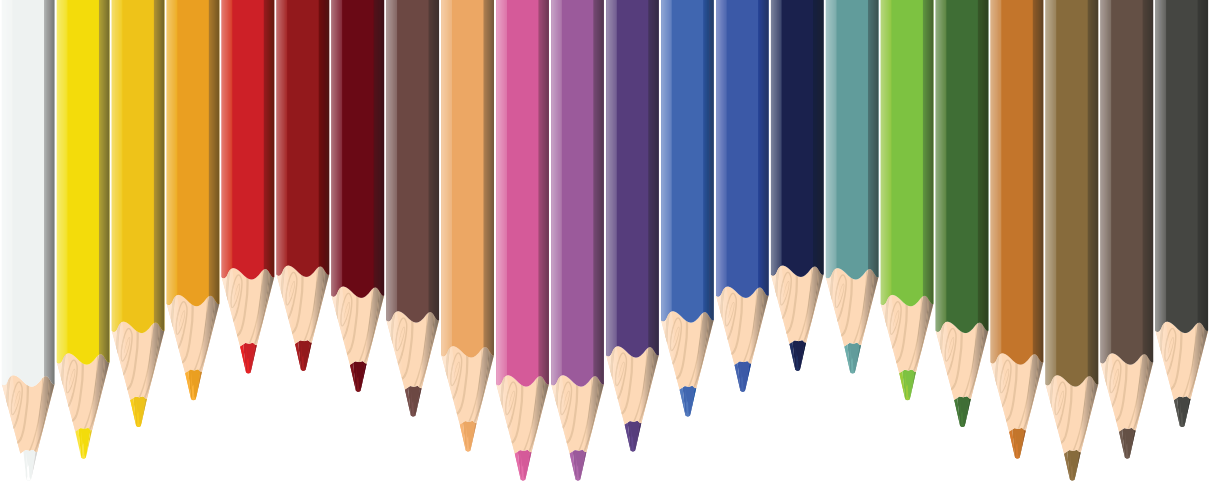
Ye, L., Gao, L., Marcos-Martinez, R.(2019). Projecting Australia's forest cover dynamics and exploring infuential factors using deep learning. Environ Modell Softw 119:407–417. https://doi.org/10. 1016/j.envsoft.2019.07.013

Wang, R., Hu, Y., Zhang, X. (2005). Extraction of road networks using pan-sharpened multispectral and panchromatic quickbird images. Geomatica, 59 (3): 1-28

Wang, Y.J., Kan, S., Zhang, S., Lu, C.(2018). Deep Proposal and Detection Networks for Road Damage Detection and Classification. 2018 IEEE International Conference on Big Data (Big Data). IEEE, 10-13 December 2018, Seattle, WA, USA.

Yuan, Q., Shen, H, Li, T., Li, Z., Li, S., Jiang, Y. (2020). Deep learning in environmental remote sensing: Achievements and challenges. Remote Sens Environ 241:111716. https://doi.org/10.1016/j.rse.111716

Zhang, Z., Liu, Q., and Wang, Y.(2018). Road extraction by deep residual u-net. IEEE Geoscience and Remote Sensing Letters 15.5 : 749-753



Chapter 6

EFFECT OF PULP BEATING PROCESS ON FIBERS AND STRENGTH OF PAPER

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INTRODUCTION

Paper is an important material needed in many different areas from education to hygiene in our daily life. Paper pulp is also a raw material suitable for producing very different products according to the needs of these areas. The change in the humidity of the environment in which the paper is used and its water exchange characteristics make it an even more functional product. For example; While it is desired that the cleaning and drying papers have high water absorption properties, on the contrary, it is preferred that the water absorption properties of the printing and packaging papers are low. However, we can make these two papers from the same raw material, with the same cooking method, and under the same conditions. With these aspects, paper pulp is perhaps the only raw material that can produce products with different properties from the same raw material. It is a physical process called 'beating' that contributes significantly to the paper's wide product range. Thanks to this physical process, the fibrillation, fringing, and cutting of the pulp obtained by chemical methods in the beaters enable the fibers to make more individual bonds in the formation of the paper sheet. As a general rule, pulp obtained by mechanical method is not beaten. Because, in the production of pulp by mechanical method, whether it is stone mechanical pulp or refiner mechanical pulp, the raw material is exposed to mechanical effects similar to the beating process. These effects can occur separately or in a double and triple combination of cutting, plucking, and stripping processes. If these pulps are subjected to the beating process again, the fiber cut and fine fiber ratio will be too high. In this case, the pulp yield and the paper quality to be obtained will also decrease due to the fine fibers formed in the pulp. In addition, during the production of paper from these pulps, the problem of filtration in the screen and thus the slowdown in the speed of the paper machine, the energy cost in the final drying will also increase.

The remaining lignin ratio in the pulp is important in the beating process, and as this ratio increases, the water absorption ability of the pulp decreases and the swelling of the fibers is limited (Rydholm, 1965). However, the resistance of paper to water absorption is only due to the surface of the fibers, it is also related to the structure of the paper (Roberts, 1997).

In that case, when the softwood and hardwood pulps obtained under the same cooking conditions are beaten in equal concentrations, the softwood pulp will be harder to beat, since it will be difficult to hydrate. This is because the pulp is obtained from softwood wood, which is high in lignin. It is more hydrophobic than hardwood pulp and therefore more rigid. Softwood pulp produced under the same conditions needs more energy to reach the same degree of freeness.

When long fiber pulps are beaten at the same time as short fiber pulps,

more fiber shearing and deformation are observed in long fiber pulps. Therefore, they may have the same probability of arriving at the same degree of freeness in equal time. This is because long fibers have a higher rate of catching on refiner blades. In this case, softwood pulps with the same lignin content will have more deformation than hardwood pulps. At the same time, since the ratio of the fiber surface caught on the blade will be high, the energy expenditure will also be high. Although beating is a physical process, its results are directly related to the paper's water absorption. Fiber-fiber bonds increase with the release of large amounts of microfibrils by fibrillation on the fiber surface after beating. Hydrogen bonds and van der Waals forces can influence fiber-to-fiber bonding (Robert 1996). There is no significant change in the chemical structure of cellulose during the beating process. This is evident from the X-ray refraction marks (Lönnberg, 2005). The result of the beating, which is a physical process, is important in terms of activating the chemical mechanism and, consequently, having a chemical bond effect.

There are many theories between the mechanism of the beating process and the bonding of the fibers with each other. For instance; Parsons found that beating of spruce sulfite pulp increased the area of the paper in specific surfaces and optical contact. However, Ingmanson and Thode believe that the total bondable area does not depend on the specific surface provided by beating, but is a constant value determined only by the surface area of the unwrought fibers. The reason is that the fine fibers from beating are reattached to the surface of the main fibers and reduce the bond area (Casey, 1960). Rydholm stated that the open ends formed by breaking the natural internal bonds between fiber cutting, fibrillation, and fringing and, cellulose crystals by forging play an important role in water uptake and swelling (Rydholm, 1965). In this way, it is ensured that a very different paper is obtained compared to the paper obtained from unbeating pulp obtained from the same raw material. Although the beating process is performed according to certain standards, the standard determined by TAPPI "TAPPI T200 sp-01 [2001] Laboratory beating of pulp (Valley beater method)" is the most used standard in laboratories. The standard set by ISO for the forging process is "Beating was performed based on the ISO method (ISO 5264-1 1979) at neutral pH using distilled water and a laboratory Valley beater".

In the paper mills, the beating was done with tools called "Hollander" in the early days. It is made by the progress of the beat pulp suspension thanks to Hollander's plates and the crushing of the fibers between the same plates. Since the Hollanders are open tanks, the pulp is directly exposed to the weather conditions during the beating process (Macdonald and Franklin,1969). In this case, it should also be taken into account that the pulp will be directly affected by the current situation and seasonal conditions of the environment where beating is done. The temperature loss of the suspension by evaporation

causes the fibers to lose the plasticization gained by the heat in the beating process. In this case, as the pulp loses temperature, the fibers become rigid again. As a result, it is also possible to reduce fiber quality, decrease machine efficiency and increase maintenance costs. In addition, other negativities that may occur in the facility from steam corrosion should also be considered. On the other hand, the negative effects of steam in the working environment can be risky for human health. Conical refiners and disc refiners were used more commonly in the beating process, as well as Hollanders. Steam and heat loss is minimized since the refiners are closed. With these aspects, the steam and heat losses of refiners from Hollanders are very low. Although many methods are used to control the forging process, the Schopper method is the most preferred. It is done on the Schopper device (Eroğlu, 1990).

Effect of Pulp Concentration on Beating

The role of pulp concentration is important in the beating process. As a result of beating the pulp obtained from the same raw material under the same conditions at different concentrations, the length and fibrillation properties of the fibers will change.

In the same pulp with a low concentration, the fiber rate caught between the blades is less than in the pulp with a high concentration. Therefore, there is a difference between high-concentration and low-concentration beating, even in the same cycle.

This is because the force exerted by the blade is the same, so the force exerted on the individual fiber in low-concentration beating will be greater than in high-concentration beating. In this case, fiber shear in low-concentration beating is higher than in high-concentration beating (Lundin et al, 2008). Low-concentration beating has been suggested to reduce fines left in the pulp. In this case, it was stated that the clogging of the cleaners in the paper machine decreased (Fulton, 1984). In addition, the interaction that will occur from the contact and friction of the fibers in high-concentration beating will increase fibrillation. The increase in fibrillation directly affects the number of interfiber bonds. Accordingly, high-concentration beating should be preferred if it is desired to have less fiber cut and increase the number of inter-fiber bonds. On the other hand, energy expenditure will be higher in high-concentration beating than in low-concentration beating.

Refining affects fibers in many ways, with the most important effects being as follows:

- Cutting and shortening of fibers

- Fines production and complete removal of parts from fiber walls, creating debris in suspension

– External fibrillation, the partial removal of the fiber wall, leaving it still attached to the fiber

- Internal changes in the wall structure, variously described as delamination, internal fibrillation, or swelling

- Curling the fiber or straightening the fiber

- Creating nodes, kinks, slip planes, and microcompressions in the cell wall, or removing those from the cell wall

- Dissolving or leaching out colloidal material into the external liquor

- Redistribution of hemicelluloses from the interior of the fiber to the exterior

Abrasion of the surface at the molecular level to produce a more gelatinous surface (Lumiainen, 2000)

With the increase in the beating time

1- Fragmentation and partial separation of the fiber primary membrane

2- Reduction of fiber length

3- Increased fiber elasticity

4- *F*ringing in fibrils

5- Physical effects such as an increase in fiber specific surface occur (Tank, 1998).

Fibrillation and abrasion, fiber hydration, and fiber length shortening occur in refiners due to the opening of the fiber structure (Dagan and Gould, 1987).

Physical changes in fibers after beating can be studied in two different environments;

1- Dry fibers or dispersed in non-swelling liquid media (suspension with aromatic or aliphatic hydrocarbons)

2- The fibers are in a suspension of water and a liquid that can swell them (Tank, 1998).

In a study, in order to reduce fiber shear in the beating process, alkali treatment prior to beating increased the fiber width while the length was decreased in the swelling process. It has been stated that the strength properties of the paper to be produced from the alkali-treated fibers may increase (Choi et al 2016).

In the beating process, the pulp content varies depending on the type of raw material from which the pulp is obtained and the pulp production method. Since the increase in the rate of hemicelluloses has a positive effect on the plasticization of the fibers by absorbing water, it has positive effects such as facilitating the beating process, shortening the time, and reducing energy expenditure (Bostancı,1987). In addition, hemicelluloses form hydrogen bonds during the drying of the paper, giving strength to the paper (Kırcı, 2000.) Although lignin, which is amorphous, is most abundant in the middle lamella and primary wall, as the remaining lignin content in the pulp increases as it is not hydrated, it becomes more difficult to beat the pulp and increases energy consumption.

The beating of chemical pulp obtained from raw materials with short fibers such as wheat straw makes drainage and drying processes difficult. Eroğlu (1983) stated that the paper pulp obtained from wheat stalks by chemical methods should not be beaten for a short time or at all. He also stated that the beating costs of these pulps are very low compared to unbleached softwood Kraft pulps. The pulp to be used in paper production is subjected to beating in the form of a water suspension. The fiber suspension is brought to the desired degree of freeness by passing between the Hollander blades. The phrase 'paper is made in the Holladers' is used in papermaking (Eroğlu, 1983). This quote sums up how important beating is. In short, Hollander is where paper acquires its properties. The reason for this definite claim is that significant changes occur in the physical properties of the fibers during the beating process. In addition, since the properties of the pulp can be changed by beating, it is possible to produce paper with different properties from the same pulp. This provides the paper manufacturer with an opportunity to meet the demands of the market. With the increase in beating time, the degree of freeness decreases, the % elongation of the paper increases (Eroğlu, 1990).

This physical change in the pulp greatly changes the physical properties of the paper. With beating, which is a mechanical process, physical changes such as gaining plastic properties, fibrillation, increasing the fiber surface area, shearing, crushing and fringing occur in the fibers. With this change, the number of hydrogen bonds in the pulp increases, especially thanks to the open ends in the cellulose chain. Thus, paper with different properties can be produced from the same pulp. However, some features can be improved with beating, while others can be adversely affected. The most important reason for this is fiber cutting. This is influenced by the physical properties of Hollander and the chemical components of the pulp. For example, very sharp blades increase fiber shear, while blunt blades increase crushing. In addition, the chemical composition of the pulp is also effective in the beating. While the remaining lignin content in the pulp makes it difficult to beat, hemicelluloses make it easier.

Effect of Beating on Fibers

As beating causes the fibers to collapse, it makes the fibers more flexible (Horn,1978). Therefore, beating should not be understood as fiber shortening. If beating was only fiber shortening, there would be no difference in strength between beaten and unbeaten fibers of the same length. The purpose of beating is not only to shorten the fibers but also to increase the number of inter-fiber bonds by providing fibrillation. With beating, the surface of the fibers increases 4-6 times.

The shape and length of the fibers that make up the paper may differ from each other.

These cells are partially similar to each other during the beating. However, the suitability of some fibers for papermaking during beating may increase, while others may decrease.

(Lönnberg, 2005). When the pulp suitable for the characteristics of the paper to be produced is obtained beating should be finished.

Although the individual fiber strength is very high, it has little effect on the structure of the paper formation (Mark, 1967). The strength of the paper increases linearly with the increase of the inter-fiber bonding area, that is, with the increase in the overlap length of the fibers (Page et al., 1962). Beating is perhaps the most used process to increase the tensile index and, accordingly, the strength properties (Robert, 1996). On the other hand, the breaking, bursting, and double folding resistances increase, the tear resistance increases rapidly at the beginning of the beating, and decreases rapidly after a while.

In order to keep the physical properties of the paper within certain limits, controlled beating is required. The following methods are suggested for beating control.

1- Concentration of pulp (usually keep between 4-6%)

2- The flow rate of the refiners, hence the transit time from the refiners.

3- If necessary, to ensure that the pulp passes through the refiner again.

4- It is to determine the power consumed in refineries (Eroğlu, 2003). These processes are carried out by an experienced laboratory or engineer.

Laboratory Refiners

1-PFI Mill

2-Valley Beater

3-Jakro Mill

4-Pilot-Refiners

Industrial Refiners

1-Disk Refiners

2-Conical Refiners

3-Cylindrical Refiners (Gharehkhani, et al 2015).

Effect of Beating on Paper Properties

Paper of equal weight, made from unbeaten pulp produced from raw material with the same method under equal conditions, has a rougher surface, greater thickness, and lower strength than paper made with beaten pulp (Eroğlu 1990).

Table 1 shows the changes in some of the mechanical properties (tear index, tensile index, and burst index) of the papers obtained from pulps whose degrees of freeness were changed by beating.

Table 1 Changes in tear index, tensile index, and burst index of papers obtained from pulps whose degrees of freeness were changed by beating.

Raw Materials/ Reference	Pulp Type	°SR	Tear index $mN \cdot m^2/g$	Tensile index$N \cdot m/g$	Burst index$kPa \cdot m^2/g$
Common hazelnut (*Corylus avellana* L.)/ Gençer and Özgül 2016	Kraft	18±2 35±2 50±2	3.83 3.63 3.34	43.23 83.29 87.86	1.87 5.01 5.19
Redwood (Sequoia sempervirens D.Don)/ Gençer et al 2015	Kraft	16±2 35±2 50±2	9.1 4.5 4.2	47.0 94.3 99.3	2.8 3.8 4.4
Common hazelnut (*Corylus avellana* L.)/ Gençer and Özgül 2015	Sulfate	Unb. 35±2 50±2	4.40 3.97 3.53	42.09 86.00 94.98	1.92 5.01 5.05
Softwood kraft pulp./ Gülsoy 2014	Kraft	15 20 30	20.0 16.0 13.0	25 80 100	1.90 2.85 4.20
European black pine (*Pinus nigra* Arn.)/ Gülsoy and Eroğlu 2011	Kraft	Unb. 35 50	30.0 14.3 13.3	44.8 103.9 99.6	2.6 6.8 6.8
Maritime pine (Pinus pinaster Ait.)/ Gülsoy et al 2016	Kraft	- Unb. 35 50	- 15.06 8.16 8.32	Breaking Length (km) 4.30 8.27 8.46	- 3.23 5.57 5.58
Turkish Calabrian pine (Pinus brutia Ten.)/ Gülsoy and Uysal 2020	Kraft	13 28	9.4 3.8	37.0 76.0	2.3 4.7
Softwood /I'Anson et al 2006	Kraft	14 41 63	Unb. - -	17.1 54.7 34.2	- - -
Bleaced hardwood pulp/ González, et al.,2012	Bleached Hardwood	- 16 22 31 43	$gf\ m^2/g$ 38.6 63.9 65.3 50.1	- 25.7 41.3 64.5 85.5	- 1.25 2.65 4.25 4.65
Sorghum/ Gençer and Hatıl 2019	Kraft	30±2 35±2 50±2	1.98 1.87 1.67	71.90 77.0 83.90	2.53 2.68 2.98
White mulbery (*Morus alba* L),Gençer et al.,2013	Kraft	20±2 35±2 50±2	2.25 2.80 2.34	- - -	0.54 2.06 2.42

Unb.: Unbeaten, °SR: Schopper-Reigler freeness

In the first stage of the beating process, the tear index first rises rapidly for a short time and decreases rapidly as the beating time increases.

As mentioned before, if we compare the unbeaten pulp fibers to a worm, the bonding of these fibers with each other will be like the tangent contact of two cylinders. Therefore, the number of bonds made only in the tangential parts of the total surface area of the two fibers next to each other is low. At the beginning of the beating, the fiber surface takes the shape of a centipede with external fibrillation and fringing, and the number of bonds increases rapidly. As a result, the tear resistance increases rapidly. If beating is continued, fiber cutting begins. For this reason, the contact area of the adjacent fibers decreases and accordingly, the tear resistance decreases rapidly. In that case, the pulp of papers with high tear resistance should not be beaten too much.

RESULTS

It should not be taken to mean that strong paper will be made from pulp with high individual fiber strength. Paper strength is directly proportional to how much bond the fibers make with each other. The increase in the number of bonds between the fibers is completely dependent on the fibrillation that occurs with beating. Even if it is obtained from the same raw material, the fibers in a paper pulp may differ morphologically from each other, especially hardwood pulp. These cells partially resemble each other as the duration of the beating process increases. For this reason, papers obtained from beaten pulps have a more uniform structure than papers obtained from unbeaten pulps. In addition, the surface smoothness of the paper increases with the increase of the beating time of the pulp. The mechanical properties of smooth surface papers are also high.

Beating improves fiber bonding and hence paper strength through a variety of effects, including fiber swelling, fibrillation, shearing, and crushing (Young 1980). However, with the changes that occur in the pulp with beating, some situations that we do not want may develop. It may be possible to prevent these with some measures being taken. Changes in the fiber wall structure in case of using alkaline solution; swelling. In addition, the degree of fiber hydration can increase the strength of the paper if it is increased by alkali treatment. Alkaline swelling can alter fiber properties such as size and degree of hydration to potentially reduce paper strength loss while improving the paper volume (Zhang et al., 2013). When starch is used as a dry-strength material, it increases the tear resistance by keeping the tensile resistance at the same level with less beating. Increases production by accelerating drainage and beating (Robert, 1996).

However, pulps obtained by chemical and semi-chemical means are malleable, mechanical and thermomechanical pulps undergo an effect similar to beating in refineries during production, so they do not need to be beaten again,

otherwise, the pulp fiber increases, and the yield and mechanical properties of the pulp decrease.

Shortening of fibers with beating Despite the significant decrease in tear index shown in Table 1, fibrillation is the reason for the significant increase in the tensile index and burst index due to bonds formed by fibrillation. Therefore, beating alone does not mean fiber shortening. In fact, the bond length lost with the shortening of the fibers increases with the fibrillation effect of the beating. By preparing a beating program according to the demand of the paper producer. Whichever mechanical property of the paper to be produced is desired can be achieved by controlling the beating time. Therefore, the paper manufacturer must decide on the duration of beating according to the paper to be obtained.

REFERENCES

Bostancı Ş (1987) Kağıt Hamuru Üretim ve Ağartma Teknolojisi. K.T.Ü. Basımevi, Trabzon, 516 sayfa.

Casey, J. P. (1960) *Pulp and Paper Chemistry and Chemical Technology*, Vol. II, Second Edition. Wiley Interscience Publisher Inc., New York, 770-771 pages.

Choi K-H, Kim A R, Cho B-U (2016) Effects of Alkali Swelling and Beating Treatments on Properties of Kraft Pulp Fibers, BioReseources 11(2), 3769-3782.

Dagan S.J. and Gould S.O. (1987) A Practical Approach for Using Fiber Length Data to Monitor Refiner Performance, Tappi Journal, Vol:70, No:4.

Eroğlu, H., (1983) Samandan Lif Hamuru ve Kağıt Üretiminde Karşılaşılan Sorunlar, Karadeniz Üniversitesi Orman Fakültesi Dergisi, Cilt:6, Sayı 1.

Eroğlu, H., (1990) Kağıt ve Karton Üretim Teknolojisi, Karadeniz Teknik Üniversitesi, 2.Baskı, Yayın No:90,Trabzon. 623 sayfa.

Eroğlu H (2003) Kağıt Hamuru ve Kağıt Fiziği Ders Notları Zonguldak Karaelmas Üniversitesi, Bartın Orman Fakültesi Yayınları, Üniversite Yayın No:27, Fakülte Yayın No:13, Bartın. 144 sayfa.

Fulton C, (1984) TMP screening another approach, Tappi Journal, Vol. 67. No.1

Gençer A, Şirin G, Gül H, Özgül U (2013) Determination of the product conditions of pulp and paper from white mulberry (Morus alba L.) by kraft method. Journal of Bartin Faculty of Forestry, 15 (1-2): 63-68.

Gençer A, Özgül U, Onat S M, Yurdakurban F, Yazıcı H (2015) Feasibility Of Redwood Wood For Paper Production And The Effects Of Beating OnPaper‟s Properties, Journal of Multidisciplinary Engineering Science and Technology (JMEST) ISSN: 3159-0040 Vol. 2 Issue 10.

Gençer A, Özgül U (2015) Yaygın Fındık (*Corylus avellana* L.) Odunundan Soda Yöntemi İle Kâğıt Hamuru Üretim Parametrelerinin Belirlenmesi. Turkish Journal of Forestry, 16(2):159-163.

Gençer, A.; Özgül, U., (2015) Determination of parameters for pulp production from common hazelnut (Corylus avellana L.) wood by the soda method. Turkish Journal of Forestry, 16 (2): 159-163. 12.

Gençer, A.; Özgül, U., (2016) Utilization of common hazelnut (Corylus avellana L.) prunings for pulp production. Drvna industrija, 67 (2): 157-162. https://doi.org/10.5552/drind.2016.1529. 13.

Gençer, A.; Gül Türkmen, H., (2016) Determination of paper production condition of wild cherry heartwood and sapwood. Bartın Orman Fakültesi Dergisi, 18 (1): 23-31. 14.

Gençer, A.; Aksoy, H., (2017) Paper production from wild dogwood (Cornus australis L.) and the effect of bark on paper properties. Artvin Çoruh Üniversitesi Or-

man Fakültesi Dergisi, 18 (2): 186-191.

Gençer A and Hatıl C (2019) Determination of Alkali and Sulfite Ratios in Paper Pulp Produced from Sorghum Stalks via the Kraft Method, BioResources 14(1) 922-930

Gharehkhani, S., Sadeghinezhad, E., Kazi, S. N., Yarmand, H., Badarudin, A., Safaei, M. R., & Zubir, M. N. M. (2015). Basic effects of pulp refining on fiber properties—A review. *Carbohydrate polymers*, *115*, 785-803.

González, I., Boufi, S., Pèlach, M. A., Alcalà, M., Vilaseca, F., & Mutjé, P. (2012) Nanofibrillated cellulose as paper additive in eucalyptus pulps. *BioResources*, *7*(4), 5167-5180.

Gülsoy S K (2014) Effects of cationic starch addition and pulp beating on strength properties of softwood kraft pulp. STARCH-STARKE, 66 (7-8), 655-659.

Gülsoy S K, Eroğlu H (2011) Biokraft pulping of European black pine with *Ceriporiopsis subvermispora*, International Biodeterioation&Biodegradation, 65(4), 644-648.

Gülsoy S K, Oğuz S, Uysal S, Simsir S, Tas M (2016) The Influence Of Potassium Borohydride (Kbh4) On Kraft Pulp Properties Of Maritime Pine, Journal of Bartın Faculty of Forestry, 18 (2): 103-106.

Gülsoy S K and Uysal S (2020) Effects of Recycled Fiber Fines on Hand Sheet Properties of Different Unbeaten and Beaten Pulps DRVNA INDUSTRIJA 71 (4) 327-337. doi:10.5552/drvind.2020.1904.

Horn, R. A. (1978) Morphology of Pulp Fiber from Hardwoods and Influence on Paper Strength, Research Paper FPL, Forest Product Labrotary Forest Service, United States Department of Agiculture, Madison/Wisconsin, 53705.

I'Anson SJ , Karademir A and Sampson WW (2006) Specific contact area and the tensile strength of paper, Appita 297-301.

ISO 5264-1 (1979) "Pulps – Laboratory beating – Part 1: Valley beater method," International Organization for Standardization, Geneva, Switzerland.

Kırcı, H (2006) Kagıt Hamuru Endüstrisi Ders Notları. *Karadeniz Teknik Üniversitesi Orman Fakültesi Yayın*, No: 86, Trabzon. 248 sayfa.

Lönnberg, B. (2005) New Development in Cellulose Technology, Polysaccharides Structural Diversity and Functional Versatility, Second Edition, Marcel Dekker, New York.

Lumiainen, J. (2000) Refining of chemical pulp. *Papermaking part*, *1*, 86-122.

Lundin T, Batchelor W, and Fardim P (2008) Fiber trapping in low-consistency refining: new parameters to describe the refining process, TAPPI JOURNAL *7*(7), 15-21.

Macdonald, R. G., and Franklin, J. N. (Eds.) (1969) Pulp and Paper Manufacture: Control, secondary fiber, structural board, coating (Vol. 2). McGraw-Hill 132-186.

Mark, R. E. (1967) C*ell Wall Mechanics of Tracheids,*New Haven: Yale University Press; 310 pp.

Page, D. H.,Tydeman, P. A. And Hunt, M. (1962) *Behavior of Fibre to Fibre Bonds in Sheets under Dynamic Conditions,* Technical Section of the British Paper and Board Markers' Association.

Robert, J.C. (1996) Paper Chemistry, Blackie Academic &Professional, ISBN 0 7514n0236 2, 267 pp. London UK.

Rydholm, S. A. (1965) *Pulping processes*. Vol. 1, 1st Ed., Interscience Publishers, California, 1269 pages.

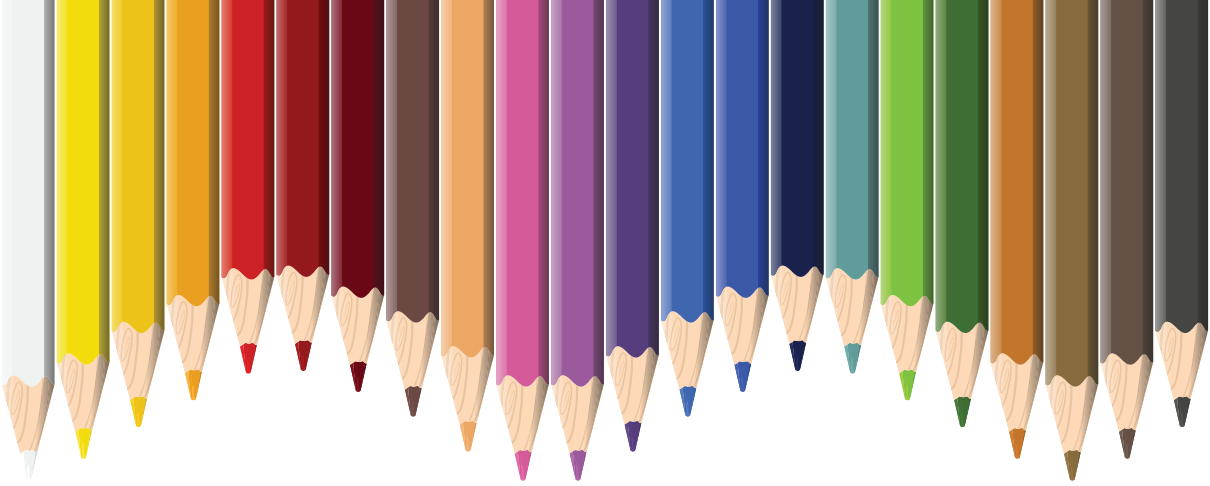
Tank T (1998) Kağıt Fabrikasyonu, İ Ü Basımevi ve Film Merkezi, Üniversite Yayın No: 4028, Fakülte Yayın No: 446, ISBN 975-404-457-0, İstanbul, 190 sayfa.

TAPPI T200 sp-01 (2001) Laboratory beating of pulp (Valley beater method).

Young, J. H. (1980) "Fiber preparation and approach flow" in: Pulp and Paper Chemistry and Chemical Technology, J. P. Casey (ed.), Wiley, New York, NY, pp. 821-914.

Zhang, S., Wang, W.-C., Li, F.-X., and Yu, J.-Y. (2013) "Swelling and dissolution of cellulose in NaOH aqueous solvent systems," Cellulose Chemistry Technology 47(9- 10), 671-679.

Zubir, M. N. M (2015) Basic effects of pulp refining on fiber properties—A review, Carbohydrate Polymers, ELSEVIER, 115 (2015, 785-803).



Chapter 7

SOME VEGETATION INDEXES USING IN LAND USE/LAND COVER, SOIL EROSION AND SOIL QUALITY STUDIES: A REVIEW.

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Introduction

Thanks to developed technologic tools and software, comprehensive data analyses and forecasting forward looking have reached promising points. Due to remote sensing systems' passive and active sensors, having a knowledge of atmospheric and earth surface data became possible (Jensen, 2009). Thanks to the ease of reaching data, having secure data, large area spectrum and examining the characteristics of parameters in detail, the research in remote sensing technology is increasing day by day (Karaca and Güllü, 2018).

Remote sensing is interested in obtaining information about the objects or the cases on earth. Taking the energy reflected or released and recording is the basics of remote sensing. Each object has a specific reflection property. Vegetation cover is easily recognized and examined in earth objects. With the use of remote sensing, providing the precious spatial and temporal information is possible when considering the dynamic properties of plants.

Vegetation cover is a general term which is expressed for plant life. It expresses soil cover provided by plants and is mostly located in the biosphere. So, vegetation cover is a crucial biophysical parameter which describes the world's surface system (Jones and Vaughan, 2010). Firstly, it provides a biogeochemical cycle. This situation is so important for the climatic conditions. Secondly, vegetation covers affect the productivity and the soil properties strongly. It also has great importance as a source of wildlife and energy (Bahre, 1991). Utilize of remote sensing and Geographical Information Systems (GIS) disciplines together in the land monitoring and assessment studies allow to reach the sensitive and accurate information in terms of land (İslam et. al., 2021; Liping et. asl., 2018; Sluiter, 2005).

Vegetation cover phenology is influenced by climatic dynamics a lot except for the other environmental factors such as soil, topography and sunbathing (Crucifix et al., 2005). In the Central Anatolian region, in dry farming areas, vegetation productivity is mostly dependent on precipitation. In years with low precipitation, vegetation cover decreases, while biomass increases in years with high precipitation, leading to an increase in the vegetation index value (Erdoğan and Akdeniz, 2004). In an area where the precipitation is sufficient, vitality of vegetation cover indicates that agricultural productivity is high. Using the relationship between these two parameters, forecasting the amount of agricultural production is possible with remote sensing data.

Spectral reflections acquired from Earth observation satellites have been used to monitor plant phenological changes since the

launch of Landsat-1 in 1972 (Jackson, 1986). The development of spectral sensors and methods involving band combinations has introduced the concept of vegetation indexes, playing a crucial role in assessing cultigens grown in large areas (Jia et al., 2011; Shou et al., 2007). Specifically, the red and Near-Infrared (NIR) bands of the electromagnetic spectrum actively contribute to monitoring agricultural ecosystem services (Liu et al., 2004).

In fact, the spectral regions relevant to biophysical changeable of plant such as height, density, and cover percentage are closely interconnected. It is well-established that the ratio of near-infrared bands to red edge spectral bands exhibits a high correlation together with crop improvement opposite dissimilar expansion periods. The spectral vegetation index is a commonly utilized method for analyzing and detecting changes in plant physiology and chemistry. The principles of vegetation indexes are grounded in determining reactions to biotic and abiotic factors related to the presence of chlorophyll, including leaf area index and plant biomass (Li et al., 2015; Kokaly and Clark, 1999).

Today, numerous spectral indexes, described as radiometric measurements, have been developed to gather information about the biophysical features of green-leafed plants. For this purpose, indexes such as NDVI (Normalized Difference Vegetation Index), Effective Leaf Area Index, Red-Edge Modified Chlorophyll Absorption in Reflectance Index, Red-Edge Optimized Soil Adjusted Vegetation Index, Green Normalized Difference Vegetation Index, Healthy Index, and LAI (Leaf Area Index) are commonly employed (Bagheri et al., 2012; Fitzgerald et al., 2010; Wójtowicz et al., 2016). The explanations and the various applications of vegetation indexes described and categorized in this chapter.

1. Combined use of the Sentinel-2A MSI and Vegetation Indexes

The Sentinel satellites constitute a fleet of remote sensing satellites launched into space under the European Space Agency's Copernicus program. Primarily, this satellite fleet serves various purposes, including assisting in managing food security, supporting agricultural and forestry practices, environmental management, understanding the impacts of climate change, and developing solution proposals. Sentinel-2 satellites capture images of land and coastal areas between 56° south and 83° north latitudes every five days, utilizing two satellites (Handbook and Tools, 2015).

Sentinel-2A MSI has much more ability to examine the plants more than the other satellites (Aghlmand et al., 2019). Dedeoğlu, (2020) aimed to monitor the nitrogen (N) nutrient status, a crucial

component in sugar beet (Beta vulgaris) plant development and the highest chemical fertilizer, using REdge and NDVI values extracted from Sentinel-2A satellite imagery. He also explored the relationship between these remote sensing indicators and ground truth data. With this study, the potential for monitoring and assessing sugar beet nitrogen (%N) content using vegetation indexes derived from high-resolution satellite images was explored. Dedeoğlu, (2020) has concluded that in this study, parcel-based relationships between Redge – NDVI values off Sentinel-2A satellite imagery and sugar beet %N content were satisfactorily established during early to mid-vegetation periods, with a noted decrease in usability during the maturation period and beyond. The study highlighted the successful monitoring of %N content, especially at the beginning of the vegetative growth period, owing to the Red Edge band's ability to reduce soil reflection and its sensitive responsiveness to chlorophyll pigments. Furthermore, the use of Sentinel-2A satellite images was recommended due to their measurement capability within the reflection range of the Red Edge wavelength (705-740-783 nm) in similar phenological research.

Multispectral Sentinel-2A satellite images have a spatial resolution of 10 m in 4 bands, 20 m in 6 bands and 60 m in the other 3 bands (Table 1).

Table 1. Characteristics of the Sentinel-2A Satellite Sensor

Band	Band Name	Wavelength (nm)	Band width (nm)	Spatial Resolution (m)
B1	Coastal Aerosol	443	20	60
B2	Blue	490	65	10
B3	Green	560	35	10
B4	Red	665	30	10
B5	Vegetation Red-Edge	705	15	20
B6	Vegetation Red-Edge	740	15	20
B7	Vegetation Red-Edge	783	20	20
B8	Infrared	842	115	10
B8A	Vegetation Red-Edge	865	20	20
B9	Water vapor	945	20	60
B10	Cirrus	1380	30	60
B11	Shortwave Infrared (SWIR)1	1610	90	20
B12	SWIR2	2190	180	20

2. General Descriptions for the Vegetation Indexes

2.1. Normalized Difference Vegetation Index (NDVI)

In remote sensing technology, NDVI is one of the most used tools monitoring the green vegetation cover. NDVI is calculated by NIR and red bands of the satellite image and is approved as the primary indicator of the supply of plants' biomass and leaf area index and is used for monitoring the development of plant growth and productivity forecasting. For every pixel, the red band's reflection value is subtracted from the NIR band reflection value belonging to that pixel.

NDVI values are changing between -1 and +1. Index value closest to 1 where the green vegetation cover is more, while clouds, snow and water have nominal NDVI index values. NDVI value closest to 0 in the instance of bare soil and weak vegetation cover (Hatfield et al., 1985). When observing the agricultural lands in a NDVI map, the areas together with nominal NDVI values point out the areas where vegetation cover is weak with the severe factors such as drought, excessive moisture, illness and detrimental effects. On the other hand, high NDVI values point out the healthy plant development areas. NDVI data is successfully used in different areas of the world by many scientists in examining the vegetation cover in large areas. The NDVI procedure is lot advantageous compared to the customary methods due to low cost and gaining fast results in the research that covers large areas.

NDVI value is calculated by the formula given below:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{RED})/(\mathrm{NIR} + \mathrm{RED}) \quad (1)$$

2.2. Leaf Area Index (LAI)

LAI firstly introduced by Watson, (1947) as total one-sided leaf texture area for per unit surface area. Many researchers have done descriptions based on this definition according to different vegetation types. No matter how the leaves where photosynthesis takes place are the basics of LAI, branches and stems of the plants are included from time to time in LAI calculations (Kucharik et al., 1998; Neves et al., 2013). In some research LAI is described as the amount of the leaf falling on unit soil area (Asner et al., 2003), while Gower et al., (1999) has described the LAI as the area of whole leaves.

Various methods have been developed to determine Leaf Area Index (LAI), categorized as either direct or indirect measures. Direct measurements involve assessing the leaf surface area of plant vegetation (Gower et al., 1999; Marshall and Waring, 1986; Peper and McPherson, 1998; Sumida et al., 2009) in a given area, relying on relationships such as those between leaf surface area and forest

openings (Chen and Black, 1992; Mason et al., 2012; Sampson and Allen, 1995). Indirect measurements utilize optical devices (Behera et al., 2015; Chianucci et al., 2014; Kara et al., 2011), particularly remote sensing methods (Hall et al., 2003; McAllister, 2005; Nagler et al., 2004; Yang et al., 2006) analyzing cover and light, often with satellite imagery. However, it is crucial to note that all indirect methods necessitate ground measurements for verification.

LAI value is calculated by the formula given below:

$$\text{LAI} = \text{Leaf Area } (\text{m}^2)/\text{Ground Area } (\text{m}^2) \quad (2)$$

2.3. Soil Adjusted Vegetation Index (SAVI)

For vegetation indexes, addressing the reflection from sub-soil biomass poses a significant challenge, and it is essential to mitigate the impact of this issue when calculating these indexes. NDVI, for instance, suffers from a non-linear relationship with biophysical properties and sensitivity to sub-soil mass. In contrast, SAVI employs a transformation technique that minimizes the influence of external factors. With red and NIR spectral bands, SAVI's graphical transformation incorporates alterations in the origin of reflection from the red and NIR in vegetated canopies, effectively eliminating the soil's effects on the indexes.

SAVI value is calculated by the formula given below:

$$\text{SAVI} = (\text{NIR} - \text{RED})/(\text{NIR} + \text{RED}) * (1 + \text{L}) \quad (3)$$

where, NIR and RED are the reflectance in spectral bands, L is the parameter which is constant value (Battay, 2013).

2.4. Red Edge-Optimized Soil Adjusted Vegetation Index (RE-OSAVI)

RE-OSAVI is an updated version of the SAVI (Soil Adjusted Vegetation Index) family which was advanced by Rondeaux et al., (1996). Red edge band (705 nm) is added instead of red band (670 nm) in RE-OSAVI. Red edge band minimizes the effectiveness of the sub-mass on the red wavelength reflection. This specialty makes RE-OSAVI much more trustworthy to define the plant biomass.

RE-OSAVI value is figured out by the formula given below:

$$\text{RE} - \text{OSAVI} = (1 + 0.16) \times [(\text{NIR} - \text{REdge})/\text{NIR} + \text{REdge} + 0.16)] \quad (4)$$

3. Application of Vegetation Indexes in Erosion Assessment Studies

With the increasing global population, the pressure on land is steadily rising, and the value of fertile soil is becoming more evident. Worldwide, the use of chemical pesticides and fertilizers is rapidly escalating to enhance the productivity of eroding or unproductive

soils, leading to various environmental challenges for both humans and ecosystems.

Erosion happens as a results of erodibility, transportation and accumulation of soil particles is a natural process. Soil erosion is one of the biggest problems of lands because it remove the productive topsoil. In geological process erosion is not a big problem. But, with inappropriate land use and wrong interventions on vegetation cover, erosion is increasing and because of it soils has been removed irreversibly. Erosion not only affect the environment, but it also affects human beings and because of this reason erosion is accepted as the most critical environmental worry in the world (Aiello et al., 2015; Phinzi & Ngetar, 2017).

Remote sensing and GIS technologies are mostly used methods determining the soil erosion and the land use/land cover change studies (Fenta et al., 2021). Image classification techniques including vegetation cover indexes have been used often in recent years (Phinzi & Ngetar, 2017). From these parameters, NDVI is the most used method in erosion studies (Seutloali et al., 2017). In one of their studies, Tombuş et al., (2012) searched for the effect of temporal change of vegetation cover data which is one of the ICONA erosion assessment methods for Çorum province. For this aim, they have used 2000 dated Landsat 7 ETM+, 2006 and 2010 dated Landsat 5 TM satellite images. They have calculated the 2000, 2006 and 2010 dated NDVI values and examined the impact of this values on results. As a result, they have concluded that the selection of high-resolution satellite images determining the vegetation cover will affect the assessment results in a positive way. With this study, it has been noted that by the researchers remote sensing in obtaining the land information belonging to large areas is very important as well as applying GIS to analyze the obtained information are really crucial.

To assign the erosion risk classes of Sinop province, Kaya and Dengiz, (2022) has used a hybrid model called Neutrosophic Fuzzy-AHP method and has determined the statistical relationship between the RE-OSAVI values obtained from dated Sun Aug 21st, 2022, Sentinel-2A (MSI) satellite image and erosion susceptibility index values. They employed the Linear Combination Technique (LCT) after establishing the de-neutrosophied weights based on predetermined criteria to generate an interpolation map illustrating erosion risk classes. The erosion susceptibility map for Sinop Province, Türkiye, was developed using seven criteria as:

- geology,
- land cover,

- land use,
- slope,
- depth,
- precipitation, and
- erodibility.

Within the framework of LCT, each parameter involved in creating the erosion susceptibility map underwent classification into sub-parameters. Weight values ranging from 1 to 4 were assigned to classes within the sub-parameters, with a value of 4 denoting a high erosion susceptibility level and a value of 1 indicating a low erosion susceptibility level (Demirağ Turan et al., 2020). The computation of the total erosion susceptibility index followed the given formula (Eq. 5).

$$S = \sum_{i=1}^{n}(W_i . X_i) \quad (5)$$

where, S is total erosion sensitivity point, W_i is the value of i parameter, X_i is the sub criteria point of i parameter and n is the total numbers of the considered criteria.

The erosion risk map was generated by assessing individual parameters separately through both the Neutrosophic Fuzzy-AHP approach and LCT. In this particular investigation, land cover (0.3148) and slope (0.2076) emerged as the criteria with the highest weight scores. The elevated weight scores assigned to land cover and slope can be rationalized by the fact that soil erosion risk escalates in areas with lower land cover percentages, primarily due to increased runoff. Managing sediment quantity in rivers becomes crucial, especially during dry seasons (Kairis et al., 2015). Furthermore, Demirağ Turan and Uzun, (2021) observed in their study that areas lacking robust land cover and featuring high slopes pose significant risks of erosion. Geology, with a weight score of 0.0865, was identified together with the most nominal weight among the criteria. Remaining criteria in the study area, like soil depth, land use, erodibility and precipitation, were assigned weights of 0.0898, 0.1086, 0.0996 and 0.0865, respectively. These weight scores contribute to the overall evaluation of erosion risk classes in Sinop Province, Turkey.

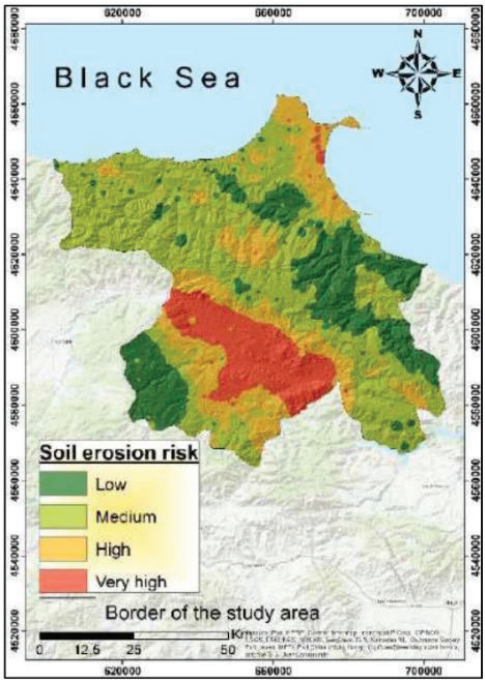


Figure 1. Soil erosion risk map belonging to the research area

The comparisons conducted reveal a robust correlation between the RE-OSAVI values and the erosion risk classes in Sinop Province, categorized as low, medium, high, and very high. The coefficient of determination (r^2) values further illustrate the strength of this relationship, with values of 0.8101, 0.8138, 0.856, and 0.8179 identified for the low, medium, high, and very high erosion risk classes, respectively (Figure 2).

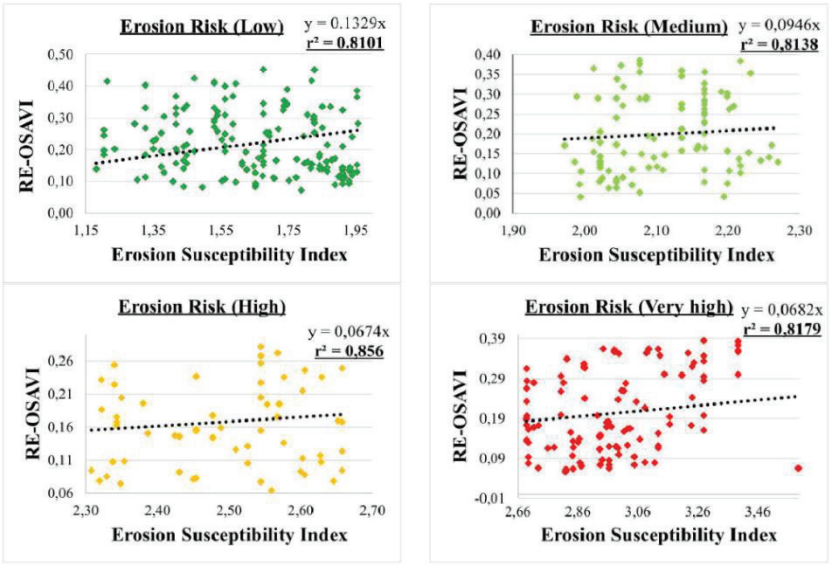


Figure 2. r^2 values corresponding to erosion susceptibility index values in Sinop Province and RE-OSAVI values extracted from Sentinel-2A satellite image dated Sun Aug 21st, 2022

The CORINE-2018 land use/land cover map presented in Figure 3 depicts the characteristics of the study area. Notably, the southern region of the study area is predominantly covered by forests, constituting 60% of the land, while the northwest part features 20% coverage of unirrigated agricultural areas (Demirağ Turan et al., 2020). However, a comprehensive evaluation of the study area in terms of slope reveals a significant portion, approximately 555680 hectares (95%), characterized by a high slope percentage. This high slope is identified as one of the crucial factors contributing to erosion, as illustrated in Figure 3.

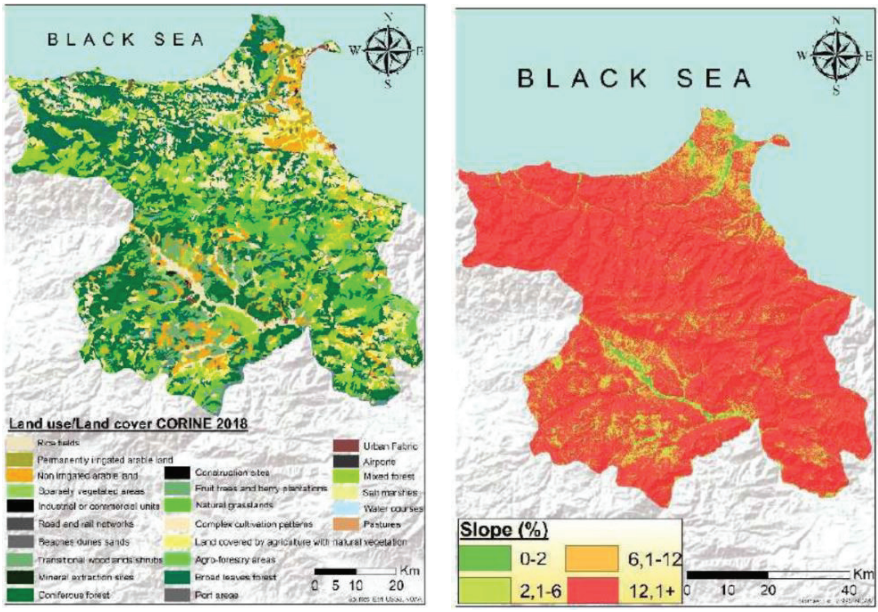


Figure 3. CORINE-2018 land use/land cover and slope maps of the research area

Hence, the correlation observed among erosion susceptibility risk classes and RE-OSAVI is attributed to the insights provided by the RE-OSAVI vegetation index. This connection is explicable by the fact that the research area, situated in the Black Sea region, boasts abundant vegetation cover due to high precipitation levels, resulting in a low to moderate likelihood of erosion for approximately 60% of the study area. Notably, Demirağ Turan et al., (2020) emphasized in their research that areas characterized by weak land cover and steep slopes, particularly agricultural zones and impoverished pasturelands, are highly sensitive to erosion. The distribution map of RE-OSAVI values, off Sentinel-2A satellite imagery, is illustrated in Figure 4.

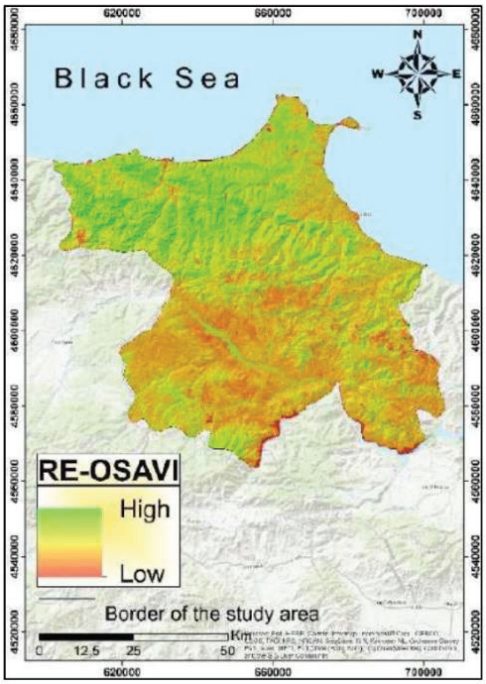


Figure 4. Distribution map of the RE-OSAVI values off Sentinel-2A satellite image dated Sun Aug 21st, 2022

As a result, they have concluded that RE-OSAVI values have represented successfully the Sinop province's soils. Especially, researchers put forward where the slope is high, transportation is and ground control is challenging, vegetation indexes can be used to forecast the erosion risk.

In one of their studies, Saygın et al., (2023) have aimed to observe the relationship between the obtained index values and the reflectance using the satellite images and soil erosion parameters (erosion rate, dispersion rate, structure stability, clay rate, aggregate stability and soil crust index). As a result, they have concluded that index values obtained from satellite images can be used as parameters determining the risk of soil erosion. At the end of the study, with the use of satellite images and soil features, potential dangers can be prevented before in the areas where the erosion is the main problem has been reported by the researchers. In addition to this, using the GIS and remote sensing applications is important in determining and examining the erosion risk is becoming important day by day.

4. Application of Vegetation Indexes in Land use/Land cover studies

In agricultural production and management practices, determining land use/land cover modifications studies have a vital role. There are several methods to detect land use/land cover alterations and one of them is the vegetation index method (Jomaa and Kheir, 2003).

To monitor and detect the land use/land cover varieties, vegetation indexes are calculated from the satellite images. Specifically, NDVI is the major vegetation index in forecasting the amount of land cover from the reflective bands of the satellite image. In one of their studies Lyon et al., (1998) for specified changes in land cover, have used seven different vegetation indexes on three differently dated Landsat MSS image data. As a consequence of this research, they have concluded that NDVI compared to the other vegetation index gave the best results for change detection. Gülersoy, (2013) in a study which investigates the changes in land use/land cover studies using the difference remote sensing techniques for the central district of Manisa, has used the supervised classification method in creating the NDVI images and digitizing the satellite images. As a result of the study, it has been reported by the researcher that the biggest change has happened in residential areas with 109% and pasture lands with 31.5% in the 24 years process which covers 1986-2010.

Vegetation indexes are one of the most effective methods in revealing the changes of plant development as temporal (Lu et al., 2004). Vegetation indexes have been developed for finding the functional relationship between the remote sensing observations and plant characteristics. With these indexes, the effects of factors as water stress, nitrogen level which have a crucial effect on development of plant growth. It's well known that plant biomass and spectral reflections on red and NIR wavelengths have strong relationships.

4. Application of Vegetation Indexes in Soil Quality Assessment Studies

Karaca et al., (2021) conducted a comprehensive assessment of soil quality in pastureland near Van Lake in the Northern East Anatolia Region of Turkey. Covering approximately 6024 ha, the high plateau study area had elevations lining up from 1641 m to 2334 m above sea level, with steep slopes in central and eastern parts. The study integrated various methodologies, including Multi-Criteria Decision Analysis (MCDA), Soil-Plant System Factor (SSF), Fuzzy Analytical Hierarchy Process (Fuzzy-AHP), Principal Component Analysis

(PCA), and Remote Sensing (RS) and Geographic Information System (GIS) technologies.

To evaluate soil quality, 150 soil samples were assembled off the surface soil depth (0–30 cm), and 26 parameters were analyzed, categorized into physical, chemical, nutrient elements, and biological aspects. The study aimed to develop a Soil Quality Index (SQI) by selecting relevant indicators, processing spatial distribution data using GIS, and validating results with satellite imagery.

The selection of appropriate indicators was crucial for SQI development, considering the study area's topography and irregular precipitation. Physical indicators included particle size distribution, water retention capacity, bulk density and aggregate stability, emphasizing their significance in assessing soil erosion risk. Chemical indicators encompassed organic matter, electrical conductivity, pH, and $CaCO_3$ due to their impact on soil fertility. The lack of a universal approach for soil quality assessment was acknowledged, and the study highlighted the importance of tailoring indicators to site-specific conditions and land use purposes.

To streamline the assessment, PCA was employed to select a representative Minimum Data Set (MDS) off the Total Data Set (TDS), focusing on physical, chemical, and biological properties. The study justified PCA's use for data reduction, aiming to minimize labor-intensive and costly data collection while ensuring reliability. The features picked because of TDS_{SQI} were hieratically categorized under 4 primary criteria (chemical, physical, fertility and biological) (Fig. 5).

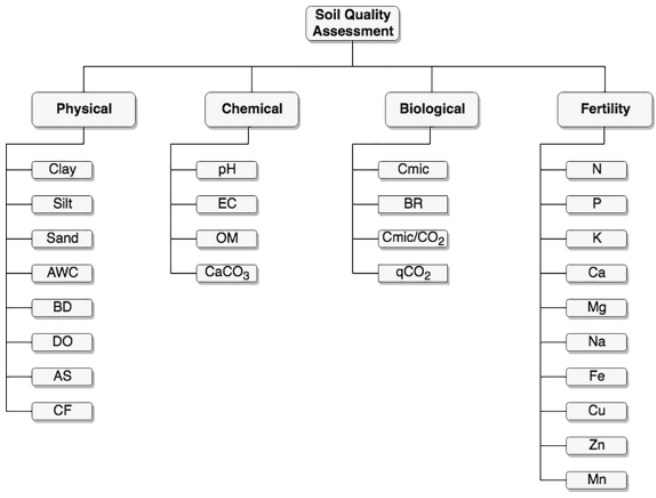


Figure 5. Hierarchical scheme of the TDS_{SQI} parameters

A multi-criteria assessment approach was applied to enhance the SQI, involving three steps: generating a representative parameter method, assigning weights to parameters using the Fuzzy-AHP method, and verifying the index through appropriate models. Standard scoring functions (SSF) were applied to accommodate diverse parameter units, and the Weighted Linear Combination (WLC) approach calculated SQI values for TDS and MDS. Fuzzy logic theory and Fuzzy-AHP addressed uncertainty, with the Natural Breaks Jenks method classifying resulting SQI values into five categories. Index values for SQI are demonstrated in Table 2.

Table 2. Soil quality index classes and index values for pastureland

Class	Description	Index Value
I	Very low	0.29-0.36
II	Low	0.36-0.41
III	Moderate	0.41-0.45
IV	High	0.45-0.49
V	Very high	0.49-0.56

The study incorporated biomass reflectance values from Sentinel–2A images, specifically using the Red Edge-Optimized Soil Adjusted Vegetation Index (RE-OSAVI) to estimate biomass during different grass growth periods. Various interpolation models, including radial basis function (RBF), Inverse Distance Weighing (IDW) and kriging, were explored to generate spatial distribution maps of SQI.

Descriptive statistics were provided for soil properties and SQI values, indicating variability in pH, bulk density, $CaCO_3$ content, organic matter, and texture constituents. The study identified 26 main parameters influencing SQI, emphasizing the importance of soil physical parameters and organic matter. The resulting SQI values were validated using remote sensing data, showing strong relationships between TDS_{SQI} and MDS_{SQI} with RE-OSAVI. The spatial and incidence distributions of TDS_{SQI} and MDS_{SQI} in the pastureland area are displayed in Table 3 and Fig. 6. In accordance with Table 3, 26.7% of total pasture area has low and very low soil quality in TDS while these classes were devised to be 18.6% for MDS_{SQI}.

Table 3. Distribution of TDS_{SQI} and MDS_{SQI} in the study area

Class	Index Value	TDS_{SQI} Area		MDS_{SQI} Area	
		ha	%	ha	%
Very low	0.29-0.36	365	6.1	175	2.9
Low	0.36-0.41	1239	20.6	946	15.7
Moderate	0.41-0.45	1167	19.4	1032	17.1
High	0.45-0.49	2182	36.2	1335	22.2
Very high	0.49-0.56	1071	17.8	2536	42.1
Total		6024	100.0	6024	100.0

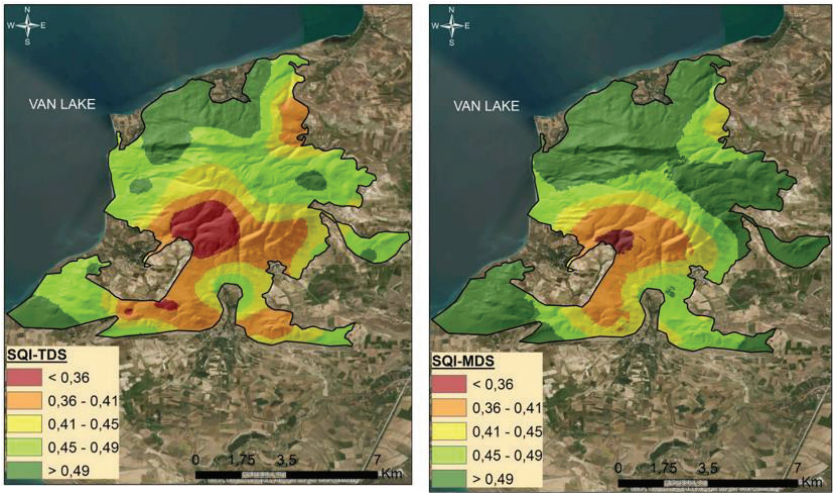


Figure 6. Spatial distribution maps belonging to TDS_{SQI} and MDS_{SQI}

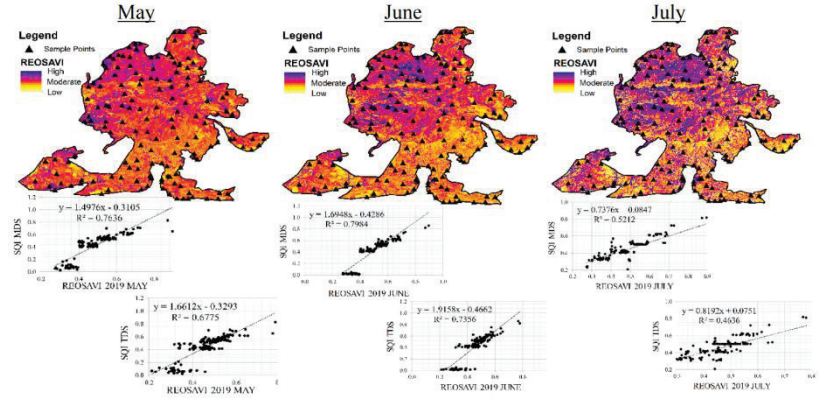


Figure 7. Relationship between REOSAVI and TDS_{SQI}-MDS_{SQI}

Conclusion

In conclusion, this comprehensive review emphasizes the pivotal role of vegetation indices, particularly focusing on the application of remote sensing technologies and various indices such as NDVI, LAI, SAVI, and RE-OSAVI in land use/land cover, soil erosion, and soil quality studies. The text underscores the significance of these tools in providing spatial and temporal information crucial for monitoring environmental changes, agricultural productivity, and soil health. The case studies presented, particularly the application of the Sentinel-2A satellite imagery and RE-OSAVI in assessing soil erosion risk in Sinop province and the integration of remote sensing with soil quality assessment near Van Lake, highlight the effectiveness of these methodologies in addressing complex environmental challenges.

Overall, the review affirms the growing importance of remote sensing and vegetation indices in advancing our understanding of large-scale environmental processes and promoting sustainable land management practices.

References

Aghlmand, M., Kalkan, K., & Onur, M. İ. Sentinel 2 Uydusunun Orman Sınıflandırma Kabiliyetinin İncelenmesi.

Aiello, A., Adamo, M., & Canora, F. (2015). Remote sensing and GIS to assess soil erosion with RUSLE3D and USPED at river basin scale in southern Italy. *Catena*, *131*, 174-185.

Almutairi, B., El, A., Belaid, M. A., & Musa, N. (2013). Comparative Study of SAVI and NDVI Vegetation İndexes in Sulaibiya Area (Kuwait) Using Worldview Satellite Imagery. *Int. J. Geosci. Geomat*, *1*, 50-53.

Asner, G. P., Scurlock, J. M., & A. Hicke, J. (2003). Global synthesis of leaf area index observations: implications for ecological and remote sensing studies. *Global ecology and biogeography*, *12*(3), 191-205.

Bagheri, N., Ahmadi, H., Alavipanah, S. K., & Omid, M. (2012). Soil-line vegetation indexes for corn nitrogen content prediction. *International Agrophysics*, *26*(2).

Bahre, C. J. (1991). *A legacy of change: historic human impact on vegetation in the Arizona borderlands*. University of Arizona Press.

Behera, S. K., Behera, M. D., & Tuli, R. (2015). An indirect method of estimating leaf area index in a tropical deciduous forest of India. *Ecological Indicators*, *58*, 356-364.

Chen, J. M., & Black, T. A. (1992). Foliage area and architecture of plant canopies from sunfleck size distributions. *Agricultural and Forest Meteorology*, *60*(3-4), 249-266.

Chianucci, F., Cutini, A., Corona, P., & Puletti, N. (2014). Estimation of leaf area index in understory deciduous trees using digital photography. *Agricultural and forest meteorology*, *198*, 259-264.

Crucifix, M., & Hewitt, C. D. (2005). Impact of vegetation changes on the dynamics of the atmosphere at the Last Glacial Maximum. *Climate Dynamics*, *25*, 447-459.

Dedeoğlu, M. (2020). Vejetasyon indis değerleri ile şeker pancarı yaprak azot içeriğinin izlenmesi. *Toprak Bilimi ve Bitki Besleme Dergisi*, *8*(1), 69-76.

Dedeoğlu, M. (2020). Vejetasyon indis değerleri ile şeker pancarı yaprak azot içeriğinin izlenmesi. *Toprak Bilimi ve Bitki Besleme Dergisi*, *8*(1), 69-76.

Demirağ Turan, İ. & Uzun A., 2021. Modeling the Risk of Soil Erosion in the Çorum Creek Basin Using Analytical

HierarchicProcess and GIS Techniques. *Jeomorfolojik Araştırmalar Dergisi*, (6), 41-55.

Demirağ Turan, İ., ÖZKAN, B., & Dengiz, O. (2020). Determination of multi-criteria decision analysis and GIS modeling forspatial distribution of soil erosion vulnerability in the Sinop Province. *Türk Coğrafya Dergisi*, (75), 57-70.

Erdoğan, M., & Akdeniz, H. (2004). Uzaktan Algılama Amaçlı Uydu Sistemlerindeki Son Gelişmeler. *Harita Dergisi*, (132), 11-25.

Fenta, A. A., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Yasuda, H., Kawai, T., ... & Sultan, D. (2021). Agroecology-based soil erosion assessment for better conservation planning in Ethiopian river basins. *Environmental research*, *195*, 110786.

Fitzgerald, G., Rodriguez, D., & O'Leary, G. (2010). Measuring and predicting canopy nitrogen nutrition in wheat using a spectral index—The canopy chlorophyll content index (CCCI). *Field crops research*, *116*(3), 318-324.

Gower, S. T., Kucharik, C. J., & Norman, J. M. (1999). Direct and indirect estimation of leaf area index, fAPAR, and net primary production of terrestrial ecosystems. *Remote sensing of environment*, *70*(1), 29-51.

Gülersoy, A. E. (2013). Farklı Uzaktan Algılama Teknikleri Kullanılarak Arazi Örtüsü/Kullanımında Meydana Gelen Değişimlerin İncelenmesi: Manisa Merkez İlçesi Örneği (1986-2010). *Electronic Turkish Studies*, *8*(8).

Hall, R. J., Davidson, D. P., & Peddle, D. R. (2003). Ground and remote estimation of leaf area index in Rocky Mountain forest stands, Kananaskis, Alberta. *Canadian Journal of Remote Sensing*, *29*(3), 411-427.

Handbook, S. U., & Tools, E. (2015). Sentinel-2 User Handbook. *ESA Standard Document Date*, *1*, 1-64.

Hatfield, J. L., Kanemasu, E. T., Asrar, G., Jackson, R. D., Pinter Jr, P. J., Reginato, R. J., & Idso, S. B. (1985). Leaf-area estimates from spectral measurements over various planting dates of wheat. *International Journal of Remote Sensing*, *6*(1), 167-175.

Islam, M. S. (2021). Assessing the dynamics of land cover and shoreline changes of Nijhum Dwip (Island) of Bangladesh using remote sensing and GIS techniques. *Regional Studies in Marine Science*, *41*, 101578.

Jackson, R. D. (1986). Remote sensing of biotic and abiotic plant stress. *Annual review of Phytopathology*, *24*(1), 265-287.

Jensen, J. R. (2009). *Remote sensing of the environment: An earth resource perspective 2/e*. Pearson Education India.

Jia, L., Yu, Z., Li, F., Gnyp, M., Koppe, W., Bareth, G., ... & Zhang, F. (2012). Nitrogen status estimation of winter wheat by using an Ikonos satellite image in the north china plain. In *Computer and Computing Technologies in Agriculture V: 5th IFIP TC 5/SIG 5.1 Conference, CCTA 2011, Beijing, China, October 29-31, 2011, Proceedings, Part II 5* (pp. 174-184). Springer Berlin Heidelberg.

Jomaa, I., Bou Kheir, R., Gitas, I. Z., & San Miguel Ayanz, J. (2003). Multitemporal unsupervised classification and NDVI to monitor land cover change in Lebanon (1987-1998). *Options Méditerranéennes: Série B. Etudes et Recherches*, (46), 43-49.

Jones, H. G., & Vaughan, R. A. (2010). *Remote sensing of vegetation: principles, techniques, and applications*. Oxford University Press, USA.

Kara, Ö., Şentürk, M., Bolat, İ., & Çakıroğlu, K. (2011). Kayın, Göknar ve Göknar-Kayın meşcerelerinde yaprak alan indeksi ile toprak özellikleri arasındaki ilişkiler. *İstanbul Üniversitesi Orman Fakültesi Dergisi*, *61*(1), 47-54.

Karaca, A., & Güllü, M. (2019). Detection of forest fire in Menderes district using a superpixel segmentation based search method. *Journal of the Faculty of Engineering and Architecture of Gazi University*, *34*.

Karaca, S., Dengiz, O., Turan, İ. D., Özkan, B., Dedeoğlu, M., Gülser, F., ... & Ay, A. (2021). An assessment of pasture soils quality based on multi-indicator weighting approaches in semi-arid ecosystem. *Ecological Indicators*, *121*, 107001.

Kaya and Dengiz, (2022). Remote estimation of the relationship between erosion risk classes using the Neutrosophic Fuzzy-AHP and RE-OSAVI for Sinop Province, Turkey. Conference: *"International Soil Science Symposium on "Soil Science & Plant Nutrition"* (7th International Scientific Meeting, Samsun Türkiye. ISBN: 978-605-63090-8-3. 133-138.

Kokaly, R. F., & Clark, R. N. (1999). Spectroscopic determination of leaf biochemistry using band-depth analysis of absorption features and stepwise multiple linear regression. *Remote sensing of environment*, *67*(3), 267-287.

Kucharik, C. J., Norman, J. M., & Gower, S. T. (1998). Measurements of branch area and adjusting leaf area index indirect measurements. *Agricultural and Forest Meteorology*, *91*(1-2), 69-88.

Li, Z., Jin, X., Wang, J., Yang, G., Nie, C., Xu, X., & Feng, H. (2015). Estimating winter wheat (Triticum aestivum) LAI and leaf chlorophyll content from canopy reflectance data by integrating agronomic prior knowledge with the PROSAIL model. *International journal of remote sensing*, *36*(10), 2634-2653.

Liping, C., Yujun, S., & Saeed, S. (2018). Monitoring and predicting land use and land cover changes using remote sensing and GIS techniques—A case study of a hilly area, Jiangle, China. *PloS one*, *13*(7), e0200493.

Liu, J., Miller, J. R., Haboudane, D., & Pattey, E. (2004, September). Exploring the relationship between red edge parameters and crop variables for precision agriculture. In *IGARSS 2004. 2004 IEEE International Geoscience and Remote Sensing Symposium* (Vol. 2, pp. 1276-1279). IEEE.

Lu, D., Mausel, P., Brondizio, E., & Moran, E. (2004). Change detection techniques. *International journal of remote sensing*, *25*(12), 2365-2401.

Lyon, J. G., Yuan, D., Lunetta, R. S., & Elvidge, C. D. (1998). A change detection experiment using vegetation indexes. *Photogrammetric engineering and remote sensing*, *64*(2), 143-150.

Marshall, J. D., & Waring, R. H. (1986). Comparison of methods of estimating leaf-area index in old-growth Douglas-fir. *Ecology*, *67*(4), 975-979.

Mason, E. G., Diepstraten, M., Pinjuv, G. L., & Lasserre, J. P. (2012). Comparison of direct and indirect leaf area index measurements of Pinus radiata D. Don. *Agricultural and Forest Meteorology*, *166*, 113-119.

McAllister, D. (2005). Remote estimation of leaf area index in forested ecosystems.

Nagler, P. L., Glenn, E. P., Thompson, T. L., & Huete, A. (2004). Leaf area index and normalized difference vegetation index as predictors of canopy characteristics and light interception by riparian species on the Lower Colorado River. *Agricultural and Forest Meteorology*, *125*(1-2), 1-17.

Neves, F. S., Sperber, C. F., Campos, R. I., Soares, J. P., & Ribeiro, S. P. (2013). Contrasting effects of sampling scale on insect herbivores distribution in response to canopy structure. *Revista de Biologia Tropical*, *61*(1), 125-137.

Peper, P. J., & McPherson, E. G. (1998). Comparison of five methods for estimating leaf area index of open-grown deciduous trees. *Journal of Arboriculture*, *24*, 98-111.

Phinzi, K., & Ngetar, N. S. (2017). Mapping soil erosion in a quaternary catchment in Eastern Cape using geographic information system and remote sensing. *South African Journal of Geomatics*, *6*(1), 11-29.

Rondeaux, G., Steven, M., & Baret, F. (1996). Optimization of soil-adjusted vegetation indexes. *Remote sensing of environment*, *55*(2), 95-107.

Sampson, D. A., & Allen, H. L. (1995). Direct and indirect estimates of leaf area index (LAI) for lodgepole and loblolly pine stands. *Trees*, *9*, 119-122.

Saygın, F., Alaboz, P., Aksoy, H., Dengiz, O., İmamoğlu, A., Çağlar, A., & Koç, Y. (2023). Farklı uydu verilerinden elde edilen indeksler ile toprak erozyon parametreleri arasındaki ilişkinin değerlendirilmesi. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, *60*(3), 501-513.

Seutloali, K. E., Dube, T., & Mutanga, O. (2017). Assessing and mapping the severity of soil erosion using the 30-m Landsat multispectral satellite data in the former South African homelands of Transkei. *Physics and Chemistry of the Earth, Parts A/B/C*, *100*, 296-304.

Shou, L., Jia, L., Cui, Z., Chen, X., & Zhang, F. (2007). Using high-resolution satellite imaging to evaluate nitrogen status of winter wheat. *Journal of plant nutrition*, *30*(10), 1669-1680.

Sluiter, R. (2005). *Mediterranean land cover change: modelling and monitoring natural vegetation using GIS and remote sensing*. Utrecht University.

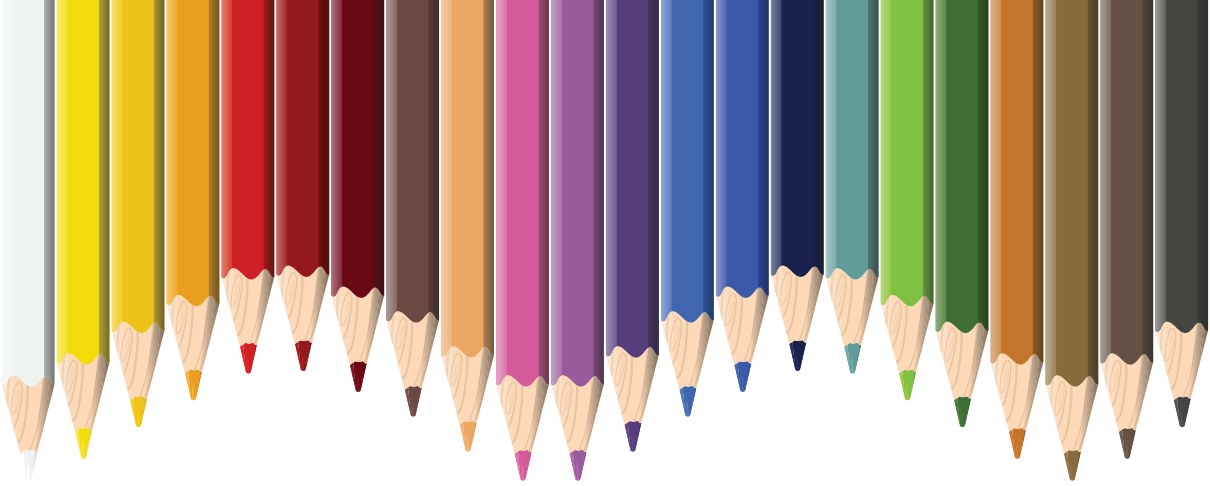
Sumida, A., Nakai, T., Yamada, M., Ono, K., Uemura, S., & Hara, T. (2009). Ground-based estimation of leaf area index and vertical distribution of leaf area density in a Betula ermanii forest. *Silva Fennica*, *43*(5), 799-816.

Tombuş, F. E., Yüksel, M., Coşar, M., & Ozulu, İ. M. (2012). ICONA Erozyon Risk Belirlenme Yönteminde Zamansal Olarak NDVI Etkisinin İncelenmesi. *Uzaktan Algılama ve Coğrafi Bilgi Sistemleri Sempozyumu, Zonguldak*.

Watson, D. J. (1947). Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. *Annals of botany*, *11*(41), 41-76.

Wójtowicz, M., Wójtowicz, A., & Piekarczyk, J. (2016). Application of remote sensing methods in agriculture. *Communications in biometry and crop science*, *11*(1), 31-50.

Yang, W., Tan, B., Huang, D., Rautiainen, M., Shabanov, N. V., Wang, Y., Myneni, R. B. (2006). MODIS leaf area index products: From validation to algorithm improvement. IEEE Transactions on Geoscience and Remote Sensing, 44(7), 1885-1898.



Chapter 8

IRRADIATION TECHNOLOGY AND ITS APPLICATION TO SEAFOOD

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1. INTRODUCTION

While the world population is increasing rapidly, the increase in foodstuffs is lagging behind. Food preservation has become one of the important branches of the industry, considering that agricultural production has decreased or it has become difficult to obtain quality products due to impossibilities in the agricultural sector, environmental factors, climate changes, etc. (Gökoğlu, 2002; Çolak, 2006).

One of the objectives of food preservation methods is to reduce the amount of microorganisms or to prevent microbial growth and/or to kill microorganisms. In the face of advancing technology and changing needs, people have resorted to different food preservation methods. While the preservation methods they use vary according to the characteristics of the food, sometimes they have had to use several methods together. In order to prolong the preservation period, not to deteriorate the product quality, to do what is healthy and less costly, preservation technology has reached up to the use of radiation today (Çolak, 2006).

The application of irradiation for food preservation started to develop in the early 20th century and the basis of this technology was the discovery of X-rays by German physicist W. Konrad Roentgen in 1895 and radioactivity by French physicist Antoine Henry Becquerel in the same year. In 1930, the French scientist patented radioactivity for use in food. In the 1940s, studies conducted in the United States in the 1940s, it was thought to be used to provide safe food for soldiers in remote areas away from the city, and since 1972, irradiated foods have been used in space travel. Irradiated foods have been used in hospitals to reduce the risk of infection in patients with weakened immune systems (Anon., 2004; Varlık et al., 2004).

In Russia, on March 4, 1985, irradiated potatoes were offered to human consumption for the first time in the world to prevent sprouting. One year later, irradiation of cereals to prevent insect infestation was authorized. In 1963, the first foodstuff irradiated at sterilizing dose level was obtained when the FDA approved the suitability for human consumption of bacon irradiated with gamma rays at a dose of 4.55 Mrad in tin cans (Anon., 2000).

Turkey, within the framework of the United Nations Development Program (UNDP), the world's first grain irradiation plant with a Co-60 source of 30-50 tons/hour and 16 krad capacity was established in Iskenderun in 1967. However, as a result of opposing views, it was dismantled and taken out of the country in 1968 without obtaining a license (Anon., 2004).

Lalahan Animal Health Nuclear Research Institute was established in Turkey on May 29, 1981 and Turkey became a member of the International Consultative Group on Food Irradiation (ICGFI) on October 5, 1983 (Tutluer, 1999).

In our country, mainly spices, dried vegetables, some dried nuts (almonds, dates, pine nuts, currants), fish, chicken meat, shrimp, tripe and frog legs are preserved by irradiation (Anon, 2002).

2. IRRADIATION TECHNOLOGY

Long-term durability of foods is realized by biological, chemical and physical methods in food technology. Among biological methods, fermentation technology is the most widely used method. Chemical methods include the use of canning agents. Physical methods include heat and pressure applications (Potter, 1973; Brennan et al., 1990).

Food irradiation is a process developed to preserve the quality of foods, ensure their hygiene and extend their storage period. This process is a physical application such as pasteurization, canning and freezing methods using heat energy. The difference of food irradiation from these methods is that the energy used in irradiation is not heat energy but ionizing energy (Demirezen and Çetinkaya, 2007).

Irradiation is considered as one of the physical canning procedures and is also called cold sterilization because there is no significant temperature increase during the process (Potter, 1973; Brennan et al., 1990).

Irradiation is a physical method that does not contain any residues. Although it is applied in the preservation of fresh and perishable foods, it cannot be applied to all foods (Lagunas-Solar, 1995).

The use of ionizing radiation in world food technology is increasing. In more than 40 countries, it is used in the preservation of some foods, especially potatoes, onions, garlic, vegetables-fruits, spices and chicken meat, by irradiation at certain doses (Erol, 2007).

2.1. PURPOSE AND ADVANTAGES OF IRRADIATION TECHNOLOGY

The use of ionizing radiation in world food technology is increasing. This is due to the need to reduce the use of food additives, prevent foodborne poisoning and new food preservation methods. Irradiated foods are used in a wide range of production areas such as cereals, meat, seafood, etc. and there is a large amount of literature on them (Desrosier, 1970; Varlık et al., 2004).

Irradiation extends the shelf life of foods, reduces microbial load, inhibits growth, inhibits microbial activity, inhibits sprouting (e.g; potatoes, onions, garlic) and over-ripening, preventing parasite transmission sources and diseases, destroying insects and pests, reducing or eliminating the use of some chemical substances used as food preservatives, preventing rotting in fruits and vegetables, protecting dry foods against molds, eliminating fungicide residue problems, and sterilization is provided while foods are packaged (Lagu-

nas-Solar, 1995; Olson, 1998; Anon., 2002).

Advantages of irradiation technology;

- Broad spectrum in terms of its effect
- No microorganism can develop resistance
- Sensory analysis such as taste, color and smell is the most studied method
- Applied to the final packaged product and leaves no chemical residue
- No need to wait after application
- Operating costs are relatively cheap (Çetinkaya, 2004).

3. BASIC CRITERIA IN FOOD IRRADIATION

Foods should only be irradiated when there is a technological need or to ensure food hygiene. Spoiled food may not be irradiated for human consumption. Post-harvest or post-production processing, storage and transportation conditions must meet the Codex General Standard on food hygiene and the current legal requirements applicable to each product. Food irradiation cannot be used as a substitute for Good Manufacturing Practice (GMP). Food quality: The irradiation dose applied must meet technological and public health objectives and comply with Good Irradiation Process Practice. For bulk irradiated products, Hazard Analysis and Critical Control Points (HACCP) rules should be followed to prevent re-infestation and contamination. Any chemical treatment to be applied for the same purpose as food irradiation cannot be used in conjunction with food irradiation. The irradiation dose to be used in food irradiation is determined by measuring the average dose absorbed in a certain volume unit of the food by internationally acceptable dosimetry methods suitable for the properties of the food and the desired dose range (Anon., 1999; Anon, 2002; Çetinkaya, 2004).

According to the statement made by the Joint Committee of Experts in 1980, it was determined that irradiation up to 10 kGy would not pose a toxicological, biological and chemical hazard to foodstuffs (Anon., 2004).

In 1980, the Joint Committee of Experts decided that irradiated food should be identified with a symbol as shown in Figure 1. It was first used in the Netherlands and then in South Africa, the USA and Canada. Later, in order for consumers to better identify irradiated food, the Food and Drug Administration (FDA) in the USA decided to use phrases such as "Treated with radiation" or "treated by radiation" together with the radura symbol on food packages (Anon., 2004; Smith and Pillia, 2004).

In our country, it is mandatory to include the phrase "irradiated" or "irradiation process" on irradiated foods and to have the green colored internation-

al food irradiation symbol on the label in an easily visible way (Anon., 1999).

Figure 1. Food irradiation symbol (green color) (Anon., 1999).

In foods irradiated in our country; the irradiation dose should not exceed 10 kGy. At maximum dose levels above 10 kGy, the average of the minimum and maximum dose in the whole food is applied in a way that does not exceed 10 kGy (Anon., 1999).

4. APPLICATION OF IRRADIATION TECHNOLOGY ON FOOD

Food irradiation includes sources, equipment and operating systems designed for the safe irradiation of food with a suitable irradiation source, licensed and registered for compliance with radiation safety and hygienic conditions. Radiation is literally defined as the emission of energy. Wave types such as radio waves and microwaves have low energy because they have large wavelengths. Therefore, although the movement of the molecule is ensured, it is not enough energy to cause a structural change in the atom within the molecule. Ionizing radiation is energy with smaller wavelengths. As radiation passes through matter, it collides and interacts with the atoms and molecules that make up the matter. In a single collision or interaction, the radiation will usually transfer a very small fraction of its energy to the atoms or molecules. The atom or molecule may turn into an ion as a result of the interaction. The ionizing radiation leaves the mass of ionized atoms or molecules and can move in different directions. As this energy passes through food or material, it cannot make the food or material radioactive (Desrosier and Rosenstock, 1960; Cameron, 1970; Desrosier and Desrosier, 1977). According to the relevant regulation in our country, the following sources are allowed to be used in food irradiation processes (Varlık et al., 2004; Anon., 1999).

- Gamma rays emitted from sealed cobalt-60 (Co-60) and Cesium-137 (Cs-137) radionucleotide sources.
- X-rays from machine sources operating at 5 MeV and lower
- Electrons produced from machine sources operating at 10 MeV and lower.

Co-60 or Cs-137 is used as a radioactive source in facilities where gamma rays are used to irradiate medical products and food. X-rays are emitted when high-energy electrons produced in electron accelerators collide with a tungsten plate and as a result of this collision, the electrons are stopped and the X-rays lost by the electrons are emitted as X-rays. This event is called Bremmstrahlung (braking beam) and the continuous spectrum of X-rays is called Bremmstrahlung. Sources producing X-rays have energies of 5 MeV and lower. The irradiation time is short since the penetration into the material and dose rate is high. Products of varying densities can be irradiated individually and independently of each other. Since the irradiation is unidirectional, the product box sizes are smaller than the box sizes in gamma irradiation. Electron accelerators are produced in devices capable of accelerating electrons to a speed close to the speed of light. In these beam generators, energy from the city grid is used as the energy source. Electron accelerators used in food irradiation are devices with energies lower than 10 MeV. Its penetration into the material is low. Therefore, products with small size and low density are irradiated. Since the dose rate is high, the irradiation time is short. Products of various densities can be irradiated individually and independently (Desrosier, 1970; Dempster, 1985; Çetinkaya, 2004).

Alpha particles, produced by the decay of radioactive isotopes or radionucleotides, are helium atoms split into two electrons. Beta particles are high-energy electrons known as cathode rays. Gamma rays, also known as photons, are a type of X-rays with a wavelength of 100-150 nm. In addition, some elements such as cobalt-60 (Co-60) and cesium-137 (Cs-137), which can give artificial radioactivity by unique methods, are also known as radioactive isotopes. Alpha, beta particles and X-rays emitted by radioactive isotopes have different levels of ionization energy and cause ionization in the substances they affect. For this reason, the application is known as ionizing radiation. ionizing radiation acts as a germicide by transforming the structure from molecules to ions with its energy. Although ultraviolet radiation contains low energy, it can have a partially lethal effect on microorganisms. Alpha rays travel slowly through the air and have low penetration. Beta rays have higher penetration power and lower specific ionization power. Gamma rays have lower specific ionization power but high penetration power. Ultraviolet radiation applications have been limited to superficial applications due to the low penetration effect. However, it is used to remove molds from packaging material or to reduce the microbial load on meat (Varlık et al. 2004).

Irradiation is an energy input that does not cause radioactivity in foods. Its unit is rad (1 rad = 100 erg g-1) or gray (1 gray = 100 rad). 1 rad is the energy of 100 erg in one gram of matter through which the beam passes (Lagunas - Solar, 1995, Anon., 2004). 1Gy: It is defined as the amount of 1 joule of energy given to 1 kg of a homogeneous substance exposed to ionizing radiation.

1 krad=1 000 rad, 1 mrad=1 000 000 rad, 1 Gy=100 rad, 1 kGy=100 000 rad (Kayaardı and Gök, 1999; Ünlütürk et al., 1999; Anon., 2002).

The power of the radiation source is expressed in terms of its activity. The unit of activity is Becquerel (Bq) and previously Curie (Ci) was used for this purpose (1Bq=1 fragmentation/s, 1Ci=3,7 X10 10 Bq) (Topal, 1988, Ünlütürk et al., 1999; Anon., 2004).

Gamma rays are produced from sources of Cobalt 60 (Co-60) and Cesium 137 (Cs-137). Co-60 is produced in a nuclear reactor by neutron bombardment of naturally occurring Co 59. Although Co-60 sources are limited, it is the most commonly used source (Lagunas-Solar, 1995; Anon., 1999).

Radioactive isotopes lose half of their activity over time. This half-life, which is specific for each radioisotope, is 5.3 years for Co-60 and 30 years for Cs-137 (Lagunas-Solar, 1995; Kayaardı and Gök, 1999, Anon., 2004).

The alpha, beta, gamma or X rays emitted by radioactive substances cause the formation of electrically charged ions in the material they hit, so these rays are called ionizing rays or ionizing rays. The most widely used ionizing ray in food preservation is gamma rays (Ünlütürk et al., 1999).

Ionizing radiation has higher energy than non-ionizing light, microwave and radio waves. Gamma rays have a wavelength of less than 100 nm and have the highest penetration properties (Topal, 1988).

In order to prevent radioactivity in foods, the energy levels of the rays used in irradiation are limited to 5 MeV for X-rays and gamma rays and 10 MeV for electrons by an international decision (Topal, 1988; Anon., 1999).

Everything in our environment, including food, contains trace amounts of radioactivity. For example, a daily dietary intake of 150-200 Bq of natural radioactivity from elements such as potassium is not considered objectionable (Kayardı and Gök, 1999).

Irradiation dose is the amount of radiation energy absorbed by the food during the irradiation process and is important for food quality and human health (Ünlütürk et al., 1999).

Radapertization is irradiation applications of 10 kGy and above. It is used as commercial sterilization. The vast majority of microorganisms are destroyed. Radicidation is the application of low dose irradiation ≤ 10 kGy to reduce the load of non-spore forming pathogenic microorganisms. Radurization (≤1 kGy) is used to preserve the quality of food and extend its shelf life (WHO, 1994; Anon., 2002).

5. APPLICATION OF IRRADIATION TECHNOLOGY TO SEAFOOD

Irradiation is applied during the production and processing stages of seafood products. One of the modern methods used to extend the lifespan of fish is radioactive irradiation. The microflora of fresh fish consists of psychrophiles such as *Pseudomonas, Achromobacter (Acinetobacter, Morexella), Micrococcus* and *Flavobacterium*, which play a primary role in the spoilage of fish. As a result of the proteolytic activities of these microorganisms, there is a high probability of histidine turning into histamine (decarboxylation) in decomposed fish meat proteins. Accordingly, high levels of histamine, which causes poisoning, may occur in many fish species, especially mackerel. Ionizing rays are used to extend the shelf life of fish meat by reducing the microorganisms mentioned primarily in fish meat to a minimum level (İnal, 1992; Varlık et al., 2004).

In many countries, research has been carried out on extending the fresh preservation period of various fish species by irradiation method and their toxicological safety, and after the positive results, industrial application studies have been started (Varlık et al., 2004).

The quality of fish meat preserved with radioactive rays changes. This change depends on the type of fish, the dose of radioactive radiation, and the method of radioactive radiation. Likewise, nutritional value losses vary depending on the irradiation dose, temperature, air and nutritional composition. Irradiation of fish and fish products at very high doses causes changes in protein molecules. If the applied irradiation dose is between 10-1000 kGy, enzymes are inactivated. When irradiation is applied at less than 10 kGy, the proteins in the structure of the fish are not damaged and the enzymes remain active (Gülyavuz and Ünlüsayın, 1999; Varlık et al., 2004).

Irradiation should be applied in high doses and for a short time. Thus, the oxidative effect of gamma rays on oily fish is reduced. As the irradiation time increases, undesirable heating also occurs. Although fats decompose to a certain extent during irradiation, proteins and propeptides do not tend to break down. However, their fat bonds have a minimal effect (İnal, 1992).

Radioactive irradiation can be used in various forms. Even when relatively low doses are used, a significant reduction of microorganisms is achieved. However, very high dosage application is needed to sterilize fish and fish products. An irradiation of 5x102 MGy applied for this purpose causes the taste of fish or fish products to change as a result of the radiolysis products of water forming compounds with amino acids. This flavor change disappears again when the fish is kept in a drafty place for a long time or when it is cooked or fried. This taste change is prevented by applying radiation in the frozen environment (İnal, 1992; Bulduk, 2002).

"D value" is used to determine the irradiation resistance of microorganisms. D value is the expression of the irradiation dose required to kill 90% of the microorganism population. Irradiation resistance varies depending on the type of microorganisms, their growth optimum, the heat generated during irradiation and the aw value of the environment where the microorganisms are found. While *Pseudomonas*, which plays an important role in the spoilage of fish, is sensitive to gamma rays, the resistance of *Moraxella/Acinetobacter* group microorganisms is high. As a rule, Gram-positive bacteria such as *Lactobacilli, Micrococci* and *Corynebacteria* show higher resistance to irradiation than Gram-negative bacteria (İnal, 1992).

The following points are important in terms of food hygiene in the successful application of irradiation.

• Radioactive irradiation should be carried out on fishing vessels in order to keep the initial number of microorganisms as minimal as possible.

• Placing irradiated fish in a cold chain as soon as they are delivered to land.

With these applications, the lifespan of fish can be extended by 10-15 days. However, in order to maintain the positive effect achieved by irradiation, hygiene conditions must be observed during cold storage of fish. Otherwise, microorganisms arising from the crates in which the fish are placed, the ice used and the personnel will cause the lifespan of the fish to decrease in the future (İnal, 1992).

Microbiological safety in irradiated foods highlights the choice of this technology. This becomes even more important especially in foods that are sensitive to microbiological development, such as seafood and spices.

In our country; Raw fish, shellfish and their products (fresh or frozen) and frozen frog legs can be irradiated at doses between 2-5 kGy in order to reduce some pathogenic microorganisms, extend shelf life and control parasitic infections (Anon., 1999). However, for complete sterilization, very high doses of irradiation are required (Varlık et al., 2004).

The effects of different irradiation applications between 1.5-10 kGy on tilapias and Spanish mackerel on different structural components were examined and it was determined that the minimum strength period increased by 20 days at 2°C (Varlık et al., 2004).

Irradiated freshwater fish were stored at 1-3°C and their quality during storage was examined. In the study, it was determined that increasing dosage affected the shelf life positively. It has been reported that 2 kGy irradiation causes 16% vitamin A and 13% vitamin D loss in fish (Varlık et al., 2004).

Clostridium botulinum is of particular importance in storing fish. Because

the irradiation doses applied before storage are not sufficient to kill the spores. However, if the fish are irradiated with 1-2 kGy and vacuum packaged and then stored between 0 and 5 °C, *Clostridium botulinum* does not form toxin (İnal, 1992).

With an irradiation dosage of 2 kGy applied to crabs, these crabs can be preserved at 4°C for 14 days, while unirradiated crabs can be preserved for 3 days. An irradiation of 2.20 kGy increases the shelf life of eels by 100% (Varlık et al., 2004).

In studies conducted on experimental animals regarding the toxicological safety of irradiated fish, it was determined that there was no negative effect on live weight gain, feed consumption, mobility, tumor formation, organ weight, reproduction, hematological and histopathological parameters due to the irradiation process (Erçin, 2006).

Application of gamma rays in combination with other protection methods has also been tried. If the fish are lightly salted and then irradiated at doses ranging from 2-4 kGy, the quality of the fish increases as a result of better inhibition of the microflora. This application has no effect on the ripening process of fish meat. It is possible to completely destroy bacillus spores by combining irradiation and sterilization (İnal, 1992).

The combined application of food additives to fish along with irradiation also extends their shelf life. It is known that low-dose sorbate application along with low-dose irradiation of fish extends the shelf life (Erçin, 2006).

Cod fillets were packaged in a modified atmosphere (80:20 CO_2:N_2) and vacuum before being irradiated with a dose of 2.2 kGy, and then stored at 4 °C. While optimizing the storage period, TVC (total aerobic viable bacterial count) was measured daily. The best results were obtained in the combined application of radiation (irradiation) and modified atmosphere packaging (Erçin, 2006).

6. CONTROL OF IRARATED PRODUCTS

The group that Germany is in is; Due to the difficulty of the control mechanism of irradiated products, there is concern that hygiene problems in third world countries will be solved by irradiation practices on bad products, and insistently emphasizes the need to inspect irradiated products with strict prohibitions. In particular, strict controls and inspections are applied even in the trade of spices, which are allowed up to a certain dose (maximum absorbed total dose of 10 kGy). Especially for these products, very careful attention is paid to the documents regarding the product origin, the institution irradiated, the date and the amount of absorbed dose, and their relevant laboratory controls. Various researches are being carried out on the analysis of irradiated foods. Particularly, rather than the irradiation dosage of a food, analyzes have been carried out on whether foods are irradiated or not, and in recent years,

working groups have been formed in different countries on irradiation dosage and research has been focused on this subject (Varlık et al., 2004).

There are some criteria that an ideal method that can be used to detect irradiated foods should include (Varlık et al., 2004; Erel, 2006). These;

- Reliability
- Repeatability
- Accuracy and ability to make precise discrimination
- Sensitivity
- Measurement speed
- Dosage adherence
- Ease of application, practicality and simplicity
- Ease of calibration
- Lower costs
- It is made with internationally accepted instruments and measurement systems.

The purpose of detection in irradiated foods; The increase and expansion of international trade, the combined use of developing and changing food processing technologies, differences in international legal regulations, monitoring compliance with the label, and providing accurate and adequate information to the consumer (Erel, 2006).

Demonstrating whether a food item has been treated with ionizing radiation in accordance with the regulations is possible by determining the specific changes that occur in the food item due to radiation. All diagnostic methods are based on the principle of determining the physical, chemical and biological changes that occur in foods with irradiation (Varlık et al., 2004).

Especially in this field, although there is no consensus on any method in the European Union (EU) countries, four methods are mainly emphasized (Varlık et al., 2004).

- Thermoluminescence (TL) analysis
- Electron Spin Resonance (ESR) Analysis
- Analysis of volatile components in oil using gas chromatography (GC) or combined use of gas chromatography and mass spectrophotometry (GC/MS).
- Analysis of ortho-tyrosine by high pressure liquid chromatography (HPLC) method

CONCLUSION; This technology, recommended and supported by the World Health Organization (WHO) for safety and health, has its own advantages and disadvantages. Although its investment cost is relatively high at first, it is a superior technology in terms of both human health and food protection. Irradiation technology, which is a method that has a very wide-ranging effect and that microorganisms cannot resist, does not leave chemical residue and does not require waiting time after application. This method, which extends the shelf life of food, is a technology that does not change sensory properties.

REFERENCES

ANONYMOUS, (1999), Gıda Işınlama Yönetmeliği Resmi Gazete23868, (6/11/1999), Ankara.

ANONYMOUS, (2000), Nükleer Tarım ve Hayvancılık Araştırma Merkezi Gıda Işınlama ve Sterilizasyon Bölümü. Gıda Işınlama Kursu. Türkiye Atom Enerji Kurumu, Ankara.

ANONYMOUS, (2002), Nükleer Tarım ve Hayvancılık Araştırma Merkezi Gıda Işınlama ve Sterilizasyon Bölümü. Gıda Işınlama Kursu. Türkiye Atom Enerji Kurumu, Ankara

ANONYMUS, (2004), Nükleer Tarım ve Hayvancılık Araştırma Merkezi Gıda Işınlama ve Sterilizasyon Bölümü. Gıda Işınlama Kursu. Türkiye Atom Enerjisi Kurumu, Ankara

BRENNAN, J.G., BUTTERS, J.R., COWELL, N.D. (1990), *Food Engineering Operations*, Department of Food Science and Technology, Üniversity of Reading, London and Newyork.

BULDUK, S. (2002), *Gıda Teknolojisi*, Detay Yayıncılık, Ankara, 270s.

CAMERON, A. G. (1970), *Food Science-A Chemical Approach*, Head of Department of Applied Science and Food Technology, Birmingham College of Food and domestic Arts, Üniversity of London Press Ltd., 381p.

ÇETİNKAYA, N. (2004), *Işınlanmış Gıdaların Ticareti ve Yasal Durum*, Antalya, Türkiye Atom Enerji Kurumu.

ÇOLAK, F. (2006), *Işınlamanın Çörekotunun (Nigella sativa) Bazı Fizikokimyasal, Mikrobiyolojik Özellikleri Ve Yağ Asitleri Kompozisyonuna Etkisi*, Trakya Üniversitesi, Fen Bilimleri Enstitüsü, Gıda Mühendisliği Anabilim Dalı, Tekirdağ, Yüksek Lisans Tezi, 41 s.

DEMİREZEN, Ü., ÇETİNKAYA N. (2007), *Gıda Işınlama İşlemi ve Önemi*, Radyasyon Sağlığı Ve Güvenliği Dairesi, Ankara Nükleer Tarım ve Ataştırma Merkezi

DEMPSTER, J.F. (1985), Radiation Preservation of Meat and Meat Products-a Review, *Meat Science,* 12, 61-89

DESROSIER, N. W. (1970), *The Technology of Food Preservation*, National Biscuit Company Resarch Center, Fair Lawn, New Jersey,493p.

DESROSIER, N.W., DESROSIER, J.N. (1977), *The Technology of Food Preservation*, The avı Publıshing Company, Inc, United States America,558p.

DESROSIER, N.W., ROSENSTOCK, H. M. (1960), *Radiation Technology in Food*, Agriculture and Biology, The Avı Publıshıng Company, United States of America.

ERÇİN, D. (2006), *Gıda Işınlamanın Kombine Uygulamaları*, Türkiye Atom Enerjisi Kurumu Sarayköy Nükleer Araştırma ve Eğitim Merkezi, Uygulama Bölümü,

Gıda Birimi, Ankara.

EREL, Y. (2006), *Işınlanmış Gıdaların Dedeksiyon Metotları*, Türkiye Atom Enerjisi Kurumu Sarayköy Nükleer Araştırma ve Eğitim Merkezi, Uygulama Bölümü, Gıda Birimi, Ankara.

EROL, İ. (2007), *Gıda Hijyeni ve Mikrobiyolojisi*, Ankara Üniversitesi Veteriner Fakültesi Besin Hijyeni ve Teknolojisi Bölümü, Ankara, 392s.

GÖKOĞLU, N. (2002), *Su Ürünleri İşleme Teknolojisi*, Akdeniz Üniversitesi Ziraat Fakültesi Gıda Mühendisliği Bölümü, Su Vakfı Yayınları, İstanbul, 157s.

GÜLYAVUZ, H., ÜNLÜSAYIN, M. (1999), *Su Ürünleri İşleme Teknolojisi*, Süleyman Demirel Üniversitesi Eğridir Su Ürünleri Fakültesi, Ankara, 366s.

İNAL, T. (1992), *Besin Hijyeni-Hayvansal Gıdaların Sağlık Kontrolü*, Final Ofset, İstanbul, 783s.

KAYAARDI, S., GÖK,V. (1999), Gıda Endüstrisinde İyonize Radyasyon Kullaımı, *Yüzüncü Yıl Üniversitesi, Veteriner Fakültesi Dergisi*, 10, 104-108.

LANGUNAS-SOLAR MC. (1995), Radiation Processing of Foods: an Overwiev of Scientific Principles and Current Status, *Journal of Food Protection*, 58(2), 186-192.

OLSON, D.G. (1998), Irradiation of food, *Food technology*, 52, 56-62.

POTTER, N.N. (1973), *Food Science*, Cornell University, Ithoca, New York.

SMITH, J. S., PILLAI, S. (2004). Irradiation and food safety. *Food Technology* (Chicago), 58(11), 48-55.

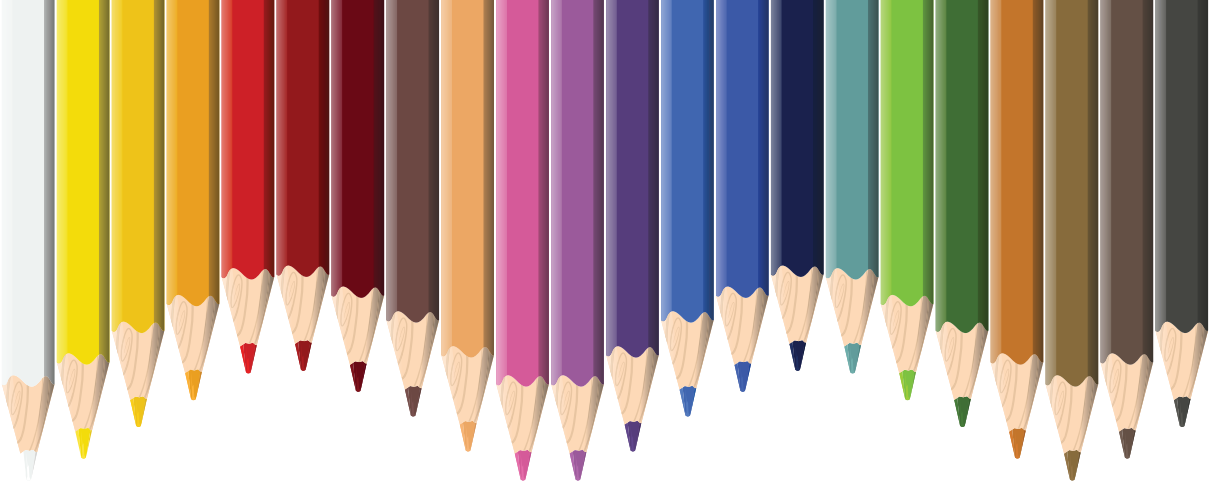
TOPAL, Ş. (1988), Gıda Muhafazasında Işınlama: Günümüzdeki Uygulamalar ve Sorunlar, *Gıda Sanayi*, 10, 21-29.

TUTLUER, H. (1999), Türkiye'de Gıda Işınlama Aktiviteleri. Çetinkaya N., Alabay, M., Siyakuş, G., (çev). Gıda Işınlama Yönetmeliği ve Yönetmeliği ve Ticareti Semineri. TAEK, İzmir, 59-79.

ÜNLÜTÜRK, A., TURANTAŞ, F., ACAR, J., KARAPINAR, M., TEMİZ A., GÖNÜL Ş.A., TUNÇEL, G. (1999), *Gıda Mikrobiyolojisi*, 2. Baskı, Mengi Tan Basımevi, İzmir.

VARLIK, C., ERKAN, N., ÖZDEN, Ö., MOL, S., BAYGAR, T. (2004), *Su Ürünleri İşleme Teknolojisi*, İstanbul ÜniversitesiSu Ürünleri Fakültesi İşleme Teknolojisi Anabilim Dalı, İstanbul.

WHO, (1994), Safety and Nutritional Adequacy of İrradiation Food, World Health Organization, Genava.



Chapter 9

SAFFLOWER PRODUCTION IN THE WORLD AND TÜRKİYE (2000-2021)

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INTRODUCTION

Safflower (*Carthamus tinctorius* L.), from the Asteraceae family, boasts multiple uses: oilseed, ornamental, feed, medicinal, and natural dye. (Yilmaz et al., 2023). *Carthamus* is a genus of 25 species found all over the world, and the only cultivated safflower is *Carthamus tinctorius* L. (Figure 1), which is one of the 25 safflower species (Singh and Nimbkar, 2006). Because it is a drought-resistant plant, safflower has been successfully produced in places with relatively low temperatures.

Figure 1. *Beginning of flowering in safflower (Carthamus tinctorius L.) (Yozgat, Türkiye)*

Safflower thrives in diverse climates, with disperse areas in China, India, South Asia, the Mediterranean Basin, the Nile Valley, and Ethiopia (Gomashe et al., 2021). Kazakhstan, Russia, the United States of America, India, Mexico, Argentina, Tanzania, China, and Türkiye are the top producers of safflower (FAO, 2022). Safflower has a long history of use, first prized for its vibrant dyes (safflower yellow and red) and medicinal benefits found in its petals. One

of the other uses of the petals is as a tonic tea. The 1920s marked a turning point when its seeds were recognized for their rich oil content, sparking research into oilseed varieties and ultimately new cultivars bred for optimal oil production (Emongor, 2010; Pearl and Burke, 2014). After the possibility of the plant being used as an oilseed crop was found, the plant began to be cultivated in wider areas. The oil content of safflower seeds varies between 11.5% and 47.5% (Li and Mündel, 1996).

Safflower oil includes a high concentration of polyunsaturated fatty acids, such as linoleic acid and tocopherol, which are used for both medical and dietary purposes (Khalid et al., 2017). Additionally, safflower oil is a significant source of phenols that have significant anti-aging and antioxidant properties and are used in cosmetics (Zemour et al., 2019). Also, oil contain rich composition of vitamins and phospholipids, which makes the oil is valuable source of vegetable oil (Mursalykova et al., 2023).

The global per capita consumption of vegetable oils was approximately 15 kg in 2008, around 18 kg in 2018, and is expected to reach 20 kg/capita by 2030. Developed countries have the highest oil consumption per capita. In the United States, per capita vegetable oil consumption was 35 kg in 2008, 37 kg in 2018, and is expected to reach 40 kg by 2030. Another developed country in China, the situation is similar, with per capita vegetable oil consumption below 20 kg in 2008, reaching 27 kg in 2018, and expected to approach 30 kg by 2030. Vegetable oil consumption per person in the least developed countries was 6-7 kg in 2008, 7-8 kg in 2018–20, and is predicted to stay below 10 kg by 2030 (Anonymous, 2023a). It is seen that developed countries have 3-4 times more per capita consumption than developing countries. Vegetable oils are increasingly in demand.

In 1995, global consumption of vegetable and animal fats were 92.9 million metric tons, increasing to 204.3 million metric tons in 2015 and reaching 208.8 million metric tons in 2021-22 (Mielke, 2018; Anonymous, 2023b). Over a 25-year period, consumption has increased by more than double.

Growing populations, a shortage of arable land, and a persistent rise in the demand for food motivate us to use resources more wisely and efficiently. Not only are agricultural areas decreasing, but the optimum conditions for plants to grow are also deteriorating. In order to ensure food security, it is necessary to diversify plant pattern and to bring plants that can be productive in arid areas to agricultural production. Among these plants stands the safflower, an underutilized crop with immense potential for diversifying food production (oil, dye, feed value, and medicinal properties).

This study provides data on safflower production in the world and Türkiye between 2000-21 and examines the last 21 years of safflower production in the world.

Trends and Dynamics of World Safflower Production in 2000-2021

Table 1 shows the area of safflower production, yield, and total production for the years 2000 to 2021, as well as their changes from the previous years.

Table 1. Worldwide safflower production between 2000 and 2021 years (FAO, 2023)

Years	Area (ha)	Change[a] (%)	Yield (kg/ha)	Change[a] (%)	Total Production (t)	Change[a] (%)
2000	868.008,00	-	751,7	-	652.439,76	-
2001	813.893,00	-6,23	687,0	-8,61	559.180,75	-14,29
2002	696.352,00	-14,44	755,0	9,90	525.736,72	-5,98
2003	849.410,00	21,98	802,7	6,32	681.806,67	29,69
2004	926.939,00	9,13	686,0	-14,54	635.878,73	-6,74
2005	804.485,00	-13,21	724,6	5,63	582.954,6	-8,32
2006	705.824,00	-12,26	764,7	5,53	539.736,84	-7,41
2007	753.910,00	6,81	837,9	9,57	631.692,72	17,04
2008	763.876,00	1,32	835,8	-0,25	638.420,51	1,07
2009	823.533,00	7,81	806,5	-3,51	664.145,77	4,03
2010	834.835,00	1,37	796,2	-1,28	664.723,09	0,09
2011	804.102,00	-3,68	843,5	5,94	678.277,88	2,04
2012	968.587,00	20,46	871,4	3,31	843.989,55	24,43
2013	896.898,00	-7,40	804,6	-7,67	721.634,48	-14,50
2014	893.054,00	-0,43	818,2	1,69	730.653,03	1,25
2015	1.053.750,00	17,99	783,2	-4,28	825.333,17	12,96
2016	1.169.705,00	11,00	810,3	3,46	947.784,78	14,84
2017	861.523,00	-26,35	853,8	5,37	735.560,8	-22,39
2018	654.947,00	-23,98	929,1	8,82	608.490,35	-17,28
2019	648.327,00	-1,01	903,7	-2,73	585.920,94	-3,71
2020	786.083,00	21,25	837,3	-7,35	658.221,25	12,34
2021	850.431,00	8,19	742,0	-11,38	631.051,6	-4,13

Source: FAO, 2023, [a] This implies calculating change based on previous year value

In 2000, safflower production was around 652.000 tons of safflower seeds on a total area of 868.000 hectares. The same year, the yield per hectare was around 751 kilograms, as shown in Table 1. The lowest yield was 686 kilograms per hectare in 2004, and the highest yield was 929.1 kilograms per hectare in 2018. When the world safflower production data between 2000 and 2021 are examined, it is seen that there is no significant change in safflower production and yield. The highest cultivated area and production values were obtained in the years 2015-2016. In the following years, it balanced again and fell back to the planting and production levels of the 2000s. Between 2000 and 2021, the global average yield of safflower production was 802.05±62.70 kg/ha. These findings indicate that during the past 20 years, safflower's genetic advancement has not risen to an adequate level.

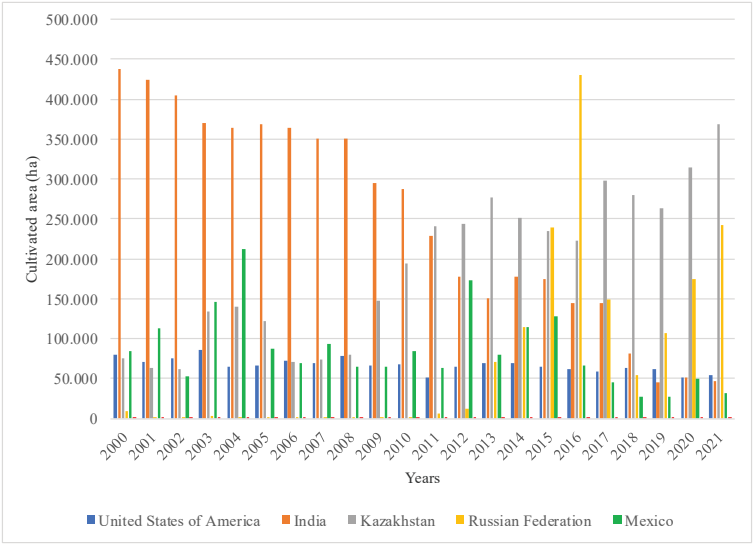


Figure 2. Safflower cultivation area in the top five producing countries, 2000-2021 (FAO, 2023).

When the safflower cultivation areas in India between 2000 and 2021 are examined, it is seen that the cultivation areas are decreasing (Figure 1). In 2000, safflower cultivated area in India was 438.500 hectares which are accounts for half of the areas where safflower is cultivated. By 2021, this area had decreased to 46.467 hectares. The cultivated area of safflower has fallen to about one-tenth of what it was in 2000. This significant reduction in cultivated areas over a 21-year period is an important indicator. The area of safflower cultivation in the United States of America decreased from 79.724 hectares in 2000 to 54.630 hectares in 2021. Despite fluctuations in the area of safflower cultivation over a 21-year period, the trend has remained stable and safflower cultivated area has not fallen below a certain level. Safflower cultivation area in Kazakhstan increased from 75.000 hectares in 2000 to 367.970 hectares in 2021. There have been fluctuations in safflower cultivation areas in Kazakhstan, but the general trend has been an increase in cultivation areas. Kazakhstan is also the most important safflower producer in the world. Although there was a decline in cultivation areas, India was the leading producer of safflower from 2000 to 2010. With the continuation of the decline in cultivation areas, India lost its position as the leading producer of safflower to Kazakhstan in 2011-2015. The increase in safflower cultivation areas in Russia in 2015-2016 brought Russia to the top, but the lack of continuity in safflower production in the following years prevented this situation from lasting long, and Kazakhstan regained its position as the leading producer. The continuation of the produc-

tion increase in Kazakhstan has ensured that Kazakhstan has maintained its position as the leading producer in recent years. Mexico is one of the countries where the area of safflower cultivation is shrinking. In 2004, it became the second largest producer of safflower after India with a cultivation area of 212.000 hectares. However, the area of cultivation did not increase significantly in the following years, and in recent years, it has decreased significantly to 31.095 hectares.

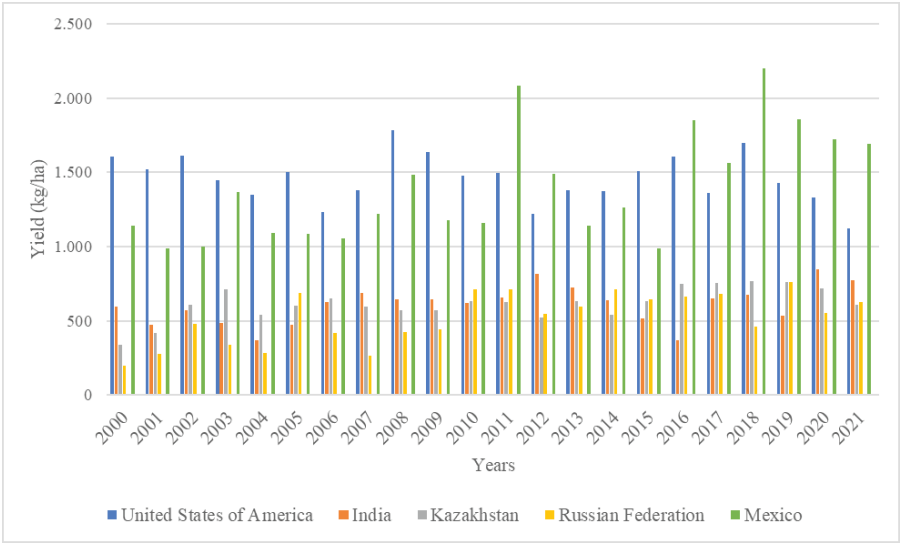


Figure 3. Safflower Yield (kg/ha) of Top 5 Producing Countries, 2000-2021 (FAO, 2023)

Figure 3 shows the yield values of the 5 countries that cultivated the most safflower in kilograms per hectare between 2000 and 2021. In comparison with other oilseed crops, safflower yield per hectare is relatively low. The United States had the most efficient safflower cultivation among the top 5 safflower-producing countries between 2000 and 2010. In these years, the average safflower yield of the United States was 1.500 kg per hectare. In the 2011-2018 period, safflower production in the top 5 countries producing the most safflower exceeded 2.000 kg per hectare. Although there has been a decline in safflower yield per hectare, Mexico has been the most efficient producer among the top 5 countries in recent years. Despite being among the top 5 producers, India, Kazakhstan, and Russia have relatively low safflower yields per hectare.

Table 2 shows the producer prices per ton for safflower in some countries that produce it, listed in US dollars (USD/ton).

Table 2. The producer prices of some countries that produce safflower (USD/ton)

Years/Price (USD/Tonne)	Kazakhstan	The United States of America	India	Mexico	China	Türkiye
2000	-	234,00	-	170,30	-	-
2001	-	240,00	236,40	140,70	-	113,59[a]
2002	-	269,00	-	184,50	-	126,88[a]
2003	-	302,00	322,00	210,60	-	140,65[a]
2004	-	267,00	342,00	208,60	-	208,83[a]
2005	-	273,00	354,90	207,00	-	230,48[a]
2006	141,50	298,00	345,40	214,50	-	345,75[a]
2007	152,90	410,00	-	216,10	-	433,10[a]
2008	189,90	547,00	379,30	333,00	1.100,70	323,12[a]
2009	189,80	377,00	-	310,60	1.142,00	359,74[a]
2010	182,30	379,00	-	343,80	1.063,50	365,09[a]
2011	213,00	538,00	-	450,20	1.680,70	357,12[a]
2012	222,60	608,00	-	459,60	1.314,90	399,58[a]
2013	253,30	615,00	-	442,60	887,70	361,04[a]
2014	213,30	551,00	-	401,30	-	316,07[a]
2015	187,60	540,00	-	336,60	-	314,33[a]
2016	132,10	456,00	-	326,90	-	113,59[a]
2017	140,60	410,00	-	295,90	-	267,10
2018	144,60	448,00	-	346,70	-	246,00
2019	147,00	434,00	-	362,20	-	303,70
2020	178,00	470,00	-	368,40	-	343,70
2021	190,30	562,20	-	402,50	-	359,20

Source: FAO, 2023, [a] Producer prices were calculated using the Turkish statistical Institute (TUIK) data for that period and the average dollar exchange rate announced by the Central Bank of Türkiye.

When the prices given in Table 2 are examined and inflation is added to the prices over the years, it is seen that the prices are not stable. In fact, it is seen that prices have fallen dramatically in some years. Producers want to know how much they can sell their products for on an annual basis, therefore they are cautious about planting products that do not have price stability. Reasons such as safflower producer prices not rising enough, the increase remaining below inflation, government support not being sufficient, or earning less profit compared to other oilseeds are driving farmers away from safflower cultivation. Diversifying production is important for the sustainability of food supply. Therefore, incentives that can provide profits at the level of other oilseed crops should be given to safflower production.

Türkiye Safflower Production in 2000-2021

Table 3 shows the cultivated area of safflower, yields (kg/ha), and total production (t) quantities in Türkiye, as well as their increases or decreases compared to the previous year. While safflower cultivation only limited with 30 hectares in 2000, it peaked at 43.935 in 2014 within the 2000 to 2021.

Table 3. Türkiye safflower production between 2000 and 2021 years (TUIK, 2023)

Years	Area (ha)	Percentage Change (%)	Yield (kg/ha)	Percentage Change (%)	Total Production (t)	Percentage Change (%)
2000	30	0	600,00	0	60,00	-
2001	35	16,67	714,30	19,05	71,43	19,05
2002	40	14,29	625,00	-12,50	62,50	-12,50
2003	250	525,00	680,00	8,80	68,00	8,80
2004	165	-34,00	910,0	33,82	150,00	120,59
2005	173	4,85	1240,0	36,26	215,00	43,33
2006	430,5	148,84	920,0	-25,81	395,00	83,72
2007	1.694,1	293,52	1350,0	46,74	2.280,00	477,22
2008	5.384,6	217,84	1310,0	-2,96	7.068,00	210,00
2009	21.514,9	299,56	930,0	-29,01	20.076,00	184,04
2010	13.497,8	-37,26	1930,0	107,53	26.000,00	29,51
2011	13.164,4	-2,47	1380,0	-28,50	18.228,00	-29,89
2012	15.589,8	18,42	1280,0	-7,25	19.945,00	9,42
2013	29.259,9	87,69	1540,0	20,31	45.000,00	125,62
2014	43.935,0	50,15	1410,0	-8,44	62.000,00	37,78
2015	42.793,1	-2,60	1640,0	16,31	70.000,00	12,90
2016	39.352,0	-8,04	1470,0	-10,37	58.000,00	-17,14
2017	27.376,2	-30,43	1830,0	24,49	50.000,00	-13,79
2018	24.693,2	-9,80	1420,0	-22,40	35.000,00	-30,00
2019	15.859,9	-35,77	1380,0	-2,82	21.883,00	-37,48
2020	15.114,1	-4,70	1410,0	2,17	21.325,00	-2,55
2021	14.452,2	-4,38	1120,0	-20,57	16.200,00	-24,03

In Türkiye, safflower production was carried out on 30 hectares of area in 2000, while the production area increased to 14,452 hectares in 2021 (Table 2). Safflower cultivation areas increased between 2000 and 2009 (excluding 2004). Between 2010 and 2015, there were increases and decreases in safflower cultivation areas, but the total production area increased. However, after 2015, there has been a significant decrease in cultivation areas. In comparison to the world average safflower yield, Türkiye is above the world average. Safflower yields in Türkiye have increased significantly over the years. For example, the yield increased from 600 kg/ha in 2000 to 1,930 kg/ha in 2010, for an increase of 321.67%. The average yield of safflower in Türkiye between 2000 and 2021 was 1231.33±376,26 kg/ha. The Türkiye average safflower yield is 53.52% higher than the world average. The highest production quantity was reached in 2015 with 70,000 tons. Between 2014 and 2021, the area of safflower cultivation in Türkiye had decreased by almost four times. In addition, the cultivated area has continued to decrease after 2014 and safflower cultivated areas have regularly narrowed. Although the total production quantity reached 70,000 tons in 2015 due to the increase in yield per hectare, the

total production volume fell to 16,200 tons in 2021. In 2000, the safflower seed yield per hectare was 600 kg. It reached its highest value of 1.930 kg per hectare in 2010. It is thought that this increase was caused by the rise in farmer culture, the introduction of new varieties to agriculture, and the support of safflower cultivation with irrigation in some parts of cultivated area. In Türkiye, safflower yield was below the world average in 2000. However, since 2014, Türkiye's safflower production has been consistently above the global average. The improved safflower productivity above the world average is due to factors such as the development of new varieties (better adapted varieties to Türkiye climate), better agricultural practices, favorable weather conditions, and the start of cultivation in better fields instead of very unproductive areas in the beginning.

CONCLUSION

Safflower is a neglected crop. Although it is a multipurpose plant, production areas have remained limited. There could be several reasons for narrowed cultivated area of safflower. Some key factors are given below.

- The initial development process of the safflower plant is quite slow, especially during the 4-leaf stage, the plant's growth slows down and root development is prioritized, therefore the plant's competition with weeds is difficult in the early period. The majority of weeds grow taller than the safflower crop and compete with it for nutrients, sunlight, and soil moisture, which causes the weeds to outcompete the safflower crop and reduce yield (Gomashe et al., 2021).

- Safflower permits the pre-plant application of very few chemical herbicides to control a wide range of grasses and weeds (Gomashe et al., 2021).

- The quality of the soil, whether condition, and the management techniques used can all affect safflower yields. Because of its volatility, farmers may find other, more stable crops more appealing (Afzal et al., 2021; Abou Chehade et al., 2022)

- In many parts of the world, safflower is grown on marginal lands. This prevents the safflower plant from fully reflecting its genetic potential and results in low yields. In addition, the fact that safflower yields are lower than the yields of other crops when grown on marginal lands is discouraging farmers from growing safflower. (Eroğlu and Demir, 2021).

- Although there seems to be no market problem for safflower seed, local producers are struggling to sell their products.

- Safflower producer prices fluctuate and sometimes increase less than the inflation rate. In some years, they also experience sharp declines. Farmers are reluctant to plant products that do not have price stability.

- Safflower cultivation should be expanded to include the collection of flowers, not just seeds. This would increase the value of the crop and make it more profitable. Various harvesting machines are being developed to make it easier to collect safflower flowers.

REFERENCE

Abou Chehade, L., Angelini, L. G., & Tavarini, S. (2022). Genotype and seasonal variation affect yield and oil quality of safflower (*Carthamus tinctorius* L.) under Mediterranean conditions. *Agronomy*, 12(1), 122.

Afzal, O., Hassan, F. U., Ahmed, M., Shabbir, G., & Ahmed, S. (2021). Determination of stable safflower genotypes in variable environments by parametric and non-parametric methods. *Journal of Agriculture and Food Research*, 6, 100233.

Anonymous, (2023a). OECD-FAO Agricultural Outlook 2021-2030, Accessed date: 17.12.2023 https://www.google.com/url?client=internal-element-cse&cx-=018170620143701104933:qq82jsfba7w&q=https://www.fao.org/3/cb5332en/Oilseeds.pdf&sa=U&ved=2ahUKEwjPhrikZaDAxXNQfEDHRsiCNUQFnoECAEQAQ&usg=AOvVaw228EovMKbk1QSzkJpnrjVJ

Anoymous, (2023b). Statista vegetable oil global consumption report. https://www.statista.com/statistics/263937/vegetable-oils-global-consumption/

Emongor, V. (2010). Safflower (*Carthamus tinctorius* L.) the underutilized and neglected crop: a review. *Asian Journal of Plant Sciences*, 9(6), 299-306.

Eroğlu, K., & Demir, İ. (2021). Aspir (*Carthamus tinctorious* L.) tarımında çiftçi eğiliminin belirlenmesi Mucur ilçesi örneği. *Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Dergisi*, 1(2), 67-80.

FAO, 2022. Safflower cultivated area. Accessed date: 15/09/2022 Accessed at: https://www.fao.org/faostat/en/#data/QCL

FAO, 2023. Crops and livestock products. Accessed date: 18/11/2023 Accessed at: https://www.fao.org/faostat/en/#data/

Gomashe, S. S., Ingle, K. P., Sarap, Y. A., Chand, D., & Rajkumar, S. (2021). Safflower (Carthamus tinctorius L.): An underutilized crop with potential medicinal values. *Annals of Phytomedicine*, 10(1), 242-248.

Khalid, N., Khan, R. S., Hussain, M. I., Farooq, M., Ahmad, A., & Ahmed, I. (2017). A comprehensive characterisation of safflower oil for its potential applications as a bioactive food ingredient-A review. *Trends in Food Science & Technology*, 66, 176-186.

Li, D., & Mündel, H. H. (1996). Safflower, *Carthamus tinctorius* L. (Vol. 7). Bioversity International.

Mielke, T. (2018). World markets for vegetable oils and animal fats: Dynamics of global production, trade flows, consumption and prices. *Biokerosene: Status and prospects*, 147-188.

Muscalu, A., Tudora, C., Sorica, C., & Anghelache, D. (2023). Mechanised Harvesting of Safflower (Carthamus tinctorius L., fam. Asteraceae) – a review . *Technium: Romanian Journal of Applied Sciences and Technology*, 14, 68–73. https://doi.org/10.47577/technium.v14i.9677

Pearl, S. A., & Burke, J. M. (2014). Genetic diversity in Carthamus tinctorius (Asteraceae; safflower), an underutilized oilseed crop. *American journal of botany*, 101(10), 1640-1650.

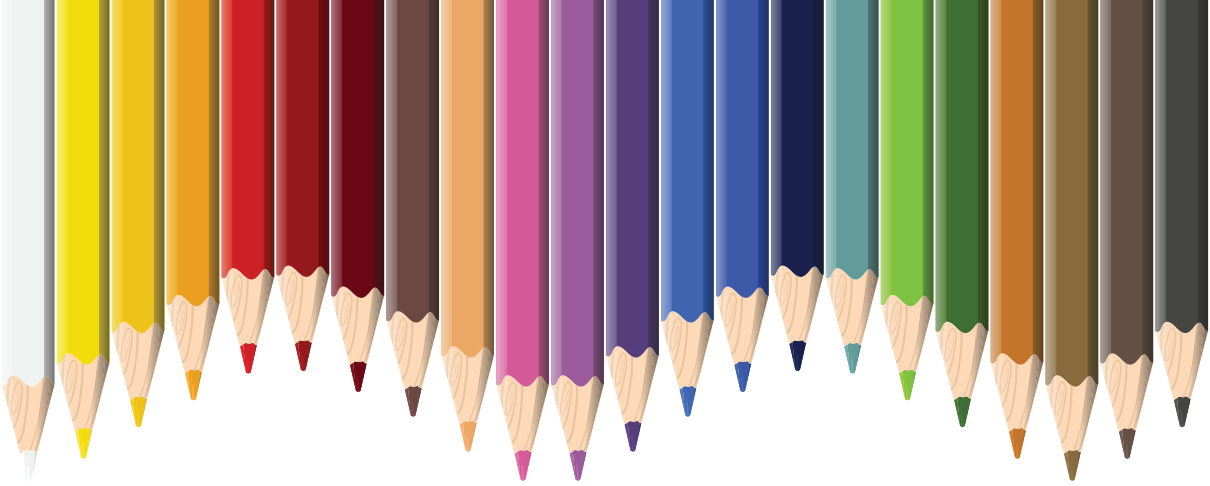
Peiretti, P. G. (2017). Nutritional aspects and potential uses of safflower (Carthamus tinctorius L.) in livestock. *Agricultural research updates*, 19, 3-22.

Singh, V., & Nimbkar, N. (2006). Safflower (*Carthamus tinctorius* L.). Chapter, 6, 167-194.

TUIK, 2023. Turkish Statistical Institute. Plant Production Statistics. Accessed date: 15.11.2023. Accessed at: https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=2

Yilmaz, M., Geçgel, Ü., Apaydin, D., & Culpan, E. (2023). Impact of development periods on chemical properties and bioactive components of safflower (*Carthamus tinctorius* L.) varieties. *Journal of the American Oil Chemists' Society*, 100(9), 723-732.

Zemour, K., Labdelli, A., Adda, A., Dellal, A., Talou, T., & Merah, O. (2019). Phenol content and antioxidant and antiaging activity of safflower seed oil (*Carthamus tinctorius* L.). *Cosmetics*, 6(3), 55.



Chapter 10

NEW HERBICIDE STRATEGIES FOR WEED CONTROL IN RICE

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Introduction

Cereals, the most commonly cultivated and produced plant product, make up 75% of all calories and 67% of all proteins used by humans (Newfood, 2023). There is no doubt that cereal grains are one of the most important sources of energy, carbohydrates, and proteins in the world. In the current estimation, 41% of cereals are used for human consumption and 35% are used for animal feed (Poutanen et al., 2022) . As incomes have risen, preferences have changed, and urbanization has resulted in a dietary diversity that accounts for just 37% of calories from grains. In the 2015 OECD-FAO Agricultural Outlook, 71% of agriculture is still supplied in underdeveloped countries, while 54% is supplied in other developing countries. As well as providing us with dietary energy, they also provide us with most of our nutrients. It is composed primarily of carbohydrates (65-75%), primarily starches (65-75%), and proteins (6-15%); fats (1-5%); contributing over 50% of the world's energy supply (Sarwar et al., 2013; Pawar et al., 2017).

As much as 70–80% of total dietary calories are provided by cereals in developing Asian countries following rice-based diets; meanwhile, just 20-30% of total dietary calories are supplied by cereals in high income countries following livestock-based diets (Alexandratos & Bruinsma, 2012). In Europe, cereals and cereal products contribute 40% of energy to the average diet (Nagyová et al., 2009).

As one of the most grown agricultural products in the world, rice ranks third after corn and sugarcane with 787293867.41 tons (FAO, 2023) Globally, rice plays a crucial role in human nutrition. Rice is the first cultivated plant in the world, the most widely cultivated and produced crop, with good nutritional value, and is easy to store and process. Since rice is so adaptable and easy to produce, it is a staple food in many countries around the world.

Crop yield is reduced as a result of pests, causing economic losses. It is possible for weeds to destroy the entire crop, which can result in a loss of yield (up to 34%). Furthermore, pests can reduce the quality of the crop as well as reduce its yield. The yields of spring wheat (Triticum aestivum), rice (Oryza sativa), corn (Zea mays), potato (Solanum tuberosum), and soybeans (Glycine max) can be significantly reduced by weeds. As a result of insects and plant diseases, yield losses are lower but still significant (18% for insects, 16% for plant diseases (Oerke, 2006)). Crops are more likely to be suppressed by weeds since they compete with light, moisture, nutrients, and space. Depending on the product type, it can cause a loss of 10% to 90% in yield. It is estimated that rice loses up to 90% of its total yield (Amare & Raghavaiah, 2015). The management of weeds is challenging, complex, expensive, and regulated in rice, making it one of the major biological threats to higher rice yields. In order to control the diverse weed infestation in rice fields, weed

management strategies need to be planned (Singh et al., 2020).

Herbicides effectively controlled the weed population and lowered weed dry matter production. It increased slowly toward the maturity of the crop because they suppressed weed populations at the early stages of crop growth due to their broad spectrum activity, which controlled the majority of weed species (Hussain et al., 2008).

It is stated that 7-49, 15-73, or 70 days after emergence is the crucial period for combating weeds in rice plants, which are especially susceptible to weed competition from the first germination (Juraimi et al., 2009; Anwar et al., 2012). To ensure rice plant productivity, it is therefore vital that weeds do not compete with them during their critical periods, as rice plants are sensitive to competition from the beginning of their development.

Herbicides used in crop cultivation today are selective herbicides, which kill weeds but are safe for crops. Such herbicides are often only selective for a particular crop or group of crops, and their selectivity depends on the crop's natural tolerance to the herbicide. In contrast, this tolerance may not be universal among all crop species, but may differ among cultivars, thereby limiting its application.

There are some weed species that are not controlled by selective herbicides because their effectiveness is not broad-spectrum. It was only in recent years that herbicide-resistant crops (HRCs) were developed that allowed herbicides to be used on crops that have no natural tolerance for herbicides, but are capable of resisting them. For this method, nonselective compounds are used mostly to control a wide variety of weed species (Green, 2012; Gage et al., 2019). Rice, sugar beet, and oilseed rape are being developed with resistant cultivars. There is no doubt that this technology has great potential. The rapid increase in acreage of herbicide-resistant crops indicates farmers' acceptance of it. Despite the popularity of this new tool for weed control, there are still debates about its pros and cons (Hurle & Petersen, 2000). As water and labour scarcity increases in rice farming areas, direct seeding rice cultivation is becoming more common, thereby making the management of weeds more challenging. Weeds can be effectively managed by using broad spectrum non-selective herbicides. In order to advocate the use of these herbicides, rice genotypes must be capable of tolerating broad-spectrum non-selective herbicides. Since the introduction of broad-spectrum, total herbicides for weed control, new resistant weeds have developed and spread around the world, posing a serious threat to high-value HR crops (Peterson et al., 2018).

On the other hand, herbicide-resistant weeds evolve through selection pressure resulting from various weed management practices. It is essential to use weed management practices to reduce selection pressure in order to preserve new traits. There is a great deal of concern over the heavy use of her-

bicides for weed control in agriculture, the environment, and human health. As herbicides are overused, herbicide-resistant weeds may evolve, a threat to crop production that has increased in incidence globally (Heap, 2014).

So far, 184 cases of weeds developing resistance to herbicides have been reported in rice cultivation (HRAC, 2023) Especially Echinochloa species has evolved resistance to many herbicides including propanil, quinclorac, bispyribac–sodium, penoxsulam, atrazine, pendimethalin, thiobencarb, butachlor, clomazone and glyphosate (Malik et al., 2010; Goh et al., 2016; HRAC, 2023).

According to data from the herbicide resistance action committee, 56 weed species found in the rice crop have evolved resistance to various herbicides (HRAC, 2023).

Somerville et al. (2017) found that pre-emergence herbicide resistance evolved more slowly than post-emergence herbicide resistance, and soil-applied herbicide mixtures could slow resistance evolution even further (Busi et al., 2020).It has been shown that soil-applied herbicides, simplified rotations or a lack of rotation can lead to resistance evolution (Busi et al., 2019); a decrease in concentrations of single applications may allow herbicide-resistant weeds to emerge as the rate of pre-emergence herbicide dissipates in the soil over time (Wuerffel et al., 2017).

The management of resistance should therefore include other strategies in addition to herbicides applied pre- and post-emergence. According to historical experience in selecting herbicide-resistant weeds, herbicide resistance is inevitable when herbicides provide the only weed control option (Shaner, 2017).

While using herbicides with different sites of action (SOA) in combination, ideally in a mixture, is an effective practice, also using them in rotation as part of a weed management program can slow the development of resistance in some cases.

Through natural or mechanical means, herbicide resistance may develop, and it may impact management beyond cropping systems. The following tables present the most recent pre-emergence and post-emergence herbicides developed (Table 1-2).

Table 1. *Pre-sowing and pre emergence herbicides, active ingredient, formulation and mechanism of action.*

Pre-sowing and pre-emergence herbicides in rice			
Active Ingredient	**Trade Name**	**Formulation**	**Mechanism of Action**
Anilophos %30	Anilourus	EC	Cell division inhibitors
Bispyribac sodium + Thiobencarb	Solo	OD	Acetolactate Synthase (ALS) Inhibitor
Clomazone 480 g/L	Clomazone	EC	Pigment Inhibitors
Foramsulfuron 2.25%	Equip	OD	ALS Inhibitors
Glyphosate + Thiobencarb	Glyphosate + Bolero	EC	Amino Acid Synthesis Ihibitors + Lipid Synthesis Inhibitors
Molinate	Ordram	EC	Lipid synthesis (Seedling, Shoot) inhibitor
Mesotirone 3.75% + S Metolachlor 3.75% + Terbuthylazine 12.5%	Lumax	SE	Pigment Inhibitors + Growth Inhibitors + Photosystem II Inhibitors
Nicosulfuron 4 %	Cruz	SC	ALS Inhibitors
Nicosulfuron 37.5 % + Rimsulfuron 37.5 %	Ultima	WG	ALS Inhibitors
Nicosulfuron %4 + Bromoxynil 20%+ 20% MCPA	Cruz + Bromocide	EC	ALS Inhibitors + Photosystem II Inhibitors + Synthetic Auxins
Oxyfluorfen	Goal 2XL, Galigan	EC	Cell Membrane (PPO) Inhibitors
Oxidiazon	Ronstar	GR	Cell Membrane (PPO) Inhibitors
Pendimethalin 5%	Pendimethalin	G	Growth Inhibitors
Pendimethalin + Clomazone	RiceOne	CS	Growth Inhibitors + Pigment Inhibitors
Pendimethalin + Thiobencarb	Prowl H2O 3.8 + Bolero	CS + EC	Growth Inhibitors + Lipid Synthesis Inhibitors
Pretilachlor + Pyribenzoxim	Solito 320EC	EC	Inhibiton of Cell Division+ Acetolactate Synthase (ALS) Inhibitor
Propyrisulfuron 10%	Sumo	SC	Acetolactate Synthase (ALS) Inhibitor
Pyrazosulfuron-ethyl 10%	Sirius	WP	Acetolactate Synthase (ALS) Inhibitor

Quinclorac 75%	Facet 75 DF or Facet L	EC	Growth Regulators
Quinclorac + Pendimethalin	Facet 75 DF + Prowl H2O 3.8	CS	Growth Regulators + Growth Inhibitors
Quinclorac + Thiobencarb	Facet 75 DF + Bolero 8E	EC + EC	Growth Regulators + Lipid Synthesis Inhibi-tors
S-metolachlor 290g/ l + Atrazine 370 g/l	Pride 100 + 660 SC	SC	Growth Inhibitors + Photosystem II Inhibitors
Thiobencarb	Bolero 8E	EC	Lipid Synthesis Inhibitors
Herbicides For Tolerant Rice			
Imazethapyr	Willowood Imazethapyr 2SL	SL	Amino Acid Synthesis Inhibitors
Imazamox	Beyond	SL	Cell Membrane Disrupters
Quizalofop-P-ethyl	Provisia 0.88	EC	Lipid Synthesis Inhibitors

Table 2. Post-emergence herbicides, active ingredient, formulation and mechanism of action.

Post-emergence herbicides in rice			
Azim sulfuron %50	Azimsulfuron 50%Wdg	WG	Amino Acid Synthesis Inhibitors
Bensulfuron	Londax	DF	Acetolactate Synthase (ALS) Inhibitor
Bıspyrıbac-Sodium %10	Bispyribac-sodium	SC	Acetolactate Synthase (ALS) Inhibitor
Butachlor	Sonic 60	EC	Growth (Long-chain Fatty Acid) Inhibitors
Bentazon	Basagran	SL	Photo synthesis (II) Inhibitors
Benzobicyclon	Rogue	SC	PSI inhibitors
Benzobicyclon + Halosulfuron	Butte	GR	PSI inhibitors + Cell Membrane (PPO) Inhibitors
Butachlor + Propanil	Advance	EC	PSI inhibitors + Photo-synthesis (II) Inhibitors
Carfentrazone-Ethyl	Shark H2O	WG	Cell Membrane (PPO) inhibitor Disrupters
Carfentrazone + Halosufuron	Aim 2 + Permit 75	EC + WG	Cell Membrane (PPO) inhibi-tor + Cell Membrane (PPO) inhibitor

Carfentrazone + Quin cloac	Aim 2 + Facet 75	EC + DF	Cell Membrane (PPO) inhibitor + Inhibitor + Photo-synthesis (II)
Clomazone	Cerano 5 MEG	G	Pigment inhibitors
Copper Sulfate Pentahydrate	Copper Sulfate Crystals	GR	Into water
Cyhalofop	Clincher CA	EC	Lipid Synthesis (ACCase) inhibitor
Fenoxaprop	Ricestar HT	EC	Lipid Synthesis (ACCase) inhibitor
Fentrazamide + Propanil	Lecspro	GR	Unknown
Florpyrauxıfen-Benzyl	Loyant CA	EC	Growth Regulators
Halosulfuron	Sandea	DF	Acetolactate Synthase (ALS) Inhibitor
Halosulfuron + Thifensulfuron	Permit Plus 75 WG	WG	Acetolactate Synthase (ALS) Inhibitor + Acetolactate Synthase (ALS) Inhibitor
Halosulfuron + Prosulfuron	Gambit 79 WDG	WDG	Acetolactate Synthase (ALS) Inhibitor + Acetolactate Synthase (ALS) Inhibitor
Metsulfuron + Chlorimuron	Almix 20	WP	Cell Membrane (PPO) inhibitors + Acetolactate Synthase (ALS) Inhibitor
Orthosulfamuron	Strada 50	WG	Acetolactate Synthase (ALS) Inhibitor
Orthosulfamuron + Halosulfuron	Strada PRO 54	WG	Acetolactate Synthase (ALS) Inhibitor + Acetolactate Synthase (ALS) Inhibitor
Orthosulfamuron + Quinclorac	Strada XT2 70	WG	Acetolactate Synthase (ALS) Inhibitor + Photo-synthesis (II) Inhibi-tors
Penoxsulam	Granite	SC, GR	Acetolactate Synthase (ALS) Inhibitor
Penoxsulam + Cyhalofop	Rebel EX	SC + EC	Acetolactate Synthase (ALS) Inhibitor + Lipid Synthesis (ACCase) inhibitor
Penoxsulam + Triclopyr	Grasp Xtra	SC + EC	Acetolactate Synthase (ALS) Inhibitor + Growth Regulators
Penoxsulam + Florpyrauxifen-benzyl	Novixid	SC + EC	Acetolactate Synthase (ALS) Inhibitor + Growth Regulators
Propanil	Stam 80 EDF-CA	DF	Photo-synthesis (II) Inhibitors
Propanil + Acifluorfen	Propanil + Ultra Blazer	DF + SL	Photo-synthesis (II) Inhibitors + Cell Membrane (PPO) inhibitor

Propanil + Bentazon	Propanil + Basagran	DF + SL	Photo synthesis (II) Inhibitors + Photo synthesis (II) Inhibitors
Propanil + Bensulfuron	Propanil + Londax 60	DF + DF	Photo-synthesis (II) Inhibitors + Acetolactate Synthase (ALS) Inhibitor
Propanil + Halosulfuron	Propanil + Permit	DF + DF	Photo-synthesis (II) Inhibitors + Acetolactate Synthase (ALS) Inhibitor
Propanil + Pendimethalin	Propanil + Prowl EC	DF + CS	Photo-synthesis (II) Inhibitors + Growth Inhibitors
Propanil + Thiobencarb	Propanil + Bolero 8E	DF + EC	Photo-synthesis (II) Inhibitors + Lipid Synthesis Inhibitors
Propanil + Triclopyr	Propanil + Grandstand	DF + SL	Photo-synthesis (II) Inhibitors + Growth Regulators
Quinclorac + Cyhalofop	Facet 75 + Clincher	DF + EC	Growth Regulators + Lipid Synthesis (ACCase) inhibitor
Quinclorac + Fenoxaprop	Facet 75 + Ricestar HT	DF + EC	Growth Regulators + Lipid Synthesis (ACCase) inhibitor
Quinclorac + Propanil	Facet 75 + Propanil	DF + DF	Photo-synthesis (II) Inhibi-tors + Photo-synthesis (II) Inhibi-tors
Bispyribac + Quinclorac	Bispyribac-sodium + Facet 75	SC + DF	Acetolactate Synthase (ALS) Inhibitor
Saflufenacil	Sharpen	WG	Cell Membrane (PPO) inhibitors
Thıobencarb	Abolish 8	EC	Lipid Synthesis Inhibitors
Triclopyr	Grandstand CA	EC	Growth Regulators
Triclopyr + Acifluorfen	Grandstand 3 + Ultra Blazer	SL + SL	Growth Regulators + Cell Membrane (PPO) inhibiçtor
Triclopyr + Halosulfuron	Grandstand 3 + Permit 75	SL + WG	Growth Regulators +

Discussion

A chemical weed control method is always more cost-effective than other weed control methods, perhaps because there is less cost involved in chemical treatment per unit of yield. A major problem in agriculture are weeds that take up a lot of resources and compete with crops for resources (light, nutrients, water, air, etc.). It has always been a major problem to control weeds in rice crops because weeds that compete with rice crops from germination lead to a significant decline in crop yield and quality, reducing the crop's profitability and productivity. It is most efficient and effective to manage weeds through the use of herbicide applications so that they are controlled in an economical, quick, efficient, and reliable manner. Because rice is grown in diverse agricultural ecosystems, weed communities and species associated with rice

fields vary greatly. Therefore, the use of a single herbicide cannot provide satisfactory and cost-effective results in weed control. Integrated strategies, monitoring of various weed flora, identification of weeds and selection of appropriate herbicides are required during the critical period of chemical weed management. Regular monitoring and early detection of the development and mechanism of herbicide resistance is necessary. It is extremely important to adopt appropriate management strategies regarding herbicides. Proper timing of herbicide application, optimal dosage and careful selection of herbicide-resistant varieties are also essential to ensure effective chemical weed control. Regular surveys should be conducted to evaluate the efficacy of chemical weed control strategies.

Conclusion

Rice cultivation is economically dependent on weed control. During the early stages of the growing season, most weeds compete against each other. Several methods of weed control are used by farmers, but they are time-consuming and expensive. Furthermore, weeds will not be controlled by a single herbicide applied before planting and before emergence. Several herbicide applications along with two or three herbicides may be more effective at controlling weeds when appropriate climate and management practices are observed. It is possible to mix herbicides to prevent the development of herbicide resistance and to prevent herbicides from drifting and damaging non-target plants as well. Choosing the right PRE-herbicide application and post-herbicide combinations will be critical to controlling weeds in adverse weather and environmental conditions. A combination of weed management practices and post-emergence herbicides will ultimately be an effective tool in managing weeds and improving rice production. As a guarantee of delaying resistance and ensuring effective weed control, it is important to discuss the use of pre-emergence and pre-planting herbicides and the application of herbicide mixtures and rotations to weed control systems in order to maintain weed resistance and biodiversity. In addition, the use of integrated weed management strategies such as crop rotation, cultural practices, and mechanical methods is also important. These strategies should be tailored to the local conditions to maximize weed control and minimize environmental impact.

References

Alexandratos, N., Bruinsma, J. (2012). *Worlds Agriculture Towards 2030/2050: the 2012 Revision. Working Paper No. 12.03;* FAO: Rome Italy, 2012.

Amare, T., & V. Raghavaiah, C. (2015). Productivity, Yield Attributes and Weed Control in Wheat (Triticum aestivum L.) as Influenced by Integrated Weed Management in Central High Lands of Ethiopia, East Africa. Advances in Crop Science and Technology, 04(01). https://doi.org/10.4172/2329-8863.1000206

Anwar, M. P., Juraimi, A. S., Samedani, B., Puteh, A., & Man, A. (2012). Critical period of weed control in aerobic rice. The Scientific World Journal, 2012. https://doi.org/10.1100/2012/603043

Busi R, Powles SB, Beckie HJ, Renton M (2019) Rotations and mixtures of soil-applied herbicides delay resistance. Pest Manag Sci 76:487–496.

Busi, R., Powles, S. B., Beckie, H. J. & Renton, M. (2020). Rotations and mixtures of soil-applied herbicides delay resistance. Pest Manag Sci 76, 487–496.

Gage, K. L., Krausz, R. F., & Walters, S. A. (2019). Emerging Challenges for Weed Management in Herbicide-Resistant Crops. *Agriculture 2019, Vol. 9, Page 180*, *9*(8), 180. https://doi.org/10.3390/AGRICULTURE9080180

Goh, S. S., Vila-Aiub, M. M., Busi, R., & Powles, S. B. (2016). Glyphosate resistance in Echinochloa colona: phenotypic characterisation and quantification of selection intensity. *Pest Management Science*, *72*(1), 67–73. https://doi.org/10.1002/PS.4005

Heap, I. (2014). Global perspective of herbicide-resistant weeds. *Pest Management Science*, *70*(9), 1306–1315. https://doi.org/10.1002/PS.3696

HRAC. (2023). | Herbicide Resistance Action Committee. (n.d.). Retrieved November 16, 2023, from https://hracglobal.com/tools/classification-lookup

Hurle, K., & Petersen, J. (2000). Cultivation of herbicide resistant crops: Weed management and environmental aspects. *Https://Pps.Agriculturejournals.Cz/Doi/10.17221/9634-PPS.Html*, *36*(3), 112–116. https://doi.org/10.17221/9634-PPS

Hussain, S., Ramzan, M., Akhter, M. and Aslam, M. (2008). Weed management in direct seeded rice. The Journal of Animal & Plant Sciences 18(2&3): 86- 88.

Juraimi, A. S., Najib, M., Begum, M., Anuar, A. R., Azmi, M., & Puteh, A. (2009). Critical period of weed competition in direct seeded rice under saturated and flooded conditions. Pertanika Journal of Tropical Agricultural Science.

Malik, M. S., Burgos, N. R., & Talbert, R. E. (2010). Confirmation and Control of Propanil-Resistant and Quinclorac-Resistant Barnyardgrass (Echinochloa crus-galli) in Rice. *Weed Technology*, *24*(3), 231–235.

Nagyová, Ľ., Rovný, P., Stávková, J., Uličná, M., Maďarová, Ľ (2009). Consumer perception of bread quality. *Acta Univ. Agric. Silvic. Mendelianae Brun. 57*, 115–122, doi:10.11118/actaun200957030115.

Oerke, E. (2006). C. Crop losses to pests. *J. Agric. Sci.*

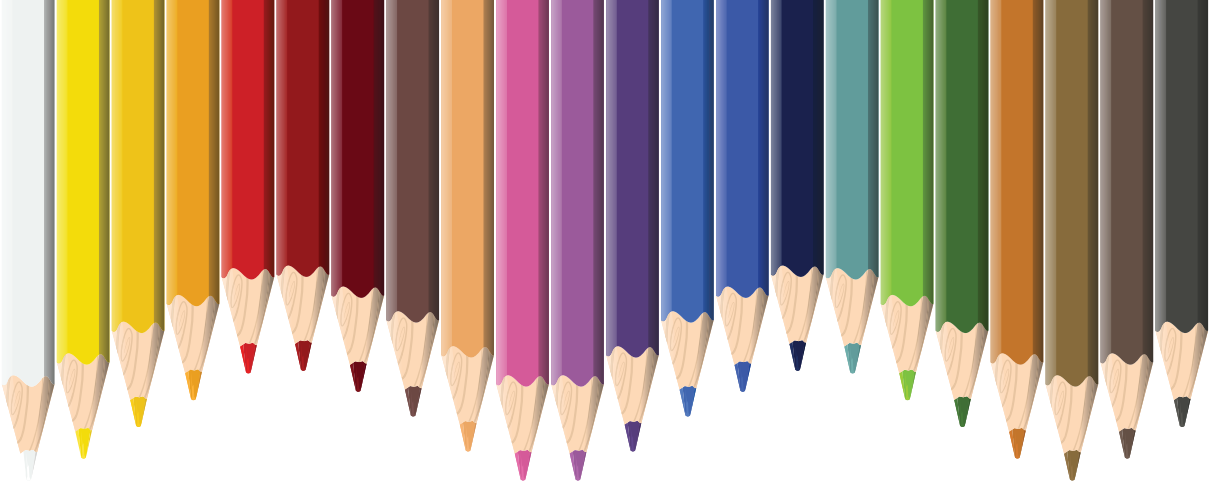
Pawar, D. A., Jadhav, M. S. and Nimbalkar, C. A. (2017). "Techniques and advances in jaggery processing: a review," *Research Journal of Chemical and Environmental Sciences*, vol. 5, no. 2, pp. 14–20.Singh,

Singh, A., Singh, A. K., & Singh, S. B. (2020). Relative Efficacy of Herbicides for Weed Control in Rice: A Review. *International Journal of Current Microbiology and Applied Sciences*, *9*(2), 2375–2382. https://doi.org/10.20546/IJCMAS.2020.902.270

Shaner, D. L. (2017). Lessons Learned From the History of Herbicide Resistance. Weed Sci., 62, 427–431.

Somerville, G. J., Powles, S. B., Walsh, M. J. & Renton, M. (2017). Why was resistance to shorter-acting pre-emergence herbicides slower to evolve? Pest Manag Sci73:844–851.

Wuerffel, R.J.; Young, J.M.; Tranel, P.J.; Young, B.G. (2017). Soil-Residual Protoporphyrinogen Oxidase–Inhibiting Herbicides Influence the Frequency of Associated Resistance in Waterhemp (Amaranthus tuberculatus). *Weed Sci.*, *63*, 529–538.



Chapter 11

PARASITE DIVERSITY OF FISHES IN TÜRKİYE – VI. CESTODA

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1. INTRODUCTION

Tapeworms (Cestoda) are one of the major groups of parasitic flatworms as a part of the phylum Platyhelminthes. They are currently classified in 19 orders with almost 5000 species in all groups of vertebrates including humans with about 1000 species parasitizing elasmobranchs and almost 500 occurring in teleost fishes as adults (Caira and Jensen, 2017; Scholz and Kuchta, 2017). They are endoparasites and their adults are found in the digestive tract of all groups of vertebrates (mainly in the intestine), whereas larval stages (metacestodes) occur in different organs and body cavities of their invertebrate and vertebrate hosts (Scholz and Kuchta, 2017). They have been reported in a vast amount of literature produced from wild and cultured fish hosts as parasites in adult and larval forms (metacestodes). Their pathogenicity on host fishes differs according to their developmental stages, while only a few adult tapeworms are pathogenic for their fish hosts, cestode larvae can be harmful for fish, especially plerocercoids migrating throughout their tissue and internal organs (Scholz et al. 2021). Tapeworm parasites are known to infest edible fish, which lowers the nutritional and commercial value of the afflicted fish since the parasites emit toxic compounds and take up necessary nutrients from the host, as a result, fish lose market value when their physical weight and size decrease (Singh et al 2020). Moreover, some cestode parasites cause human infection when ingested raw or undercooked flesh of infected fishes. Larval stages of the members of some genera have also been shown to infect humans by penetrating intact human skin (Hughes and Biggs, 2002).

The body of a tapeworm is typically elongated, dorsoventrally flattened, and divided into three sections: the proliferative region, or neck, the anterior portion with attachment function known as the scolex, and the lengthy strobila (Scholz et al. 2021). A variety of attachment structures, including loculi, four spherical muscular suckers or bothridia, an apically located rostellum that is frequently furnished with hooks, and four evertible tentacles with hooks are among the key taxonomical traits of the scolex. The posterior lobe of most tapeworms is called strobila which is composed of a chain of proglottids and each proglottid contains one, rarely more sets of male and female reproductive organs (Caira and Jensen, 2017). Both scolex and strobilar anatomy, are crucial for the classification and identification of cestodes (Caira and Jensen 2017).

Cestodes have a complex life cycle that includes first, intermediate and definitive hosts (Beveridge, 2001). Both the adult and larval (metacestode) stages of their life cycle can be found in fish hosts, while adults occur in the intestinal tract, larvae are usually located in the body cavity, in the internal organs, or in the muscles (Hoole, 1994). Planktonic crustaceans, oligochaetes, and amphipods are the first intermediate hosts, whereas fishes serve as second

intermediate, paratenic, or definitive hosts in this complex life cycle.

In Türkiye, studies on the cestode parasites of fishes in freshwater and marine environments have provided a very extensive amount of papers, as well as several checklists, (Akmırza, 2002, 2013, Keser et al. 2007, Öktener, 2003, 2005, 2014, Özer, 2019, 2020, 2022, Özer et al. 2015, Güneydağ et al. 2017, Tepe et al. 2014). Özer (2021) published the first and very comprehensive host-parasite, as well as parasite-host checklist book based on all previous reports in Türkiye, and this chapter on the cestode parasites of fishes in Türkiye has been created based on the data presented in this recent book which contains all the individual publications on each cestode parasite species.

2. CESTODE diversity of fishes in TürkİYe

Özer (2021) reported a total of 65 cestode species from all fish species that inhabited marine and freshwater environments in Türkiye and this number of cestodes corresponded with 9% of the whole parasite species reported from fishes in Türkiye (Figure 1). Of the reported 65 cestode species, the highest number was reported from wild marine fishes (33), followed by wild freshwater fishes, and cultured freshwater fishes (Figure 2).

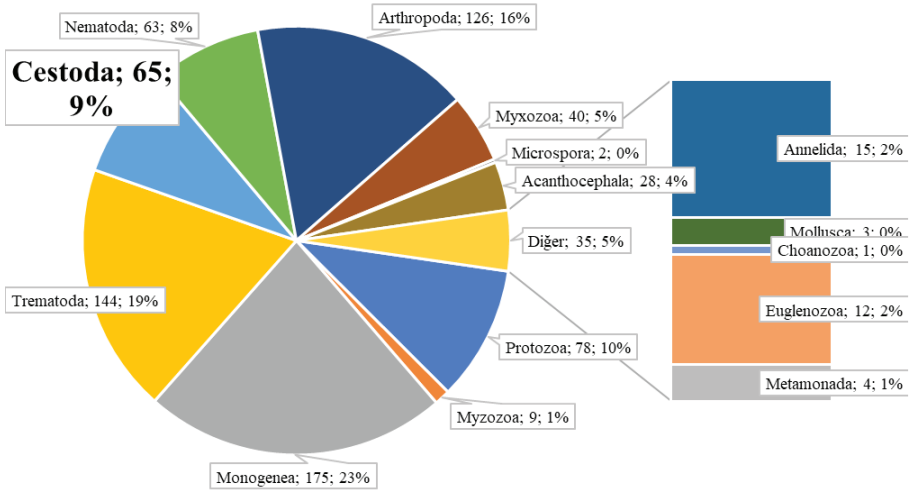


Figure 1. *Total number and percentage of cestode parasites reported from fishes in Türkiye.*

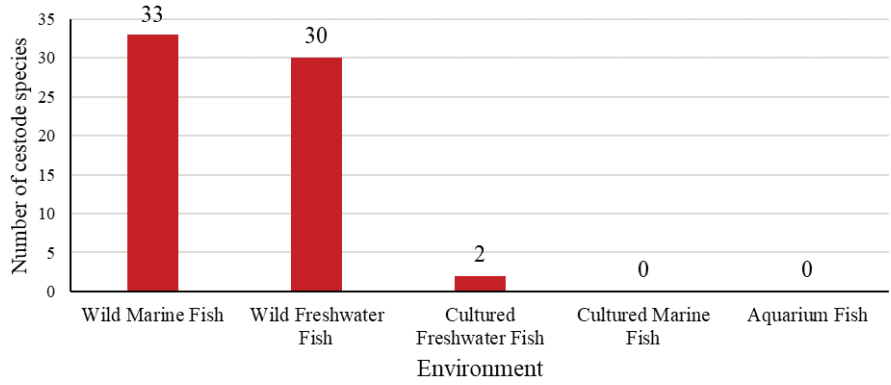


Figure 2. *The total number of cestode species reported from marine, freshwater, and aquarium fishes in Türkiye.*

3. CESTODE diversity of marine fishes

3.1. Wild marine fishes

Cestode species diversity was the highest in wild marine fishes inhabiting the surrounding seas of Türkiye among other environments as can be seen in Figure 2 and the highest number of cestode diversity came from the Aegean Sea (17), followed by the Black Sea, the Sea of Marmara, and the Mediterranean Sea (Figure 3).

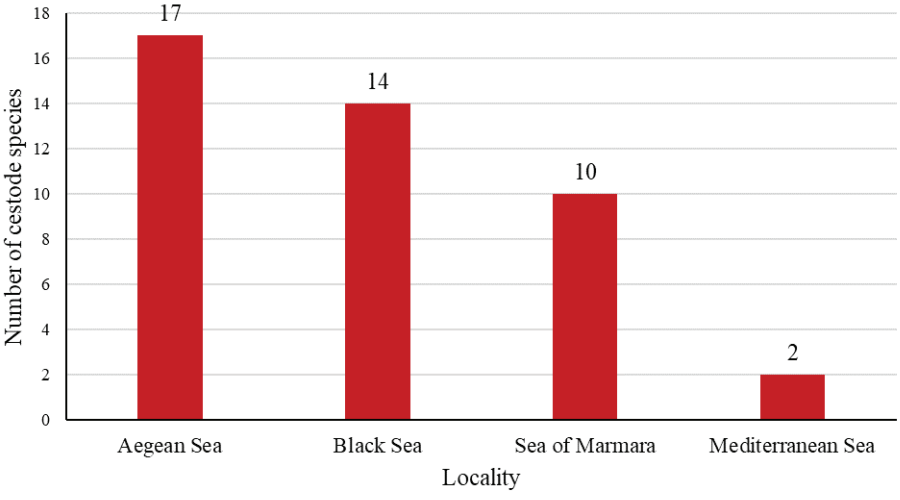


Figure 3. *The number of cestode species reported from wild marine fish species inhabited the surrounding seas of Türkiye.*

Demersal and pelagic wild marine fishes belonging to many genera were the host for cestode parasites from the surrounding seas of Türkiye (Figure 4). It can be seen in Figure 4 that the highest number of cestode species were reported from two demersal fish hosts raja *Raja clavata* (9), and common sole *Solea solea* (8), followed by five other demersal fish species black goby *Gobius niger*, red mullet *Mullus barbatus*, European flounder *Platichthyes flesus*, blackhand sole *Pegusa nasuta* and spotted weever *Trachinus araneus* which hosted 4 cestode species and the rest with a different number of cestodes (Figure 4).

When the cestode species infecting marine host fishes are considered, cestode parasites reported from ≥3 wild marine fishes are illustrated in Figure 5. The larval form of *Scolex pleuronectis* was the highest reported species from 29 different marine fish hosts, followed by *Progrillotia dasyatidis* (9 fish species), *Bothriocephalus scorpii* (8 fish species), and Tetraphyllid larvae (8 fish species) and the rest had host numbers of between 3 and 4 (Figure 5). Other cestode species infecting a lesser number of fish hosts can be seen in Özer (2021).

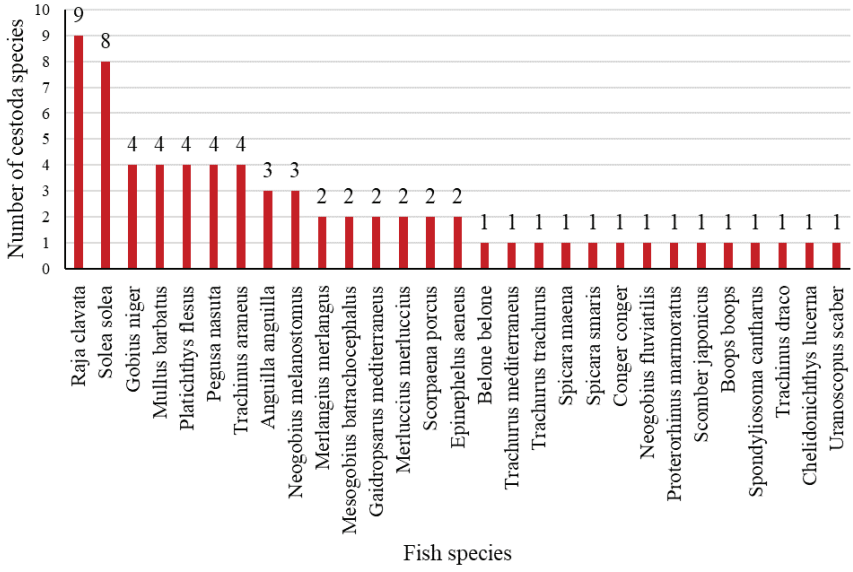


Figure 4. *The number of cestode species infecting the wild marine host fishes in Türkiye.*

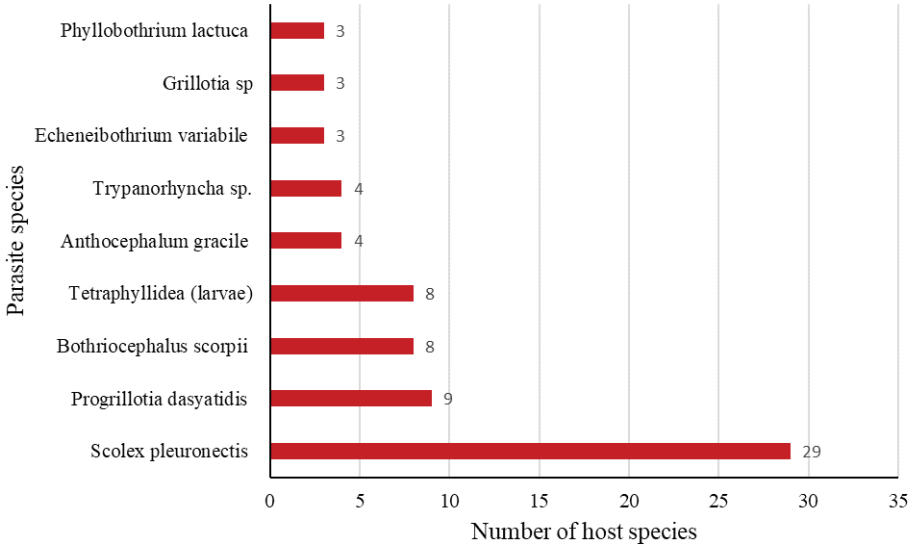


Figure 5. *The number of cestode species infecting ≥3 wild marine fish species in Türkiye.*

3.2. Cultured marine fishes

Despite the increasing number of cultured fish species and their amounts in marine environments of Türkiye, no cestode species were reported from any aquaculture activities as a result of the requirement for more hosts in their complete life cycle.

4. CESTODE diversity of freshwater fishes

4.1. Wild freshwater fish

According to Özer (2021), a total of 30 cestode species has been reported from wild freshwater fishes in Türkiye, and common carp *Cyprinus carpio* had the highest number of 13 cestode species, followed by chub *Squalius cephalus* (9), Tigris scraper *Capoeta umbla* (6), and the rest of the fish species had lesser numbers of cestode species (Figure 6).

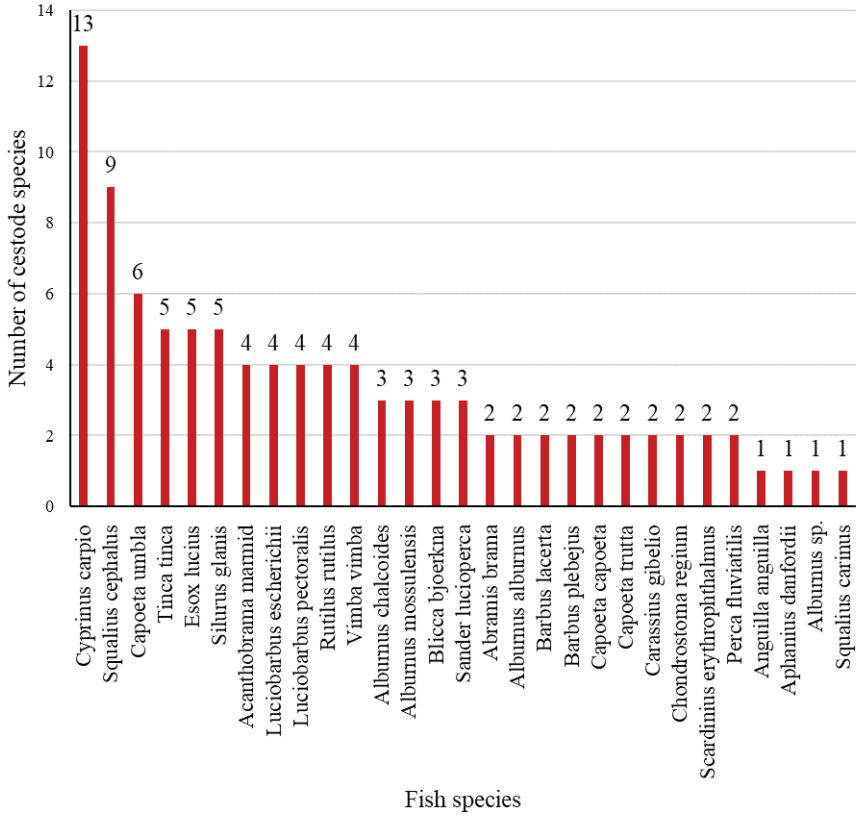


Figure 6. *The number of cestode species infecting the wild freshwater host fishes in Türkiye.*

On the other hand, when the cestode species reported from wild freshwater fish hosts in Türkiye are considered, Figure 7 illustrates that Ligula intestinalis was the top species reported from 32 different fish species according to Özer (2021). Similarly, *Bothriocephalus acheilognathi* was the other species reported from high number of host species 28, followed by *Caryophyllaeus laticeps* (17) (Figure 7), and lesser than 5 host species infected by cestode parasites can be seen in Özer (2021).

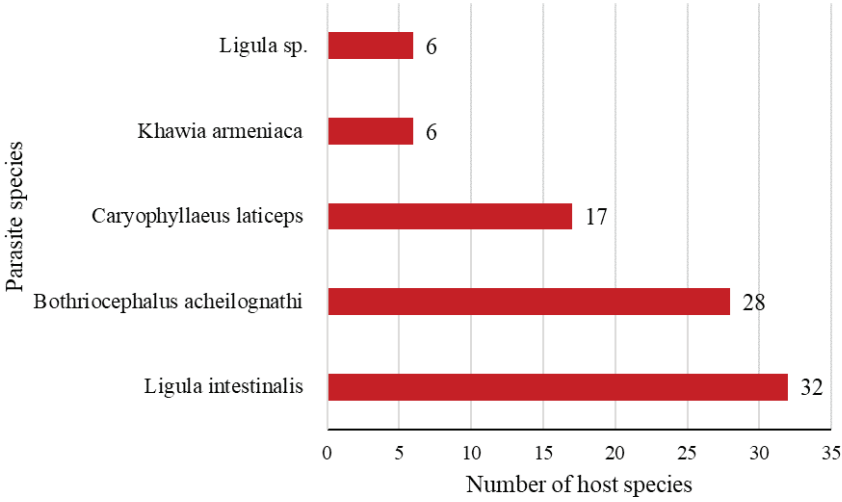


Figure 7. *The number of cestode species infecting ≥5 wild freshwater fish species in Türkiye.*

4.2. Cultured freshwater fish

Aquaculture activities in the freshwater environment in Türkiye focused mainly on two commercial fish species, namely rainbow trout *Oncorhynchus mykiss,* and common carp *Cyprinus carpio.* However, despite their high amount of production, only grass carp *Ctenopharyngodon idella* was reported to be the host for only 2 cestode species, *Bothriocephalus acheilognathi,* and *Ligula intestinalis* (Özer, 2021).

5. CESTODE diversity of aquarium fishes

Despite 32 ornamental fish species either imported or cultured in Türkiye, no cestode species was reported from any of them (Özer, 2021).

6. CONCLUSION

This chapter provided up-to-date illustrations on cestode parasites of wild and cultured host fishes in marine, freshwater, and aquariums in Türkiye by the recent comprehensive work by Özer (2021). Wild marine and freshwater fishes were reported as hosts for mostly larval cestode parasites, whereas culture environments did not favor their distribution among fishes possibly as a result of the complex life cycles requiring more involved hosts apart from fishes. The number of fish species hosting cestodes is 45 in wild marine, 47

wild freshwater environments according to Özer (2021) and these numbers are very low when considering the reported 561 marine and 401 freshwater fish species in Türkiye by Froese & Pauly (2022). It is not known what the actual number of cestode species infecting host fishes in marine and inland waters of Türkiye and in the future, however, more studies will yield more numbers of cestode species or their expanded number of host species.

References

Akmırza, A. (2002). Gökçeada civarındaki balıklarda görülen akantosefal ve sestod parazitleri. Türkiye Parazitol Dergisi 26: 93–98.

Akmırza, A. (2013). Parasitic cestodes of fish in the waters off Gökçeada, North Aegean Sea. Journal of Black Sea/Mediterranean Environment, 19: 178-184.

Beveridge, I. (2001). The use of life-cycle characters in studies of the evolution of cestodes. Chapter 23. In D. T. J. Littlewood, & R. A. Bray (Eds.), Interrelations of the Platyhelminthes (pp. 250–256). Taylor & Francis.

Caira, J. N., Jensen, K. (2017). Planetary Biodiversity Inventory (2008–2017): Tapeworms from Vertebrate Bowels of the Earth. University of Kansas, Natural History Museum, Special Publication No 25.

Froese, R., & Pauly, D. (2022). *FishBase.* World Wide Web electronic publication. www.fishbase.org, version (02/2022).

Hoole, D. (1994). Tapeworm infections in fish: Past and future problems. In A. W. Pike, & J. W. Lewis (Eds.), Parasitic diseases of fish (pp. 119–140). Samara Publishing Limited.

Hughes, A. J., Biggs, B. A. (2002). Parasitic worms of the central nervous system: An Australian perspective. Intern. Med. J. 32: 541–553.

Keser, R., Bray, R.A., Oğuz, M.C., Çelen, S., Erdoğan, S., Doğutürk, S., Aklanoğlu, G. (2007). Helminth parasites of digestive tract of some teleost fish caught in the Dardanelles at Çanakkale, Turkey. Helminthologia, 44(4): 217 – 221.

Öktener, A. (2003). Checklist of metazoon parasites recorded in freshwater fish from Turkey, Zootaxa, 394: 1-28.

Öktener, A. (2005): A checklist of parasitic helminths reported from sixtyfive species of marine fish from Turkey including two new records of monogeneans. Zootaxa 1063: 33-52

Öktener, A. (2014). Revision of parasitic helminths reported in freshwater fish from Turkey with new records. Transylv. Rev. Syst. Ecol. Res. 16: 1–56.

Özer, A. (2019). *Invasive, Endemic Localized Fishes and Their Parasites*, 177 pp, İdeal Kültür Yayıncılık (In Turkish)

Özer, A. (2020). *Marine Fishes and Parasites*. İdeal Kültür Yayıncılık, 280 pp, (In Turkish)

Özer, A. (2021). *Checklist of Marine Freshwater and Aquarium Fish in Turkey*. Turkish Marine Research Foundation (TÜDAV), 311 pp, Publication No: 62.

Özer, A. (2022). Parasite Biodiversity of Marine, Freshwater and Aquarium Fishes in Turkey. (Editors; Akar, T., Daşdemir, İ., Cengizler, İ.), Current Research in Agriculture, Forestry and Aquaculture, Gece Kitaplığı, pp. 127-143.

Özer, A., & Öztürk T. (2017). Parasite Diversity of the Black Sea Fishes in Turkish Coastal Areas. (Eds: Sezgin, M., Bat, L., Ürkmez, D., Arıcı, E., Öztürk, B.), *In: Black Sea Marine Environment; The Turkish Shelf,* Turkish Marine Research

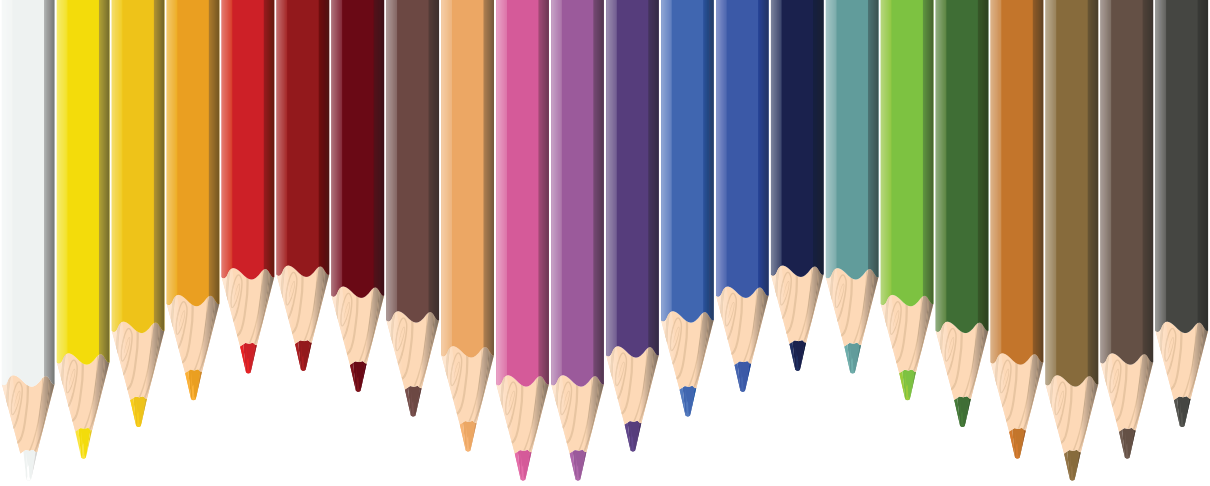
Foundation (TÜDAV) Publication No: 46, pp. 289-309.

Özer, A., Kornyychuk, Y.M., Öztürk, T., Yurakhno, V. (2015). Comparative study on parasite fauna of the whiting *Merlangius merlangus* in the Northern and Southern Zones of the Black Sea. Turkish Journal of Fisheries and Aquatic Sciences, 15: 285-294.

Scholz, T., Kuchta, R., Oros, M. (2021). Tapeworms as pathogens of fish: A review. Journal of Fish Diseases, 44, 1883–1900.

Singh, A.J., Narayan, A., Singh, S. (2020). Taxonomy of piscian cestodes of freshwater fsh: A cladistic model of morphotaxonomic study of rare tapeworm from the Dehradun Region (U.K.), India. International Journal of Basic Sciences and Applied Computing, 2(11): 7-13.

Tepe, Y., Oğuz, M.C., Heckmann, R.A. (2014). Digenean and cestode parasites of teleost fish from the Eastern Black Sea Region. Turkish Journal of Zoology, 38: 209-215.



Chapter 12

GENOTOXIC EFFECT OF CYPERMETHRIN ON DAPHNIA MAGNA

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INTRODUCTION

Pesticides include all chemicals used in insect control. They are generally classified as insecticides, herbicides, fungicides, etc. according to the active agent. It is also possible to group pesticides according to their chemical, physical, area of use, persistence and developmental stages they affect.

The use of pesticides dates back to ancient times. A papyrus from 1500 BC records the preparation of insecticides against lice, fleas and wasps. In the 15th century, chemicals such as arsenic, mercury and lead were used to kill pests in agricultural crops, while in the 17th century nicotine sulphate was extracted from tobacco to be used as an insecticide (Miller, 2002).

The widespread use of pesticides in the fight against insects started in the mid-1940s. In 1939, the Swiss chemist Paul Mueller discovered the pesticidal properties of dichlorodiphenyl tricholoroethamine (DDT) and DDT, which was introduced to the market in 1942, rapidly became widespread (Güler and Çobanoğlu, 1997).

The escalating global population's demand for food has made the use of agricultural chemicals like fertilizers and pesticides inevitable to maximize yields from existing agricultural areas (Storck et.al. 2017; Chen et al. 2017). Today, it is almost impossible to produce in sufficient quantity and quality anywhere in the world without supportive substances such as agricultural pesticides (Engindeniz 2008; Hillocks, 2012; Barriere et al. 2015; Topal et al. 2017). Despite their known harmful effects on natural resources, humans and other living organisms, pesticides have become indispensable for agricultural production. Unfortunately, as a result of the intensive use of pesticides, some problems arise in terms of human, animal and environmental health. Pesticides applied to agricultural areas are transferred to air, water and soil, and from there to other living organisms living in these environments and undergo transformation (Yıldırım, 2008).

Pesticides have been found to have teratogenic and mutagenic effects. Dose and stress are important factors in the formation of teratogenic effect. In addition, pesticides with mutagenic effects cause chromosomal fractures (Kolayanova and Tarkowski 1991).

Cypermethrin, whose effect was investigated in our study, is a pyrethroid widely used in agriculture against insects and in the treatment of ectoparasite infestations in livestock (Farag et al., 2021). According to their chemical structure, they are classified into two groups: type 1 pyrethroids without cyano group (alletrin, permethrin, pyrethrin) and type 2 pyrethroids with cyano group (deltamethrin, cypermethrin). Type 1 is less toxic because it lacks a cyano group, while type 2 pyrethroids are highly toxic. Pyrethroids exert their effects by disrupting sodium ion transport across the nerve cell membrane.

Continuous opening of the sodium channel leads to continuous depolarization of the membrane, preventing the generation of action potentials. The nerve cell is thus paralyzed. Pyrethroids enter the body through dermal, inhalation or food/water intake. Cypermethrin, a type II pyrethroid, is a broad-spectrum pesticide widely used for veterinary, agricultural and domestic applications. Humans are exposed to Cypermethrin during the application or consumption of pesticide-contaminated products (Chrustek et al., 2018).

The objective of this study is to assess the genotoxic effects of Cypermethrin on *Daphnia magna* using single-cell gel electrophoresis.

MATERIAL METHOD

Daphnia magna

Daphnia magna obtained from Akdeniz Su Ürünleri Araştırma Merkezi, Kepez, Antalya, Türkiye. *Daphnia magna* was grown in American Society for Testing and Materials medium (14 h light-10 h dark) at a temperature of 20 °C ± 1. Daphnia culture was refreshed three times in 7 days and fed with Spirulina sp. Juveniles used for toxicity tests were 6th generation Daphnia.

Test Chemical

The commercial form of Cypermethrin was supplied in 100 g/L. Concentrations were prepared from the commercial form.

Dose Determination

In the scientific literature, acute toxicological evaluation of Cypermethrin on *Daphnia magna* was performed and LD_{50} values were determined. Yordanova et al. 2009 determined the 48-hour LD_{50} value of Cypermethrin as 0.8 µg/mL. In our study, based on these values, $LD_{50}/8$ (0.1 µg/mL), $LD_{50}/4$ (0.2 µg/mL), $LD_{50}/2$ (0.4 µg/mL), and LD_{50} (0.8 µg/mL) values were tested.

Daphnia magna Comet assay test

Daphnia (less than 24 h, 5 specimens, 4 repeat) were placed in petri dishes. Cypermethrin added at a concentration of 0.8, 0.4, 0.2, 0.1 µg/mL for 48 h. All organisms were homogenized to obtain the hemolymph. As buffer 1 ml of PBS, EDTA (20 mM) and DMSO (10%) were used. Following homogenization, 150 µL of the sample was mixed with equal amounts of LMA (Low melt agar, 0.65%) and transferred onto slides which is coated agar previously and covered with lamella. Then, cold application was performed on cold ice for 10-15 minutes to solidify the slides. Following solidification, the lamellae were removed. Then, it was treated with lysis solution (2.5 M NaCl, 100 mM EDTA, 10 mM Tris pH=10, 10% DMSO and 1% Triton X-100) at 4 C and kept for a minimum of 1 hour and a maximum of 16 hours. After the lysis process, the slides were placed in electrophoresis buffer (1 mM EDTA, 300 mM NaOH, pH = 13) and waited for approximately 20-25 minutes. Cells were

run in electrophoresis for 20 min (1 V/cm, 300 mA). Following electrophoresis, neuralization was performed twice. Each procedure was performed for 5 minutes, for a total of 10 minutes. At the end of the procedures, each slide was stained with 50 µl ethidium bromide (20 µg/mL) and the prepared preparations were examined with a fluorescence microscope.

Evaluation and Statistics

100 cells were examined at each concentration. Three comet parameters (tail intensity, tail moment and tail length) were analyzed using BS 200 ProP; BAB Imaging System, Ankara, Turkey to detect genotoxic potential of Cypermethrin on *Daphnia magna*. The data were statistically analyzed with the t-test (IBM SPSS 21 package program).

RESULTS

Single cell gel electrophoresis, also known as Comet assay, is a sensitive, reliable and rapid method that can detect DNA damage in eukaryotic cells on a cell-by-cell basis. In our study with this method, the damage frequencies of Cypermethrin in *Daphnia magna* DNA were analyzed. The results obtained are presented in Table 1.

Table 1. DNA damage frequencies in Daphnia magna by Cypermethrin application

Substance	Concentrations (µg/mL)	Comet Tail Length (µm)	Comet Tail Moment	Comet Tail Intensity (%)
Control	0.00	10.44 ± 1.6	6.63 ± 1.20	261.55 ± 0.48
MMC	0.20	100.57 ± 4.71	99.44 ± 4.95	302.17 ± 0.63
Cypermethrin	0.1	17.41 ± 2.92*	13.50 ± 1.51*	280.84 ± 0.78**
	0.2	16.98 ± 1.22*	10.71 ± 1.07*	280.58 ± 0.54**
	0.4	15.51 ± 1.21*	8.58 ± 0.83	270.37 ± 0.77**
	0.8	17.63 ± 2.3**	16.80 ± 2.58**	271.48 ± 0.77**

According to the negative control *P<0,05, ** p<0,01

According to the data obtained at the end of single cell gel electrophoresis test, Cypermethrin treatment induced the tail length in Daphnia magna at all doses. Statistical evaluation of the increased tail length showed that this increase was statistically significant. On the other hand, this increase in comet tail length as a result of Cypermethrin treatment did not show a significant dose-dependent correlation (r = 0.66, Figure 1a).

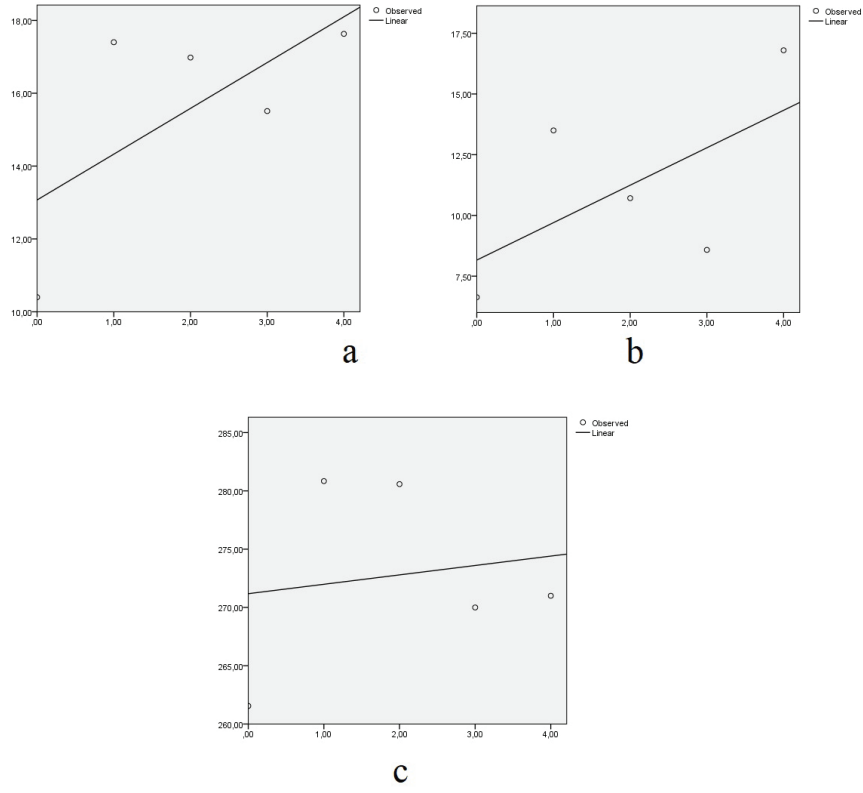


Figure 1. Dose-dependent changes in comet test a. Tail length, b. Tail moment, c. Tail density

The comet tail moment obtained by the comet test did not show a statistically significant increase compared to the negative control at all concentrations except 0.4 µg/mL. At the other concentrations (0.1, 0.2 and 0.8 µg/mL) there was an increase compared to the control and this increase was statistically significant. On the other hand, when the increase in comet tail moment caused by Cypermethrin treatment was evaluated; it was found that the increase formed a significant correlation depending on the dose (r=0.6, figure 1b).

It was determined that exposure to cypermethrin increased comet tail density in Daphnia magna at all concentrations (Table 1). In the statistical evaluation of this increase, significance was detected at all concentrations. This increase in concentrations did not show a significant correlation depending on the dose (r = 0.25, Figure 1c).

As a result, in this study, the in vivo genotoxic effects of Cypermethrin were investigated with a reliable and still valid test such as single cell gel electrophoresis. Within the scope of the experiments, it was understood that

Cypermethrin has a direct or indirect effect on DNA. From this, it has been understood that Cypermethrin causes a genotoxic effect.

CONCLUSIONS

Pesticides are substances or mixtures of substances used to prevent, control or reduce the damage of harmful organisms. Pesticides can be a chemical substance, a biological agent such as a virus or bacteria, an antimicrobial, a disinfectant, or any other tool. However, uncontrolled and excessive use of pesticides causes many environmental pollutions. Environmental pollution also occurs due to mistakes made during the storage of pesticides and the disposal of excess drugs (Zabit and Tongur, 2019).

A correlation has been found between the presence of pesticides and cancer incidence (Blair et al. 1985; Pearce and Reif, 1990). Some pesticides have been found to increase the formation of "DNA adducts" in leukocyte samples. The effects of 15 commonly used pesticides (dithiocarbamate, methidation, paration-methyl, paration, vinclozolin, fenarimol, etc.) on the liver xenobiotic enzyme system and 8-OH-2-guanosine level in liver DNA, an index of oxidative damage, were investigated (Lodovici et al. 1994; Peluso et al. 1996). After these pesticides were given to rats for 10 days, it was observed that low doses of the pesticide mixture caused free DNA damage, while high doses inhibited the detailed expression of oxidative damage. The data obtained in our study are in parallel with the studies mentioned above.

Pyrethroid insecticides are highly toxic to insects and fish and have a lower incidence of toxicity in mammals than in insects and fish (Segmenoglu, 2020).

Lethal, sublethal and toxic effects of Cypermethrin commercial formulation were studied in *Physalaemus gracilis*, one of the Anura (frog) species, and Cypermethrin was reported to be toxicologically effective (Natani et al 2023). Based on this, it is understood that this chemical poses a high risk to living species, may cause many problems in the short and long term and may have the potential to affect the dynamics of the ecosystem.

When the effect of Cypermethrin on Zebrafish (*Danio rerio*) was examined, it was reported to increase the frequency of oxidative damage and genotoxicity (Paravani et al. 2018). Negative effects of Cypermethrin were determined in immunotoxicological evaluations in carp fish (*Cyprinus carpio*) (Soltanian and Fereidouni, 2017). Similarly, it was found to induce DNA damage, histopathological changes and apoptosis in carp fish (Khafaga et al. 2020). In studies on *Catla catla*, it was determined that Cypermethrin caused hepatic toxicity, apoptosis in brain cells and neural toxicity (Jindal and Sharma 2019; Sharma and Jindal 2020).

There are studies investigating the effect of Cypermethrin on *Daphnia*

magna, Gammarus pulex, Ceriodaphnia dubia and many other invertebrates and vertebrates (Christensen et al. 2005; Meems et al. 2004; Yordanova et al. 2009). In these studies, the negative effects of Cypermethrin were reported.

Kim et al. (2008) reported important problems in their study such as increased calving time, decreased litter size and decreased total number of offspring as a result of exposure of Daphnia newborns (< 24 hours) to Cypermethrin for 21 days. The common point in the studies mentioned above is the negative effects of Cypermethrin exposure on *Daphnia magna*. In our study, the statistical increase in all three Comet test parameters in *Daphnia magna* with Cypermethrin exposure compared to the control group is in line with the above studies.

When all the studies mentioned above and the results of the present study are evaluated, the harmful effects of Cypermethrin on *Daphnia magna* are obvious. In addition, the continuous accumulation of pesticide in aquatic environments unfortunately leads to a great concern. These include raising people's awareness about the environment, especially starting with children, administrative and political authorities supporting recycling, and it being part of the environmental policies of national governments.

REFERENCES

Yıldırım, E. (2008). Tarımsal zararlılarla mücadele yöntemleri ve kullanılan ilaçlar. Atatürk Üniversitesi Ziraat Fak. Yayınları, Yayın, (219).

Miller, G. T. (2002). Living in the environment . Belmont: Wadsworth/Thomson learning. ISBN o-534-37697-5.

Storck, V., Karpouzas, D. G., & Martin-Laurent, F. (2017). Towards a better pesticide policy for the European Union. Science of the Total Environment, 575, 1027-1033.

Chen, Y. H., Wen, X. W., Wang, B., & Nie, P. Y. (2017). Agricultural pollution and regulation: How to subsidize agriculture?. Journal of cleaner production, 164, 258-264.

Hillocks, R. J. (2012). Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. Crop Protection, 31(1), 85-93.

Barriere, V., Lecompte, F., & Lescourret, F. (2015). Efficacy of pest and pathogen control, yield and quality of winter lettuce crops managed with reduced pesticide applications. European Journal of Agronomy, 71, 34-43.

Engindeniz, S. (2008). Economic analysis of agrochemical use for weed control in field-grown celery: a case study for Turkey. Crop protection, 27(3-5), 377-384.

Topal, A., Çomakli, S., Özkaraca, M., Baran, A., Köktürk, M., Parlak, V., … Ceyhun, S. B. (2017). Immunofluorescence evaluation of 4-Hydroxynonenal and 8-hydroxy-2-deoxyguanosine activation in zebrafish (Daino rerio) larvae brain exposed (microinjected) to propyl gallate. Chemosphere, 183, 252–256. doi:10.1016/j.chemosphere.2017.05.110

Güler, Ç., & Çobanoğlu Z. (1997). Pestisitler. Çevre Sağlığı Temel Kaynak Dizisi No: 52. Basım. Ankara: TC Sağlık Bakanlığı, Sağlık Projesi Genel Koordinatörlüğü yayını, 9-10.

Kolayanova F, Tarkowski S. (1981). Toxicology of Pesticide. Copenhagen, p41-123.

Pearce, N., & Reif, J. S. (1990). Epidemiologic studies of cancer in agricultural workers. American journal of industrial medicine, 18(2), 133-148.

Blair, A., Malker, H., Cantor, K. P., Burmeister, L., & Wiklund, K. (1985). Cancer among farmers: a review. Scandinavian journal of work, environment & health, 397-407.

Peluso, M., Merlo, F., Munnia, A., Bolognesi, C., Puntoni, R., & Parodi, S. (1996). (32) P-postlabeling detection of DNA adducts in peripheral white blood cells of greenhouse floriculturists from western Liguria, Italy. Cancer epidemiology, biomarkers & prevention: a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology, 5(5), 361-369.

Lodovici, M., Aiolli, S., Monserrat, C., Dolara, P., Medica, A., & Di Simplicio, P. (1994). Effect of a mixture of 15 commonly used pesticides on DNA levels of 8-hydroxy-2-deoxyguanosine and xenobiotic metabolizing enzymes in rat liver. Journal of Environmental Pathology, Toxicology and Oncology: Official Organ of the International Society for Environmental Toxicology and Cancer, 13(3), 163-168.

Segmenoglu, M. S. (2020). The effect of pyrethroid group pesticides on honey bee deaths in Cukurova region. Turkish Journal of Agriculture-Food Science and Technology, 8(3), 594-597.

Özcan, Z., & Tongur, S. (2019). Pestisitlerin toksisitesinin lepidium sativum test moduyla çevre ve insan sağlığı açısından değerlendirilmesi. Ulusal Çevre Bilimleri Araştırma Dergisi, 2(4), 144-150.

Macagnan, N., Rutkoski, C. F., Folador, A., Skovronski, V. J., Müller, C., Hartmann, P. A., & Hartmann, M. (2023). Mortality and toxicity of a commercial formulation of cypermethrin in Physalaemus gracilis tadpoles. Scientific Reports, 13(1), 17826.

Farag, M. R., Alagawany, M., Bilal, R. M., Gewida, A. G., Dhama, K., Abdel-Latif, H. M., … Naiel, M. A. (2021). An overview on the potential hazards of pyrethroid insecticides in fish, with special emphasis on cypermethrin toxicity. Animals, 11(7), 1880. doi:10.3390/ani11071880

Paravani, E. V., Simoniello, M. F., Poletta, G. L., Zolessi, F. R., & Casco, V. H. (2018). Cypermethrin: Oxidative stress and genotoxicity in retinal cells of the adult zebrafish. Mutation Research/Genetic Toxicology and Environmental Mutagenesis, 826, 25-32.

Khafaga, A. F., Naiel, M. A., Dawood, M. A., & Abdel-Latif, H. M. (2020). Dietary Origanum vulgare essential oil attenuates cypermethrin-induced biochemical changes, oxidative stress, histopathological alterations, apoptosis, and reduces DNA damage in Common carp (Cyprinus carpio). Aquatic Toxicology, 228, 105624.

Soltanian, S., & Fereidouni, M. S. (2017). Immunotoxic responses of chronic exposure to cypermethrin in common carp. Fish physiology and biochemistry, 43, 1645-1655.

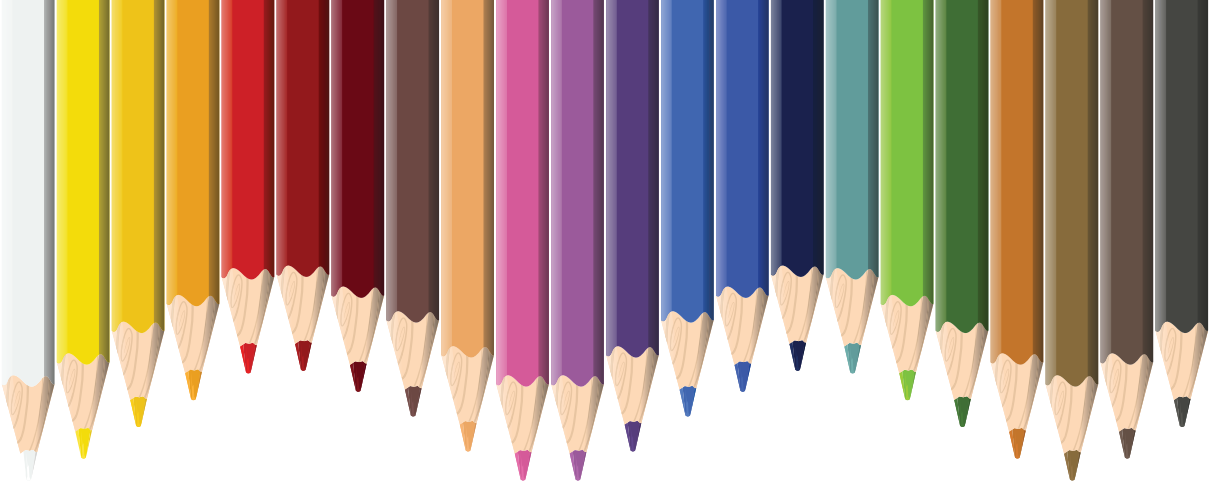
Sharma, R., & Jindal, R. (2020). Assessment of cypermethrin induced hepatic toxicity in Catla catla: A multiple biomarker approach. Environmental Research, 184, 109359.

Christensen, B. T., Lauridsen, T. L., Ravn, H. W., & Bayley, M. (2005). A comparison of feeding efficiency and swimming ability of Daphnia magna exposed to cypermethrin. Aquatic Toxicology, 73(2), 210-220.

Meems, N., Steinberg, C. E. W., & Wiegand, C. (2004). Direct and interacting toxicological effects on the waterflea (Daphnia magna) by natural organic matter, synthetic humic substances and cypermethrin. Science of the total environment, 319(1-3), 123-136.

Yordanova, V., Stoyanova, T., Traykov, I., & Boyanovsky, B. (2009). Toxicological Effects of Fastac Insecticide (Alpha—Cypermethrin) to Daphnia Magna and Gammarus Pulex. Biotechnology & Biotechnological Equipment, 23(sup1), 393-395.

Kim, Y., Jung, J., Oh, S., & Choi, K. (2008). Aquatic toxicity of cartap and cypermethrin to different life stages of Daphnia magna and Oryzias latipes. Journal of Environmental Science and Health, Part B, 43(1), 56-64.



Chapter 13

CHARACTERISTICS AND IMPORTANCE OF BLACK ELDERBERRY (SAMBUCUS NIGRA L)

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Intoduction

Black elderberry is known to have been one of the most consumed fruits during the Chalcolithic Period. In the Neolithic Period, only S. ebulus and S. nigra species were documented to be used as food by Romans, Dacians, and Gauls and for medicinal purposes. Ancient healers such as Dioscorides and Hippocrates used various Sambucus species for numerous health purposes and described this plant as nature's greatest medicinal herb. It is mentioned that Hippocrates regarded black elderberry trees as a medicine chest (Kilham, 2000; Tejero et al., 2015).

Sambucus nigra L. (Tree elderberry, Black elderberry) is a plant species in the form of shrubs and trees in the Adoxaceae family. he Adoxaceae family is noted for representing a heterogeneous wild, semi-wild, or cultivated species with diverse biochemical, genetic, physiological, and morphological characteristics within the Sambucus L. genus (Bolli, 1994; Mikulic-Petkovsek, 2015). These species are perennial plants that can be woody, shrubby, or rhizomatous (rooted) in form. Many sources indicate that the height of the elderberry plant can reach up to 10 meters (Wilczynski and Podlaski, 2005; Ulbricht et al., 2014; Gilman et al., 2018). In another study, it was reported that the height of the elderberry plant can reach up to 3 meters in the northern regions and 4.5 meters in the southern regions (Elias, 1980; McLaughlin et al., 2008; Charlebois et al., 2010). Gilman et al. (2018) stated in their research that the height of the plant varies between 1.5 and 3.6 meters, and its spread is between 1.8 and 3.0 meters. It is reported that the elderberry plant has fibrous, lateral and fascicular roots that can reach depths of up to 20 meters (Charlebois et al., 2010). This small tree has brownish-gray bark and a generally cylindrical trunk (Gilman et al., 2018). The upper side of the leaves is dark green, the lower part is paler green and generally has a shiny appearance. In autumn, the leaves turn yellow and the plant sheds its leaves. It is stated that leaf sizes vary between 10 and 15 cm. The leaves have a feathery structure (pinnate), irregular margins, and serrated teeth (3 to 15 serrated teeth) (Bolli, 1994; Mikulic-Petkovsek et al., 2015; Gilman et al., 2018). Sambucus nigra is described as a small tree or shrub with a height of 1-8 meters and a strong aroma. The bark has a brownish color with longitudinal cracks and deep grooves. The leaves are opposite, serrated, and consist of 5-7 leaflets. The flowers are white and, in an umbrella, shaped clusters. The fruits are globular and have a shiny black-purple color, containing a hard seed (Kolesarova et al., 2022).

It has been reported that there are 40 species of Sambucus worldwide (Dündar, 2009). Through research, the number of species has been revised several times, leading to a reduction in the total count. In the most recent revision, the number of recognized Sambucus species is defined as 9: S. ebulus, S. adnata, S. australis, S. wightiana, S. australasica, S. javanica, S. racemosa, S. gaudichaudiana and S. nigra. Additionally, there are wild, semi-wild, and

uncultivated varieties of the Sambucus plant (Bolli, 1994; Mikulic-Petkovsek et al., 2015).

Black elderberry is a species native to many regions in North Africa, Europe, Asia, and America (Veberic et al., 2009). It is commercially cultivated in countries such as Germany, Denmark, Italy, Switzerland (Charlebois et al., 2010), Austria, Hungary, Slovakia, and the Czech Republic (Costica et al., 2019). In another study, it was noted that black elderberry flowers are grown for trade purposes in Romania, Bosnia and Herzegovina, Bulgaria, Croatia, Hungary, Serbia, Macedonia, Albania, Montenegro, and Russia (Engels and Brinckmann, 2013).

In Turkey, Sambucus nigra is known by various names, including Mundarağ, Mındar, Mindiraç, Melesir, Patlak, Patlangoz, Patlayak, Patlangıç, Patlavuç, Patlankuç, Patlangaç, Şişni, Yalangaz, and Yalankoz (Dündar, 2009; Karaduman, 2019). In other countries, it is referred to as European or Black elder, Sambucus, Bourtree flowers (in England), Holunderbluten, Aalhornblüten, Fliedertee, Schwitztee (in Germany), and Fleurs de sureau (in France) (Dündar, 2009). Sambucus nigra L. is one of the two species that naturally grow in Turkey. Black elderberry is a species unique to most regions of Europe, Asia, North Africa, America, and in Turkey, it is known to grow predominantly in the northern parts of the country, occasionally in the eastern Anatolia region, including provinces such as Bolu, Trabzon, Kırklareli, Sinop, and İzmit (Alıç et al., 2021; Dündar, 2009).

Black elderberry fruits are preferred for consumption in forms such as jam, preserves, fruit juice, vinegar, tea, wine, and liqueur rather than being consumed fresh (Veberic et al., 2009; Duymuş, 2010). Additionally, there is a snack known as fried elder flower (Hollerküchln) (Valles et al., 2004). Elderflower, with its attractive aroma and taste, is used in the preparation of various cakes and confections, while elderflower extract is used in the production of infusions and wine-like beverages (Kaack 2008; Viapiana and Wesolowski, 2017).

Important components of the black elderberry (Sambucus nigra L)

Due to its medicinal properties, Sambucus nigra L. is considered one of the most important medicinal plants used in Europe. It is noted in the literature that elderberry trees were defined by Hippocrates as a “medicine chest” and the elderberry plant is regarded as nature’s greatest medicinal herb (Kilham, 2000). In folk medicine, it is used for the treatment of various ailments such as toothache, ear and eye problems, wounds, arthritis, dysentery, fever, skin burns, rheumatism, epilepsy, and the common cold (Tejero et al., 2015). Studies have reported that the Sambucus nigra L. species possesses antioxidant (Dawidowicz et al., 2006), anti-inflammatory, anti-influenza (Torabian et al., 2019), antidiabetic, anticonvulsant, antidepressant (Mahmoudi et al., 2014),

and antibacterial (Hearst et al., 2010) activities. Ancient Egyptians discovered the plant's beneficial effects in healing skin and burns (Öney and Başer, 2023).

Phenolic compounds are known for their positive effects on human health. Phenolic compounds, recognized as micronutrients in our diets, have protective effects such as being anti-inflammatory, anti-allergenic, anti-atherogenic, cardioprotective, antithrombotic, antimicrobial,vasodilatory agents, and preventive against degenerative disorders. The healing and therapeutic properties of elderberry are attributed to the presence of phenolic compounds (Dominguez et al., 2020). Chemical studies conducted on elderberries have examined volatile substances and substance groups such as phenolic compounds and proteins. Elderberry (Sambucus nigra L.) is a rich source of phenolic compounds, primarily phenolic acids, flavonols, and anthocyanins. Polyphenols are predominantly found in elderberry leaves, flowers, and fruit (Sidor and Gramza-Michałowska, 2015). Phenolic compounds are substances containing a benzene ring and are divided into two groups: flavonoids and phenolic acids (hydroxycinnamic acids and hydroxybenzoic acids). Phenolic compounds function as antioxidants by scavenging free radicals through various pathways. These compounds act as nucleophiles, binding to free radicals generated by lipid peroxidation, thereby preventing lipid peroxidation reactions. Additionally, they function as chelators for metal ions that induce oxidation (Han and Baik, 2008). Phenolic substances include phenolic acids, flavonols, and anthocyanins.

Anthocyanins

Anthocyanins (from Greek anthos, flower, and kyaneos, blue) is a term originally used to describe the blue pigment of cornflowers (Centaurea cyanus). Approximately 500 different anthocyanins have been identified in nature to date. Anthocyanins are highly potent antioxidants with various benefits for human health (Horbowicz et al., 2008). They possess bioactive properties, such as antidiabetic, anti-inflammatory, antiallergic, antiviral, antimicrobial, and anticarcinogenic effects, and have been observed to have positive effects on the cardiovascular system and vision functions, making them beneficial antioxidant compounds for health (Mozaffari-Khosravi et al., 2009).

The main anthocyanins identified in Sambucus nigra fruits are Cyanidin-3-glucoside (Chrysanthemin), Cyanidin-3-rutinoside, Cyanidin, Cyanidin-3-sambubioside-5-glucoside, Cyanidin-3,5-diglucoside, Pelargonidin-3-glucoside, Cyanidin-3-sambubioside, and Pelargonidin-3-sambubioside (Vlachojannis et al., 2010).

Flavonoids

Flavonoids are phenolic pigments synthesized in various plants, and over 8150 different flavonoids have been isolated from plants (Andersen and

Markham, 2006). Flavonoids constitute an important group of compounds with various biological activities, including antiviral, antioxidant, anti-inflammatory, anticancer, antiallergic, wound-healing, and vasodilatory effects (Dong et al., 2010).

The flavonoids identified in Sambucus nigra fruits include Astragalin (Kaempferol-3-glucoside), Hyperoside, Isoquercitrin, Quercetin, and Rutin (Quercetin-3-rutinoside). Sambucus nigra fruits are also rich in phenolic compounds such as caffeic acid, ferulic acid, chlorogenic acid, and protocatechuic acid (Jakobek et al., 2008).

Protein Derivatives

Proteins have also been identified in black elderberries. These proteins are lectins and ribosome inactivating proteins. It is thought that these proteins may also play a role in the antiviral and anticarcinogenic effects of black elderberry fruit (Citores et al., 2002). With all these features, black elderberry is a plant that has the potential to make a significant contribution to the enrichment and/or development of modern food and medicinal products.

Uses of Elderberry Fruit in the Health and Food Industry

Black elderberry fruit has traditionally been widely used in the food and pharmaceutical industries in Europe. Fructose and glucose contents in black elderberry fruits are considerably higher than sucrose content (Veberic et al. 2009). The sucrose content of black elderberry juice is also low, and most of the total sugar content consists of reducing sugars (Galic et al., 2009). It is especially used in making fruit juice, wine, jam and marmalade due to the high sugar content and coloring properties of the fruits. It is also known that the fruits and flowers of the plant are used as medicinal tea for complaints such as cough, cold and flu (Inami et al., 2006).

Fresh consumption of elderberries is not common. This is generally due to the presence of cyanogenic glycosides such as sambunigrin in the seeds, leaves, bark and unripe fruits of elderberry plants. If fruits are consumed immature or in very high doses, cyanogenic glycoside can cause nausea, vomiting, diarrhea, weakness, dizziness and gastrointestinal disorders (Senica et al., 2016a).

Cyanogenic glycosides are not harmful on their own. However, the α-glucosidase enzyme present in the gastrointestinal system stimulates the breakdown of the glycoside portion in cyanohydrins, leading to the separation of hydrogen cyanide and aldehyde portions. A dose of 0.5-3.5 mg/kg body weight of hydrogen cyanide can cause acute cyanide toxicity in humans. To reduce or prevent cyanide toxicity, some processes are recommended, such as peeling, crushing, heating, drying, and heat treatment of elderberry fruit (Bolarinwa et al., 2014).

In Turkey, elderberry is primarily used as a garden ornament, but in some regions, it is also used in molasses production. However, molasses production is extremely limited and traditional. Therefore, due to the lack of any scientific research on elderberry molasses, its potential benefits are not yet fully understood. Elderberry (Sambucus nigra L.) plant is traditionally used in many countries around the world for the treatment of viral infections such as flu and the common cold. Additionally, it is observed to be used for conditions like sprains, skin burns, swelling, cuts, skin rashes, insect bites, toothaches, fever, eye and ear problems, rheumatism, and hemorrhoids (Krüger et al., 2015; Sidor et al., 2015; Tejero et al., 2015). The contemporary use of elderberry as a natural antibiotic has become widespread, believed to be attributed to its content of rutin, tannins, and flavonoids. Black elderberry is rich in flavonoids, vitamin C, vitamin A, vitamin B6 and calcium. (Vlachojannins et al., 2010) and (Veberic et al., 2009) found in their studies that black elderberry fruits are rich in fumaric acid, malic acid, citric acid, shikimic acid, and contain important compounds such as nicotinic acid and β-carotene. When studies on its health benefits are examined, especially its phenolic content and antioxidant effect come to mind (Duymuş, 2010). Especially the use of its flowers for colds is also included in monographs and the monographs of the World Health Organization. Researchers have also reported that the use of black elderberry in the treatment of diseases such as influenza dates back to ancient Roman history (Bergner, 1996). In another study, it was reported that elderberry ended the flu within 3 days and triggered the formation of antibodies (Bergner, 1996). It has also been stated that black elderberry has positive effects not only in the treatment of diseases such as influenza but also in preventing cancer, diabetes and cardiovascular diseases (Ciocoiu et al., 2012; Krüger et al., 2015). Researchers have stated that this potential of black elderberry against diseases is due to the anthocyanins and other polyphenols it contains (Krüger et al., 2015). In many in-vitro and in-vivo studies conducted with black elderberry fruit; It has been reported to show immunomodulatory, anticancer, antibacterial, antiviral, antimicrobial, anti-inflammatory and antioxidant activity (Engels and Brinckmann, 2013).

Researchers have indicated that the elderberry plant exhibits antibacterial and antiviral activities in the treatment of respiratory infections such as influenza and the common cold (Sidor et al., 2015). In another study, it was found that elderberry leaves have inhibitory properties on certain bacteria (*Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Bacillus megaterium*) and yeasts (*Debaryomyces hansenii, Rhodotorula rubra, Zygosaccharomyces rouxii, Candida shehata*) (Hussein et al., 2011).

Major metabolites found in elderberry flowers are quercetin-3-O-rutinoside, kaemferol-3-O-rutinoside, isorhamnetin-3-O-rutinoside, 5-O-caffeoylquinic acid, 3,5-di-O-caffeoylquinic acid, 5-O-p-coumaroylqui-

nic acid, naringenin, α-linolenic and linoleic acid (Christensen et al., 2008). The presence of phenolic acids, caffeic acid and its derivatives, and flavonoids, quercetin and kaempferol derivatives, have been identified in the leaves (Skowrońska et al., 2022). The presence of caffeic acid, p-coumaric acid, ferulic acid, gallic acid, syringic acid, 3,4,5-trimethoxybenzoic acid and chlorogenic acid was detected in the bark of Sambucus nigra. All parts of black elderberry contain cyanogenic glycosides, the most abundant of which are sambunigrin and prunasin. These compounds are potentially toxic and life-threatening (Mlynarczyk et al., 2018). In a study investigating the temperature-dependent antioxidant activities of alcoholic extracts of Sambucus nigra leaves, flowers and fruits, the highest antioxidant activity was found in the flowers, while the lowest activity was found in the leaves (Dawidowicz et al., 2006). Elderberry extract is effective in treating flu. In a study, the mechanism of action of elderberry and its primary active compound, cyanidin 3-glucoside, against influenza virus was investigated, and as a result of the research, it was determined that elderberry had a mild inhibitory effect in the early stages of the influenza virus cycle, while it had a very strong effect in the post-infection stage (Torabian et al., 2019).

Hearst et al. (2010) investigated the antibacterial activity of elderberry leaf, fruit and flower extracts against methicillin-resistant Staphylococcus aureus and 13 different pathogens. The research revealed that S. nigra extracts showed antibacterial effects by inhibiting most pathogens. Consumption of functional foods has also gained popularity as consumers seek solutions to health problems and preventive measures against diseases in order to live a quality and healthy life (Hacıoğlu and Kurt, 2012). Functional foods not only meet the body's basic nutritional needs, but also contribute to the healthier functioning of chemical and physical processes. It also provides additional benefits by regulating metabolic and physiological processes, aims to prevent diseases and achieve a healthier life. Consumption of these foods, which strengthen the body's defense system and increase its resistance, has become widespread due to their protective effects against some diseases such as Alzheimer's and dementia. It is also suggested that functional food consumption has a reducing effect on treatment costs (Krystallis et al. 2008; Hacıoğlu and Kurt 2012).

Recently, elderberry has attracted a lot of attention, especially when used with antioxidants. Elderberry, a plant species known for its medicinal properties, was evaluated as nature's most healing plant and used as medicine by historical figures such as Hippocrates, Dioscorides, and Pliny the Elder. Hippocrates even referred to elder trees as a "medicine box." The traditional use of elderberry as both medicine and food in Europe continues today (Kilham, 2000; Ağalar, 2019).

The health effects of elderberry are attributed to its chemical composition, which includes bioactive components such as anthocyanins, phenolic acids, flavonoids, tannins and polyphenols (Veberic, 2009; Tejero et al., 2015). Elderberry is reported to have antioxidant, immunomodulatory, antiviral, antimicrobial, anti-inflammatory, and antidepressant effects (Ağalar, 2019). The use of elderberry as a remedy for colds and influenza dates back to ancient Rome. In Britain and America, traditional therapeutic use involves making teas from elderberry flowers to treat conditions like colds and sore throats. Furthermore, elderberry has been proven to alleviate cold symptoms within three days and positively enhance antibody production (Bergner, 1996).

In traditional European medicine, elderberry is used as a treatment for various conditions, including fever, toothaches, wounds, burns, rheumatism, dysentery, ear and eye problems, and epilepsy (Tejero et al., 2015). Additionally, consuming elderberry fruit is reported to have a significant relationship with preventing diseases such as cardiovascular issues, Alzheimer's, and cancer (Netzel et al., 2005; Mikulic-Petkovsek et al., 2014).

Genç and Özhatay (2006) reported various traditional uses of elderberry in the Çatalca region: leaves are externally applied to animal wounds, flower infusions are considered for diabetes treatment and diuretic effects, and infusions from the roots are used for rheumatism. In Edirne city, extractions from elderberry flowers are observed to be used against cough, diabetes, and abdominal pain (Tuzlacı et al., 2010). Yeşilada et al. (1997) mentioned that elderberry fruits are beneficial for hemorrhoids, and the leaves are helpful for rheumatism. S. nigra, known as elderberry or mürver in Izmir city, is used for colds, flu, constipation, lactative, diuretic, and respiratory disorders through extracts made from its flowers and leaves (Ugulu et al., 2009). In the Manavgat region, a paste made from fresh shoots and leaves of the plant is applied to treat boils. In Kırklareli city, elderberry flowers are used to make tea and jams are prepared from its fruits (Kültür, 2007).

The significance of the elderberry plant in nutrition and medicine is substantial, and it is also utilized for erosion control (Costică et al., 2019). Soil, precipitation, and temperature are major factors influencing plant growth. Elderberry has demonstrated significant adaptability to different soil and climate conditions (Costică et al., 2019). However, some elderberry species (such as American elderberry) have been observed to be highly affected by changing environmental conditions (Costică et al., 2019).

Balck elderberry has a long history dating back to the 5th century BC. Its medicinal use by ancient healers like Hippocrates, Dioscorides, and Pliny has been documented, supporting its historical significance (Ağalar, 2019). In Europe, it is still used in medicine and food. The traditional use of all parts of this plant for the treatment of various diseases is widespread due to its therapeutic

effects (Ağalar, 2019). The chemical composition of elderberry includes carbohydrates, proteins, lipids, vitamins, organic acids, amino acids, phenolic acids and anthocyanins (Veberic et al., 2009; Costică et al., 2019). Table 1 provides an overview of the nutritional contents in 100 grams of raw edible portions of elderberry according to the USDA (United States Department of Agriculture) (USDA, 2018).

Black elderberry has a higher content of fat, carbohydrates, and dietary fiber compared to other fruits. Dietary fiber is increasingly recognized for its importance in healthy dietary patterns, particularly in preventing certain modern-day diseases such as diabetes, obesity, various types of cancers, and cardiovascular disorders (Dülger and Şahan, 2011). It has been reported that fiber-rich foods facilitate the easier removal of waste from the body, contribute to the faster functioning of the digestive system, and reduce the contact between harmful compounds and the gastrointestinal system (Vulic et al., 2008).

Table 1.The nutritional contents in 100 grams of raw edible portions of elderberry

Chemical Composition (%)		Mineral content		Vitamin content	
Water	79.8	Calcium, Ca	38 mg	Vitamin C	36 mg
Energy	73 kcal	Iron, Fe	1.6 mg	Thiamin	0.07 mg
Energy	305 kj	Magnesium, Mg	5 mg	Riboflavin	0.06 mg
Protein	0.66	Phosphorus, P	39 mg	Niacin	0.5 mg
Total lipid (fat)	0.5	Potassium, K	280 mg	Pantothenic acid	0.14 mg
Ash	0.64	Sodium, Na	6 mg	Vitamin B-6	0.23 mg
Carbohydrate	18.4	Zinc, Zn	0.11 mg	Folate	6 µg
Diatery fiber	7	Copper, Cu	0.061 mg	Vitamin A	30 µg
		Selenium, Se	0.6 µg		

In another study, nine out of the total 16 essential amino acids were identified in elderberry flowers, leaves, and extracts, indicating the presence of valuable nutritional components (Charlebois et al., 2010). The total essential amino acid content was reported to be 8.9% in flowers, 10.03% in extracts, and 11.49% in leaves (Kislichenko and Velma, 2006). Table 2 provides the amino acid content in elderberry (USDA 2018). The high biological value of elderberry, attributed to its total essential amino acid content, positions it as a valuable protein source, making it suitable for various food and dietary products (Künsch and Temperli, 1978).

Table 2.The aminoacid contents in 100 grams of raw edible portions of elderberry

Aminoacids					
Tryptophan	0.013 g	Methionine	0.014 g	Histidine	0.015 g
Threonine	0.027 g	Cystine	0.015 g	Alanine	0.03 g
Isoleucine	0.027 g	Phenylalanine	0.04 g	Aspartic acid	0.058 g
Leucine	0.06 g	Tyrosine	0.051 g	Glutamic acid	0.096 g
Lysine	0.026 g	Valine	0.033 g	Glycine	0.036 g
Proline	0.025 g	Serine	0.032 g		

The chemical composition of elderberry fruit generally consists of organic compounds such as carbohydrates (simple, soluble, polysaccharides), proteins, fats, vitamins, organic acids, and phenolic compounds (flavonoids, phenolic acids, anthocyanins). Elderberry; %79.8 water, %18.4 carbohydrates, %0.5 fat, %0.66 protein, and 7% fiber content. Additionally, 100 grams of elderberry fruit contains 38 mg of calcium, 39 mg of phosphorus, 6 mg of sodium, and 36 mg of vitamin C. Studies have also reported that fresh elderberries are rich in organic acids such as malic acid, citric acid, fumaric acid, shikimic acid, as well as important compounds like B2, B6, C vitamins, pantothenic acid, biotin, β-carotene, and niacinamide (Veberic et al., 2009).

Vulic et al. (2008) reported that elderberry fruits have sugar content of 8.88%, with 8.55% as reducing sugar and 0.33% as sucrose. Galic et al. (2009), however, mentioned slightly lower values, indicating 6.16%, 6.12%, and 0.04% for total, reducing, and sucrose, respectively. Another study reported glucose at 42.62 g/kg, fructose at 43.96 g/kg, and sucrose at 1.04 g/kg in fresh weight of elderberries (Veberic et al., 2009). Consequently, elderberry fruits consist mainly of reducing sugars, with glucose and fructose making up a significant portion, and total sugar content being predominantly composed of reducing sugars. Vulic et al. (2008) also found that elderberry fruits contain a substantial amount of protein (2.84 g/100 mL) with all essential amino acids.

Dominguez et al. (2020) reported that the oil content of fresh elderberries is 0.35%, emphasizing a high content of essential fatty acids, particularly linoleic (39.47 g/100 g) and α-linolenic (38.07 g/100 g) acids. Moreover, it was mentioned that polyunsaturated fatty acids (PUFAs), constituting 78% of total fatty acids, are predominantly composed of omega-6 (39.54 g/100 g) and omega-3 (38.12 g/100 g). The balanced ratio of omega-3 to omega-6, in a 1:1 proportion, highlights elderberry as a rich source of α-linolenic acid, positioning it as a fundamental PUFA in human nutrition.

Minerals in elderberries can exist in complex forms, including organic and inorganic acid salts or organic combinations (Vulic et al., 2008). Elderberries are noted to contain various minerals such as copper, potassium, manganese, magnesium, calcium, iron, phosphorus, sodium, and zinc. The mineral content of elderberries is presented in Table 1. In addition to being a good

source of minerals, elderberries are suggested to provide both macro and trace elements in nutrition. It has been reported that consuming 100 g of elderberries can meet 0.2% to 30% of the recommended daily intake for minerals such as potassium, sodium, calcium, copper, magnesium, manganese, iron, phosphorus, and zinc. The composition of elderberries varies depending on the harvest year and region. Elderberries grown in five different regions have been reported to exhibit variations in dry matter content (16.06% to 28.48%), organic matter content (8.76% to 21.68%), and total mineral content (5.93% to 9.19%) (Costica et al., 2019).

Research on elderberry juice has indicated that certain parameters such as sugar, pH, and organic acids create a lethal environment for microorganisms (Cirlini et al., 2019). Elderberries are noted to be rich not only in mineral content but also in vitamins A, B6 (pyridoxine), and C. It is reported that fresh elderberries can provide 60% of the daily recommended intake for vitamins C and A and 12% for vitamin B6. Elderberries are specified to contain 660 IU of vitamin A, 0.230 mg of vitamin B6, and 36 mg of vitamin C (Charlebois et al., 2010). Fruit juices obtained from elderberries are reported to contain various primary metabolites, including several organic acids. The most prevalent acid in elderberries is citric acid, followed by malic acid, shikimic acid, and fumaric acid (Veberic et al., 2009). Elderberries, with a high citric acid content (4.81 g/kg FW), have been reported to be richer in organic acids compared to other fruits such as cherries (0.54 g/kg FW), apples (0.52 g/kg FW), and sour cherries (0.14 g/kg FW) (Veberic et al., 2009).

Phenolic compounds are recognized for their positive effects on human health (Senica et al., 2016a). Phenolic compounds, considered micronutrients in our diets, exhibit protective effects such as anti-allergenic, anti-inflammatory, antithrombotic, anti-atherogenic, antimicrobial, vasodilatory, cardioprotective, and preventative against degenerative diseases. The healing and therapeutic properties of elderberries are attributed to the presence of phenolic compounds (Dominguez et al., 2020), making it a valuable plant in terms of bioactive polyphenolic compounds. The phenolic compounds found in elderberries include hydroxycinnamic acids, anthocyanins, flavanols, and flavonol glycosides. Studies have identified a total of 54 phenolic compounds in various elderberry species and hybrids (Kaack et al., 2008; Duymuş et al., 2014; Mikulic et al., 2015).

Dominguez et al. (2020) noted in their research that the most abundant phenolic compound in elderberries is flavonoids, with rutin (813.08 μg/100 g) and quercetin (228.83 μg/100 g) being the main contributors. They also reported the presence of phenolic acids, including gallic acid, gentisic acid, and trace amounts of vanillic acid, ferulic acid, coumaric acid, and 4-hydroxybenzoic acid in elderberry extracts. Fazio et al. (2012) found a total phenolic compound content of 54.2 mg GAE/g in elderberry seeds, identifying spe-

cific compounds such as pelargonidin-3-rutinoside, cyanidin-3-sambubioside-5-glucoside, quercetin-3-rutinoside, and quercetin-3-glucoside. Phenolic acids have been reported to exhibit antifungal and antibacterial effects against bacteria and certain yeasts (Antolak et al., 2017). Flavonoids, on the other hand, have been documented in numerous studies for their antioxidant, antibacterial, antiviral, and antiallergenic properties (Pascariu and Israel-Roming, 2022). Additionally, some research suggests that flavonoids may act synergistically with other antibacterial agents (Antolak et al., 2017).

The pharmaceutical and food industries show a growing interest in natural antioxidant sources. Elderberry (Sambucus nigra L.) stands out among many vegetables and fruits due to its high antioxidant capacity attributed to its phenolic compounds (Bermudez-Soto et al, 2004; Seabra et al., 2008). This characteristic is mainly derived from anthocyanins, a dominant phenolic compound in elderberry. The literature also indicates that a significant portion of elderberry's polyphenol group is composed of anthocyanins and anthocyanidins (Dominguez et al., 2020). The antioxidant capacities of anthocyanins have been associated with various diseases, including viral infections, cardiovascular disorders, arthritis, asthma (Kilham, 2000), and potential protection against cancer (Veberic et al., 2009). The organic acids contained in the Black Elderberry fruit are very important for human nutrition and health and are important for the evaluation of this plant and its fruits.

The healing and therapeutic properties of elderberry are attributed to its content of phenolic compounds (Dominguez et al., 2020). Therefore, the plant is valuable in terms of bioactive polyphenolic compounds (Pliszka, 2017). Phenolic compounds found in elderberry include hydroxycinnamic acids, anthocyanins, flavanols, and flavonol glycosides. Studies have identified 54 different phenolic compounds from various elderberry species and hybrids (Lee and Finn, 2007; Kaack et al., 2008; Duymuş et al., 2014; Mikulic et al., 2015). In their research, Dominguez et al. (2020) indicated that the predominant phenolic compounds in elderberry fruit are flavonoids, specifically rutin (813.08 μg/100 g) and quercetin (228.83 μg/100 g). Additionally, in elderberry extracts, they reported the presence of phenolic acids such as gallic acid, gentisic acid, and trace amounts of ferulic acid, vanillic acid, coumaric acid, and 4-hydroxybenzoic acid.

Senica et al. (2016a) in their study on elderberry products, they stated that the anthocyanin contents of the products were higher than many berries. Elderberry juice pressed from the fruit was found to contain cyanidin-3,5-diglucoside at 24.9 mg/100 ml, cyanidin-3-sambubioside-5-glucoside at 81.7 mg/100 ml, cyanidin-3-glucoside at 331 mg/100 ml, and cyanidin-3-sambubioside at 379 mg/100 ml (Kaack et al., 2008; Schmitzer et al., 2012). When compared to fruits like black figs (95 mg/100 g) and cherries (100 to 120 mg/100 g), elderberry showed a higher anthocyanin content (Del Caro and

Piga, 2008; Usenik et al., 2008; Veberic et al., 2009).

Elderberry plants contain toxic compounds known as cyanogenic glycosides, in addition to beneficial compounds (Senica et al., 2016b). These toxic compounds are particularly accumulated in the leaves, seeds, and unripe fruits of the elderberry plant (Senica et al., 2016b). Cyanogenic glycosides (CNG) are natural molecules in plants composed of secondary plant metabolites (aglycon) and sugar components (Mazza and Cottrell, 2008; Bolarinwa et al., 2015). It has been reported that cyanogenic glycosides are stored in the vacuoles of plants and, in the event of any disruption to the plant tissue (such as animal attacks, crushing, chewing, drought, freezing), they hydrolyze into the toxic hydrogen cyanide (HCN) (Vetter, 2000). Panter (2018) stated that cyanogenic glycosides are a type of glycoside and are relatively non-toxic compounds for both animals and plants. They become toxic only when the released hydrogen cyanide is enzymatically separated from the glycosides. It has also been reported that enzymes increase hydrogen cyanide when the plant is under stress or damaged, coming into contact with glycosides (Burrows and Tyrl, 2013; Panter, 2018).

Elderberry is a rich source of phenolic compounds, and its antioxidant activity is attributed to these compounds. Anthocyanin, a phenolic compound, is dominant in elderberry and has been noted to significantly impact antioxidant activity. An increase in anthocyanin content is reported to enhance antioxidant activity. The antioxidant activity of elderberry and its products has been confirmed through in vitro studies (Sidor et al., 2015). Dawidowicz et al. (2006) stated in their research that elderberry flowers, leaves, and fruits exhibit antioxidant activity. Moreover, elderberry has been reported to show higher antioxidant activity than vitamins E and C (Thole et al., 2006).

Abuja et al. (1998) reported that even black elderberry fruits, which contain anthocyanins at a low rate of 4 μg/mL, are more effective against perocyte radicals than α-tocopheroxyl and α-tocopherols, and also have effects against LDL oxidation. They stated that with these properties, it will be an important product in the treatment of diseases caused by free radicals such as cardiovascular, cancer, neurodegenerative, peripheral vascular disease, MS and autoimmune diseases.

Elderberry has been noted to have anticancer activity, primarily attributed to cyanidin-3-O-glycoside, a predominant polyphenol (Marczylo et al., 2009). Observations show that elderberry leaf and fruit extracts inhibit tumors in leukemia (Goun et al., 2002; Sidor et al., 2015). Thole et al. (2006) also reported that elderberry extract exhibited anticancer activity and attributed this to certain polyphenolics found in elderberry (Sidor et al., 2015; Thomas et al., 2020).

Olejnik et al. (2016) examined the antioxidant activity of black elderberry in an in-vitro study on human colonic cells. Research has shown that by preparing and using black elderberry extract from freeze-dried black elderberries at a concentration of 1 mg/ml, reactive oxygen production in colon cells was reduced by 22% and oxidative DNA damage was reduced by 46%. In another study, the effects of cyanidin-3-glycoside anthocyanin, the dominant phenolic compound in black elderberry, on fatty acids in the liver of rats were examined and it was observed that tocopherol levels in the liver decreased (Frank et al., 2002).

Elderberry (Sambucus nigra) extracts, due to their rich phenolic composition, exhibit high antioxidant activity (Ferraria et al., 2020). Anthocyanins significantly influence elderberry's antioxidant activity. The antioxidant activity of elderberry fruit is characterized by inhibition against DPPH radicals, ranging from 82.08% to 89.25%. Elderberry's antioxidant property is primarily linked to the presence of phenolic compounds and, to a large extent, the chemical structure of individual molecules and the composition of separate fruits (Rice-Evans et al., 1996; Zheng and Wang, 2003).

In a study by Duymuş et al. (2014), the IC50 value (the concentration required to scavenge 50% of free radicals) for elderberry extract prepared with 70% acetone was determined to be 117 μg/mol, while for the extract prepared with water, it was 123 μg/mol. Although none of the extracts exhibited activity control as high as BHT, the highest inhibition concentration was found in the 70% ethanol extract, and it was noted that elderberry inhibited linoleic acid oxidation. Generally, elderberry flower parts show higher antioxidant activity compared to fruit and leaf parts (Mlynarczyk et al., 2018). Researchers found the TEC50 value for elderflower to be between 23-75 s, while for elderberry fruit, this time was recorded between 91-133 s. In another study, the radical-scavenging property of elderflower extract was evaluated compared to the standards rutin, BHT, and BHA. In this study, where elderflower extract concentration (10 μg/mL) was lower than the concentrations of the standards (40, 20, 20 μg/mL, respectively), DPPH inhibition (97.70%) was much higher compared to the others (77.47%, 82.40%, 89.98%, respectively). The IC50 concentration of elderberry extract for inhibition (0.152 μg/mL) was lower than the IC50 concentrations of rutin, BHT, and BHA (14.65, 4.407, and 1.120 μg/mL, respectively) (Stoilova et al., 2007).

Conclusion

The food industry continuously develops and reformulates traditional product formulations to meet the increasing demand for natural and functional foods. Therefore, in recent years, many natural sources have been utilized instead of synthetic additives to promote healthy nutrition. Among these natural sources, plant-based products with high functional properties, such as the black elderberry plant, are particularly prominent. The leaves and fruits of the black elderberry plant are utilized in both the food and health sectors. Due to its high anticancer, antiviral, antimicrobial, and antioxidant activities, it is recommended for consumption by individuals for protection against diabetes and ultraviolet radiation. Products derived from the black elderberry plant, such as herbal tea, jam, marmalade, vinegar, fruit juice, and molasses, are consumed as food. Its components are also used as additives in food items to enhance color and increase nutritional value. Additionally, many brands offer black elderberry extract as a dietary supplement. Its consumption is on the rise in Turkey and worldwide due to its positive contributions to nutrition. Raising awareness among producers in regions where elderberry is cultivated and introducing a new understanding of production, processing, marketing, and consumption of the resulting products can potentially create a new source of income, especially for disadvantaged producers in rural areas. To contribute more to production, it is also crucial from an organizational behavior perspective to support the current production and marketing practices of elderberry producers and enhance them through the establishment of a cooperative. Diversifying elderberry and elderberry-derived products in line with consumer preferences for value-added products can also contribute to the economic development of elderberry producers. The promotion of elderberry products that have been produced should be done at festivals, fairs, and conferences dedicated to healthcare professionals. Emphasizing the positive contributions of these products to health can lead to increased revenue.

References

Abuja P M, Murkovic M, Pfannhauser W., (1998). Antioxidant and Prooxidant Activities of Elderberry (Sambucus nigra) Extract in Low-density Lipoprotein Oxidation. Journal of Agricultural and Food Chemistry, 46: 4091-4096.

Ağalar, H.G. (2019). Elderberry (Sambucus nigra L.). In nonvitamin and nonmineral nutritional supplements. Academic Press, 211-215.

Alıç B, Olcay N, Demir M. K., (2021). Kara Mürverin (Sambucus nigra L.) Besinsel İçeriği ve Fonksiyonel Özellikleri. Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 11(2): 1140-1153.

Andersen, Ø.M., Markham, K.R. (2006). Flavonoids: Chemistry, Biochemistry and Applications, CRC Press, Boca Raton, syf 5.

Antolak H., Czyzowska A., Kregiel D. (2017). Antibacterial and Antiadhesive Activities of Extracts from Edible Plants against Soft Drink Spoilage by Asaia spp. J. Food Prot. 2017;80:25–34. doi: 10.4315/0362-028X.JFP-16-134

Bergner, P., (1996). Elderberry (Sambucus nigra, canadensis), Medical Herbalism, 8(4), 11-12

Bermúdez-Soto, M.J.; Tomás-Barberán, F.A.; García-Conesa, M.T. (2007). Stability of polyphenols in chokeberry (Aronia melanocarpa) subjected to in vitro gastric and pancreatic digestion. Food Chem. 2007, 102, 865–874

Bolarinwa I.F., Orfila C., Morgan M.R. (2015).Determination of amygdalin in apple seeds, fresh apples and processed apple juices. Food Chem. 170:437–442. doi: 10.1016/j.foodchem.2014.08.083

Bolarinwa, I. F., Orfila, C., & Morgan, M. R. (2014). Amygdalin content of seeds, kernels and food products commercially-available in the UK, Food Chemistry, 152, 133- 139.

Bolli R, (1994). Revision of The Genus Sambucus. Dissertationes Botanicae, 223: 1–227

Burrows, G.E., Tyrl, R.J., (2013). Toxic plants of north america, John Wiley and Sons Publishing, Ames, 1381

Charlebois D., Byers P.L., Finn C.E., Thomas A.L.,(2010). Elderberry: botany, horticulturae, potential.In: Horticulture Reviews. J. Janic (Ed.), Wiley-Blackwell, New Jersey, USA, 37, 213-280

Christensen, K.B., Petersen, R.K., Kristiansen, K. and Christensen, L.P. (2010). Identification of bioactive compounds from flowers of black elder (Sambucus nigra L.) that activate the human peroxisome proliferator-activated receptor (PPAR) γ. Phytotherapy Research, 24 (2): 129-132

Ciocoiu, M. Badescu, L. Badulescu D., Badescu, M. (2012). Intervention of Sambucus nigra polyphenolic extract in experimental arterial hypertension World Academy of Science, Engineering and Technology, 64, pp. 244-247

Citores, L., Ferreras, J.M., Munoz, R., Benitez, J., Jimenez, P., Girbes, T. (2002). Tar-

geting cancer cells with transferrin conjugates containing the non-toxic type 2 ribosome-inactivating proteins nigrin b or ebulin l, Cancer Lett., 184, 29–35.

Costica, N., Stratu, A., Boz, I., Gille, E., (2019). Characteristics of elderberry (Sambucus nigra L.) Fruit, Original Scientific Paper, 84 (1), 115-122

Dawidowicz, A.L. Wianowska, D. Baraniak, B. (2006). The antioxidant properties of alcoholic extracts from Sambucus nigra L. (antioxidant properties of extracts) LWT – Food Science and Technology, 39, pp. 308-315

Domínguez R, Zhang L, Rocchetti G, Lucini L, Pateiro M, Munekata PE, Lorenzo JM, (2020). Elderberry (Sambucus nigra L.) as Potential Source of Antioxidants. Characterization, Optimization of Extraction Parameters and Bioactive Properties. Food Chemistry, 330: 127266.

Domínguez, M., Dugas, E., Benchouaia, M. et al.(2020). The impact of transposable elements on tomato diversity. Nat Commun 11, 4058. https://doi.org/10.1038/s41467-020-17874-2

Dominguez, R., Zhang, L., Rocchetti, G., Lucini, L., Pateiro, M., Munekata, P.E.S., Lorenzo, J.M., (2020). Elderberry (Sambucus nigra L.) as potential source of antioxidants. Characterization, optimization of extraction parameters and bioactive properties, Food Chemistry, 330, 127266.

Domínguez, R.; Zhang, L.; Rocchetti, G.; Lucini, L.; Pateiro, M.; Munekata, P.E.S.; Lorenzo, J.M. (2020). Elderberry (Sambucus nigra L.) as potential source of antioxidants. Characterization, optimization of extraction parameters and bioactive properties. Food Chem., 330, 127–266.

Duymuş H G, (2010). Türkiye'de Yetişen Sambucus nigra Meyveleri Üzerinde Ön Kimyasal Araştırmalar. Anadolu Üniversitesi Sağlık Bilimleri Enstitüsü, Yüksek Lisans Tezi (Basılmış).

Duymuş, H.G., Goger, F.,Baser, K.H.C., (2014). In vitro antioxidant properties and anthocyanin compositions of elderberry extracts, Food Chemistry, 155, 112-119.

Dülger, D., Şahan, Y. (2011). Diyet lifin özellikleri ve sağlık üzerindeki etkileri. Uludağ Üniversitesi Ziraat Fakültesi Dergisi, 25(2), 147-157

Dündar, S., (2009). Sambucus L. türleri üzerinde fitoterapötik çalışmalar, Yüksek Lisans Tezi, Gazi Üniversitesi Sağlık Bilimleri Enstitüsü, Ankara.

Elias, T.S. (1980) The Complete Trees of North America. Van Nostrand Reinhold, New York

Engels, G. and Brinckmann, J., (2013). European elder, The Journal of the American BotanicalCouncil, 97, 1-7

Fazio A, Plastina P, Meijerink J, Witkamp RF, Gabriele B, (2013). Comparative Analyses of Seeds of Wild Fruits of Rubus and Sambucus Species from Southern Italy: Fatty Acid Composition of the Oil, Total Phenolic Content, Antioxidant and Anti-Inflammatory Properties of the Methanolic Extracts. Food Chemistry, 140 (4): 817-824.

Genç, E.G., Özhatay, N. (2006). An Ethnobotanical study in Çatalca (European part of İstanbul) II. Turkish Journal of Pharmaceutical Sciences. Vol. 3:73–89

Gilman E F, Watson D G, Klein R W, Koeser A K, Hilbert D R, McLean D C, (2018). Sambucus nigra ssp. Canadensis: Elderberry. UF/IFAS Extension, University of Florida, USA.

Hacıoğlu, G., Kurt, G. (2012). Tüketicilerin Fonksiyonel Gıdalara Yönelik Farkındalığı, Kabulü ve Tutumları: İzmir İli Örneği. Business and Economics Research Journal Volume 3 Number 1 2012 pp. 161-171

Han, H., Baik, B.K. (2008). Antioxidant activity and phenolic content of lentils (Lens culinaris), chickpeas (Cicer arietinum L.), peas (Pisum sativum L.) and soybeans (Glycine max), and their quantitative changes during processing. International Journal of Food Science & Technology, 43(11):1971 – 1978.

Hearst C, McCollum G, Nelson D, Ballard LM, Millar BC, Goldsmith CE, Rooney PJ, Loughrey A, Moore JE, Rao JR, (2010). Antibacterial Activity of Elder (Sambucus nigra L.) Flower or Berry Against Hospital Pathogens. Journal of Medicinal Plants Research, 4 (17): 1805-1809.

Horbowicz, M., Kosson, R., Grzesiuk, A., Debski, H. (2008). Anthocyanins of fruits and vegetables- their occurrence, analysis and role in human nutrition, Veget. Crops Res. Bull., 68, 5-22.

Hussein, A.M.S., Shedeed, N.A. Abdel-Kalek, H.H., El-Din, M.H.A.S., (2011). Antioxidative, antibacterial and antifungal activities of tea infusions from berry leaves, Carob and Doum Polish Journal of Food and Nutrition Sciences, 61, pp. 201-209

Inami, O., Tamura, I., Kikuzaki, H. and Nakatani, N. (1996). Stability of anthocyanins of Sambucus canadensis and Sambucus nigra, Journal of Agricultural and Food Chemistry, 44, 3090-3096.

Jakobek, L., Seruga, M., Novak, I., Medvidovic-Kosanovic, M., Šeruga, B., (2008). DPPH radical inhibition kinetic and antiradical activity of polyphenols from chokeberry and elderberry fruits, Pomologia Croatica, 14(2), 101-118

Kaack K (2008) Aroma composition and sensory quality of fruit juices processed from cultivars of elderberry (Sambucus nigra L.). Eur Food Res Technol 227(1):45–56.

Karaduman, O., (2019). Mürverde (Sambucus nigra L.) bor uygulamasının bitkisel özellikleri üzerine etkisi, Yüksek Lisans Tezi, Tokat Gazi Osman Paşa Üniversitesi Fen Bilimleri Enstitüsü, Tokat.

Kilham, C. (2000). Health benefits boost elderberry. Herbal Gram, American Botanical Council, 50: 55.

Kislichenko, V.S., Velma, V.V. (2006). Amino-acid composition of flowers, leaves, and extract of Sambucus nigra flowers. Chemistry of Natural Compounds, 42, 125-126.

Kolesarova, A., Bojnanska, T., Kopcekova, J., , Kolesarova,A. (2022). The influ-

ence of non-tradıtıonal fruıts and elder flowers on rheologıcal propertıes of the dough. Journal of microbiology, biotechnology and Food Sciences. 11 (6) e467

Krüger S, Mirgos M, Morlock GE. (2015). Effect-directed analysis of fresh and dried elderberry (Sambucus nigra L.) via hyphenated planar chromatography. J Chromatogr A. 24;1426:209-19. doi: 10.1016/j.chroma.2015.11.021. Epub 2015 Nov 12. PMID: 26643726.

Krystallis A, Maglaras G, Mamalis S (2008) Motivations and cognitivestructures of consumers in their purchasing of functional foods. Food Qual Prefer 19:525–528.

Kültür Ş, (2007). Medicinal Plants Used in Kırklareli Province (Turkey). Journal of Ethnopharmacology, 111 (2): 341-364

Künsch U, Temperli A, (1978). Changes in Free and Protein-Bound Amino Acids in Elderberry Fruit (Sambucus nigra) During Maturation. Journal of the Science of Food and Agriculture, 29 (12): 1037-1040.

Lee, J., Finn, C.E.,(2007). Anthocyanins and other polyphenolics in American elderberry (Sambucus canadensis) and European elderberry (S. nigra) cultivars, Journal of the Science of Food Agriculture, 87, 2666-2675. Dong, H., Lin, W., Wu, J. et al. (2010). Flavonoids activate pregnane × receptor-mediated CYP3A4 gene expression by inhibiting cyclin-dependent kinases in HepG2 liver carcinoma cells. BMC Biochem 11, 23 https://doi.org/10.1186/1471-2091-11-23

Mahmoudi, M., Ebrahimzadeh, M.A., Dooshan, A., Arimi, A., Ghasemi, N. and Fathiazad, F. (2014). 34 Antidepressant Activities of Sambucus Ebulus and Sambucus Nigra, European Review for 35 Medical and Pharmacological Sciences, 18 (22), 3350-3353.

Mazza G., Cottrell T. (2008). Carotenoids and cyanogenic glucosides in saskatoon berries (Amelanchier alnifolia Nutt) J. Food Compos. Anal. 2008;21:249–254. doi: 10.1016/j.jfca.2007.11.003.

McLaughlin, J., L. Vasquez, and J. Haynes. (2008). Native landscape plants for South Florida. ENH 875, University of Florida IFAS Extension

Mikulic-Petkovsek M, Ivancic A, Todorovic B, Veberic R, Stampar F, (2015). Fruit Phenolic Composition of Different Elderberry Species and Hybrids. Journal of Food Science, 80: 2180–2190.

Mikulic-Petkovsek M, Schmitzer V, Slatnar A, Todorovic B, Veberic R, Stampar F, Ivancic A, (2014). Investigation of Anthocyanin Profile of Four Elderberry Species and Interspecific Hybrids. Journal of Agricultural Food Chemistry, 62: 5573–80.

Mlynarczyk, K.; Walkowiak-Tomczak, D.; Lysiak, G.P. (2018). Bioactive properties of Sambucus nigra L. As a functional ingredient for food and pharmaceutical industry. J. Funct. Foods 2018, 40, 377–390.

Mozaffari-Khosravi H., Jalali-Khanabadi B. A., Afkhami-Ardekani M., Fatehi F. and

NooriShadkam M. (2009). The effects of sour tea (Hibiscus sabdariffa) on hypertension in patients with type II diabetes. Journal of Human Hypertension. 23. 48-54.

Netzel M, Strass G, Herbst M, Dietrich H, Bitsch I, Frank T, (2005). The Excretion and Biological Antioxidant Activity of Elderberry Antioxidants in Healthy Humans. Food Research International, 38: 905–910.

Olejnik, A., Olkowicz, M., Kowalska, K., Rychlik, J., Dembczyński, M. and Myszka, K. (2016). Gastrointestinal digested Sambucus nigra L. fruit extract protects in vitro cultured human colon cells against oxidative stress, Food Chemistry, 197, 648-657.

Öney, B., Başer, Z. (2023).Kara Mürverin Bağışıklık Sistemi Üzerine Etkisi. Samsun Sağlık Bilimleri Dergisi 8(1), Nisan 2023: 11-26.

Panter, K.E., (2018). Cyanogenic glycoside containing plants, Veterinary Toxicology, 935-940

Pascariu O-E, Israel-Roming F. (2022). Bioactive Compounds from Elderberry: Extraction, Health Benefits, and Food Applications. Processes.10(11):2288. https://doi.org/10.3390/pr10112288

Pliszka, B., 2017, Polyphenolic Content, Antiradical Activity, Stability and Microbiological Quality of Elderberry (Sambucus Nigra L.) Extracts, Acta Science Polonorum Technolgia Alimentaria, 16 (4), 393-401.

Seabra, I.J.; Braga, M.E.M.; Batista, M.T.P.; de Sousa, H.C. (2010. Fractioned high pressure extraction of anthocyanins from elderberry (Sambucus nigra L.) pomace. Food Bioproc. Tech. 3, 674–683.

Senica, M.; Stampar, F.; Veberic, R.; Mikulic-Petkovsek, M.(2016a). The higher the better? Differences in phenolics and cyanogenic glycosides in Sambucus nigra leaves, flowers and berries from different altitudes. J. Sci. Food Agric. 97, 2623–2632

Senica, M.F.; Stampar, R.; Veberic, R.; Mikulic-Petkovsek, M.(2016b). Processed elderberry (Sambucus nigra L.) products: A beneficial or harmful food alternative? LWT-Food Sci. Technol. 72, 182–188.

Sidor, A. and Gramza-Michalowska, A. (2015). Advanced research on the antioxidant and health benefit of elderberry (Sambucus nigra) in food, Journal of Funtional Foods, 18, 9451-958.

Skowrońska, W., Sebastian G., Monika, E., Agnieszka, B., (2022). Sambucus Nigra L. Leaves Inhibit TNF-α Secretion by LPS-Stimulated Human Neutrophils and Strongly Scavenge Reactive Oxygen Species. Journal of Ethnopharmacology 290:115116

Tejero J, Jiménez P, Quinto E J, Cordoba-Diaz D, Garrosa M, Cordoba-Diaz, M., Gayoso M J, Girbés T, (2015). Elderberries: A Source of Ribosome-Inactivating Proteins With Lectin Activity. Molecules, 20 (2): 2364-2387.

Thole J M, Kraft T F B, Sueiro L A, Kang Y H, Gills J J, Cuendet M, Pezzuto J M,

Seigler D S, Lila M A, (2006). A Comparative Evaluation of The Anticancer Properties of European and American Elderberry Fruits. Journal of Medicinal Food, 9: 498-504.

Torabian, G.; Valtchev, P.; Adil, Q.; Dehghani, F. (2019). Anti-influenza activity of elderberry (Sambucus nigra). J. Funct. Foods, 54, 353–360.

Tuzlacı, E., İşbilen, D.F.A., Bulut, G. (2010). Turkish folk medicinal plants, VIII: Lalapaşa (Edirne). Marmara Pharmaceutical Journal. 14:47–52.

Ugulu, İ., Yörek, N. Doğan, Y., (2009). The investigation and quantitative ethnobotanical evaluation of medicinal plants used around Izmir Province, Turkey, Journal Of Medicinal Plant Research, 3 (5), 345-367

Ulbricht C, Basch E, Cheung L, Goldberg H, Hammerness P, Isaac R, Khalsa K P, Romm A, Rychlik I, Varghese M, Weissner W, Windsor R C, Wortley J, (2014). An Evidence-Based Systematic Review of Elderberry and Elderflower (Sambucus nigra) by The Natural Standard Research Collaboration. Journal of Dietary Supplements, 11: 80-120.

USDA Food Composition Databases, (2018). United States Department of Agriculture, https://fdc.nal.usda.gov/fdc-app.html#/food-details/171727/nutrients, [Erişim Tarihi: 27.08.2023].

Valles, J., Bonet, A., Agelet, A., (2004). Ethnobotany of Sambucus nigra L. in catalonia (Iberian Peninsula): the ıntegral exploitation of a natural resource in mountain regions, The Society Economic Botany, 58 (3), 456-469

Veberic, R., Jakopic, J., Stampar, F. and Smitzer, F. (2009). European elderberry (Sambucus nigra L.) Rish in Sugars, Organic acids, Anthocyanins and Selected Polyphenols. Food Chemistry, 114: 511-515.

Vetter, J., (2000). Plant cyanogenic glycosides, Toxicon, 38, 11-36

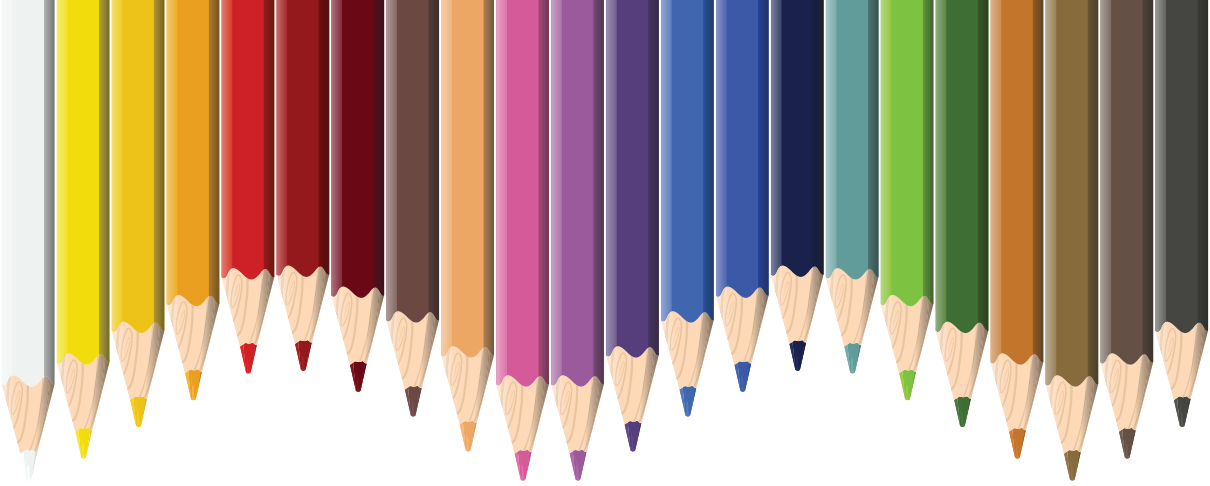
Viapiana A, Wesolowski M (2017) The phenolic contents and antioxidant activities of infusions of Sambucus nigra L. Plant Foods Hum Nutr 72(1):82–87.

Vlachojannis, J.E., Cameron, M., Chrubasik, S. (2010). A Systematic Review on the Sambuci fructus Effect and Efficacy Profiles, Phytother. Res., 24, 1-8.

Vulic J J, Vracar L O, Sμmic Z O, (2008). Chemical Characteristics of Cultivated Elderberry Fruit. Acta Periodica Technologica, 39: 85-90.

Wilczynski S and Podlaski R, (2005). A climatic model ofcambium vascular activity for white willow (Salix alba L.) fromthe Świętokrzyski National Park. Sylwan 7: 14–22

Yeşilada E, Ustün O, Sezik E, Takaishi Y, Ono Y, Honda G. (1997). Inhibitory effects of Turkish folk remedies on inflammatory cytokines: interleukin-1alpha, interleukin-1beta and tumor necrosis factor alpha. J Ethnopharmacol. 58(1):59-73.



Chapter 14

THE INFLUENCE OF CURING TEMPERATURE ON THE PERFORMANCE OF CEMENT-BONDED WOOD BOARDS MADE OF SPRUCE PLANER SHAVINGS AND PORTLAND CEMENT-SILICA FUME BLEND

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INTRODUCTION

Cement-bonded wood boards are widely used composite building materials with outstanding properties, consisting of wood particles/strands/fibers/wools, cement, water, and small amounts of cement setting accelerator. This type of composite takes advantage of the natural characteristics of wood and the structural properties of cement, resulting in a material that is suitable for various construction and building applications, such as acoustic ceiling tiles, siding, sub-flooring, roofing, insulating concrete forms, fencing, and roadside noise barriers (Na et al. 2014; Aras et al. 2022). However, cement production has significant environmental impacts, including carbon emissions, air and water pollution, and habitat disruption. Economically, it affects infrastructure, healthcare, and climate change costs, along with natural resource depletion and regulatory compliance expenses (Das et al. 2023; Mohamad et al. 2022). The utilization of supplementary cementing materials, such as ground granulated blast-furnace slag, silica fume, rice husk ash, and fly ash, as partial substitution of Portland cement in cement-bonded wood boards and concrete, is a sustainable and environmentally friendly practice that offers multiple advantages, including improved performance, reduced environmental impact, energy savings, waste utilization, and potentially cost savings (Snellings *et al.* 2019; Ramzi and Hajiloo, 2023).

There are many variables that affect the properties of cement-bonded wood boards. One of these factors is the ambient temperature during cement hydration. The curing temperature and time are well-known to have a significant effect on the cement's hydration process and the cement-bonded composite's performance (Yel *et al*. 2020; Daneshvar *et al.* 2021; Ma *et al.* 2023). Daneshvar et al. (2021) found that applying a curing temperature exceeding 40°C caused a reduction in the mechanical performance of concrete, including interfacial bond strength. Ma *et al.* (2023) stated that curing temperature under 0 °C inhibited the cement's hydration reaction and destroyed the bonding effect between the cement matrix and the basalt fiber. Ji *et al.* (2023) reported that high-temperature curing enhanced the cement paste system's compressive strength through an impact on the $Ca(OH)_2$-based reaction rate during the initial stage. A study by Lu *et al*. (2022) demonstrated that raising the curing temperature (5°C to 50 °C) considerably improved the properties of cement-bonded composites subjected to CO_2 curing. In another study by Deschner *et al*. (2013), who researched the temperature impact on the Portland cement hydration process mixed with 50 wt.%fly ash, it was found that the cement hydration accelerated as the temperature rose from 7 °C to 80 °C. On the other hand, Humbert *et al.* (2019) reported that the temperature exceeding 60 °C obstructed the carbonation process due to the rapid water evaporation. Wang *et al.* (2011) explored the effect of curing temperatures (0 °C, 20 °C, 40 °C, and 60 °C) on the hydration degree and durability values of activated- coal

gangue and fly ash-cement blends and stated that raising the curing temperature in cement with supplementary cementing materials substantially accelerated the reaction of hydration and improved the durability values. Yel *et al.* (2020) researched the temperature effect on wood-cement composites produced from Portland cement and two different tree species (poplar and spruce) and reported that the optimal temperature was 40 ℃ for the cement-bonded wood panels made of poplar and 60 ℃ for the cement-bonded wood panels made of spruce. A work by Aras *et al.* (2022) on the effect of press temperatures (20 ℃ and 60 ℃) on the technological features of the cement-bonded wood boards produced from Portland cement and CCA-treated scotch pine planer shavings showed that high-press temperature enhanced the boards' mechanical and dimensional stability properties compared to the low press temperature. Another study conducted by Aras and Yel (2023) on the impact of press time and temperature on the performance of cement-bonded particleboards made from poplar veneer wastes and Portland cement demonstrated that physico-mechanical properties enhanced with increasing pressing time.

This study investigated the impact of temperature employed during the first 24 hours of cement curing on the physical and mechanical performances of cement-bonded wood boards produced from spruce planer shavings and Portland cement blended with 10 wt.% of silica fume.

MATERIAL AND METHODS

Materials

Spruce wood (*Picea orientalis* (L.) Link.) planner shavings were provided by the Artvin Coruh University's Furniture Workshop in Artvin, Türkiye. The spruce planner shavings were initially hummer milled into particles and then screened to obtain fine particles. The spruce particles retained on a 0.5-mm sieve and passed through a 3-mm sieve were used for making the cement-bonded wood boards. CEM II 32.5R type Portland cement supplied by Askale Cement Co. (Turkey) was employed as a mineral binder in this study.

Tablo 1. *Composition of silica fume and Portland cement*

Oxide	Portland cement (wt.%)	Silica fume (wt.%)
SiO_2	19.60	91.92
Fe_2O_3	2.13	0.20
Al_2O_3	4.20	0.42
CaO	57.85	2.06
MgO	1.50	3.69
SO_3	2.59	0.37

Silica fume used as a substitute for Portland cement was supplied by Eti Electrometallurgy Inc. in Antalya, Türkiye (Figure 1). The compositions of Portland cement and silica fume are depicted in Table 1. To reduce the inhibitory effect of spruce wood particles on cement hydration, calcium chloride ($CaCl_2$) was added to the mixture at 5% w/w of the cement for all board groups. Calcium chloride replaced an equivalent weight of cement.

Manufacture of Cement-Bonded Wood Board

Production parameters of the cement-bonded wood boards are presented in Table 2. Wood-cement ratio (w/c) of 1:3, water-cement ratio (w/c) of 0.61, specific gravity of 1200 kg/m^3, 10 wt.% replacement ratio of silica fume with Portland cement, and addition of 5 wt.% $CaCl_2$ were constant for all the cement-bonded wood boards. 10 wt.% silica fume and 90 wt.% Portland cement were homogeneously blended by a mechanical mixer prior to the production of boards. After that, silica fume-Portland cement blend, water, wood particles, and calcium chloride solution (accelerator) were mixed until a homogenous mixture was obtained. The mixture was then formed into a compact laminate mold sizing 450 mm × 450 mm x10 mm. Afterwards, all the formed mats were compressed by a hot press at 18-20 kg/cm^2 pressure and at different temperatures (20 ℃, 30 ℃, 40 ℃, 50 ℃, and 60℃) for 24 h. After 24-h compression process, the cement-bonded wood boards were transferred to a climate room at 65% relative humidity and 20 ◦C for 4 weeks. Two replicated test boards were produced for each condition to derive reliable conclusions through statistical analysis of the results. After 28 days of curing, the conditioned boards were cut by a circular saw into test specimens to evaluate their physical and mechanical performance.

Table 2. *The production design of cement-bonded wood boards*

Board ID	Silica Fume (wt.%)	Cement (wt.%)	Applied Temp. (℃) for 24 h	Other parameters
SF20	10	90	20	Wood-cement ratio: 1/3 Water-cement ratio: 0.61 Board size: 450 mmx450 mm x10 mm Press pressure: 18-20 kg/cm^2 Cement curing accelerator: $CaCl_2$, 5% w/w of the cement) The board target density: 1.2 g/cm^3
SF30	10	90	30	
SF40	10	90	40	
SF50	10	90	50	
SF60	10	90	60	

Test Procedure

The moisture content (MC) values of specimens were determined in accordance with the EN 322 standard (1993), and density was evaluated by the EN 323 standard (1993). Thickness swelling (TS) and water absorption (WA) tests were conducted on the specimens with the size of 5 cm*5 cm*1 cm, submerged under distilled water for 24 h, in accordance with the EN 317 standard (1993).

Modulus of elasticity (MOE) and modulus of rupture (MOR) tests were implemented in accordance with the EN 310 (1993) standard. Moreover, screw withdrawal resistance (SWR) and internal bond strength (IB) tests were done following the EN 320 (2011) and the EN 319 (1993) standards, respectively. Zwick Universal Testing Machine was used to conduct all the mechanical tests.

Using the SPSS 21.0 package software, the data from the mechanical and physical tests were subjected to analysis of variance (One-Way ANOVA) to compare the means of board groups. Duncan's test was applied to determine homogeneity groups as the difference between the means of the panel groups was significant ($p< 0,05$).

RESULTS AND DISCUSSION

Physical properties

Figure 1 illustrates the cement-bonded wood boards' density and moisture content means with homogeneity groups and standard deviations. It was observed that the effect of the temperature applied during the first 24-h of cement curing on the moisture content and density of the boards was statistically significant. The moisture content values ranged from 10,77% to 11,77%, while the density values ranged from 1,22% to 1,26% after 24-h immersion. The density values were highest in the boards (SF-60) produced at 60 ℃ and lowest in the boards (SF-30) produced at 30 ℃. Raising the temperature applied during the production slightly increased the density of the boards. Similar results were found by Gallucci et al (2013), who demonstrated that the density of cement paste increased as the curing temperature rose from 5 ℃ to 60 ℃. According to Gallucci et al (2013), this increase in the density was linked to the reduction of bonded water. In another study, Kaleta-Jurowska and Jurowski (2020) reported that concrete' density slightly increased as the curing temperature rose from 12 ℃ to 30 ℃. The moisture content values were highest in the boards (SF-40) produced at 40 ℃ and lowest in the boards (SF-20) produced at 20 ℃. The moisture content of the boards increased as the temperature increased up to 40 ℃, but as the temperature rose above 40 ℃, the moisture content tended to decrease. According to the EN 631-1standard

(1999), the moisture content limit values for cement-bonded particleboards are 9±3%. All the boards' moisture content values (10,77% - 11,78%) satisfied the standard requirements.

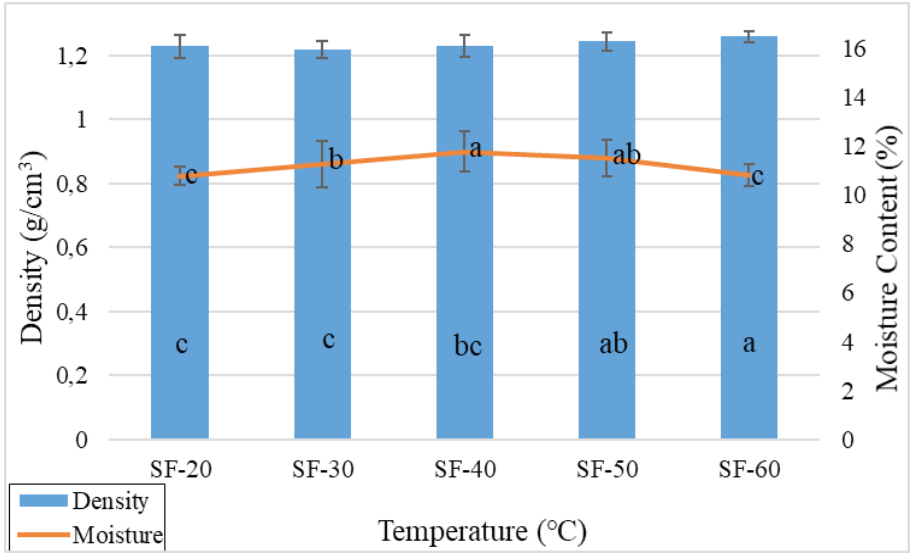


Figure 1. *Density and moisture content of the cement-bonded wood boards (Error bars show the standard deviations, the letters refer to the homogeneity groups)*

Figure 2 presents the experimental boards' water absorption (WA) and thickness swelling (TS) mean values with homogeneity groups and standard deviations after being immersed in water for 24 hours. The effect of the temperature applied during the first 24-h of curing on the WA and TS values of the boards was statistically significant. It was seen that raising the temperature applied during the first 24-h of curing resulted in decreased WA and TS values of the boards. The water absorption values ranged from 13,13% to 14,51%, while the thickness swelling values ranged from 1,05% to 1,711% after 24-h immersion. Both the WA and TS values were highest in the boards (SF-20) produced at 20 °C and lowest in the boards (SF-60) produced at 60 °C. Similar results were found by Aras *et al*. (2022), who concluded that the cement-bonded particleboards produced at 20 °C had higher water absorption and thickness swelling values than the boards produced at 60 °C. The elevated temperature promoted the silica fume's pozzolanic activity and the cement hydration reaction, which resulted in producing more calcium silicate hydrates and more compact microstructures through its reaction with calcium hydroxide supplied by the cement hydration (De Weerdt et al. 2012; Wang et al. 2023). Therefore, the WA and TS properties of the boards significantly improved as the curing temperature increased. In EN 634-2 standard (2009), it

is stated that the maximum thickness swelling values for cement-bonded particleboards must be 1,5%. Thickness swelling values (in the range of 1,05% - 1,38%) of all the board groups, except the boards (SF-20) produced at 20 °C, met the standard requirement mentioned above.

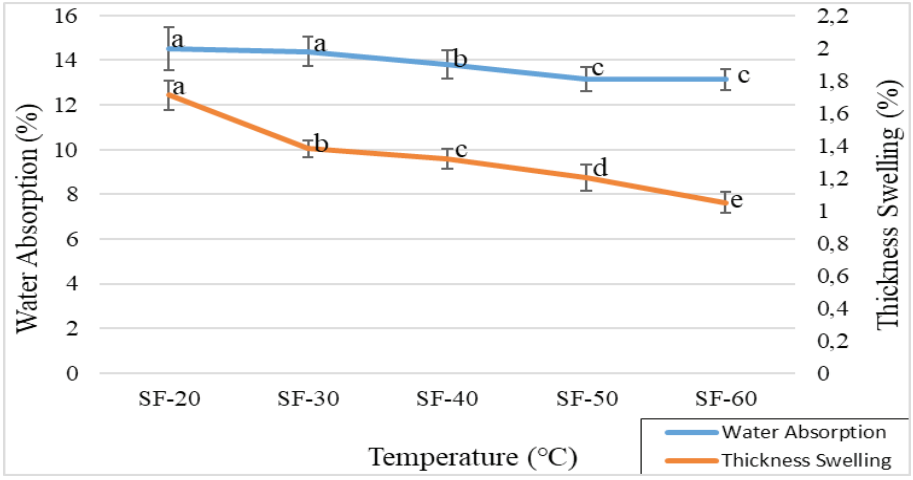


Figure 2. *Water absorption and thickness swelling values of the cement-bonded wood boards (Error bars: the standard deviations, and the letters: the homogeneity groups)*

Mechanical Properties

The boards' modulus of rupture (MOR) and modulus of elasticity (MOE) values with homogeneity groups and standard deviations are depicted in Figure 3 and Figure 4. The effect of temperature applied during the first 24-h of curing on the MOR and MOE values of the cement-bonded wood boards produced from Portland cement blended with 10 wt.% of silica fume was found to be statistically significant. The modulus of rupture values of the boards ranged from 15,49 N/mm^2 to 16,02 N/mm^2, while the MOE values ranged from 8037 N/mm^2 to 9160 N/mm^2. Both MOR and MOE values were highest in the boards (SF-40) produced at 40 °C and lowest in the boards (SF-20) produced at 20 °C.

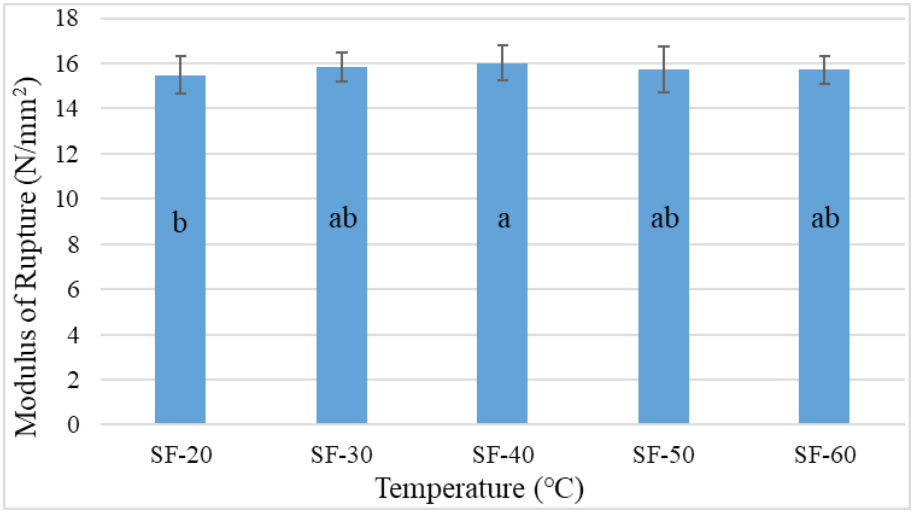


Figure 3. *MOR values of the cement-bonded wood boards (Error bars show the standard deviations, and the letters on the columns refer to the homogeneity groups)*

It was recorded that the MOE and MOR values of the boards increased as the temperature increased up to 40 °C during the first 24 hours of cement curing. The elevation of temperature accelerates both Portland cement hydration and silica fume pozzolanic reactions, resulting in improved mechanical properties (Deschne et al. 2013; Daneshvar et al. 2021). However, the bending properties of the boards tended to decrease as the temperature rose above 40 °C. Some research demonstrated that using a curing temperature exceeding 40 °C can have an adverse effect on the cement-bonded composites' mechanical performance, including elastic modulus, fracture energy, compressive, tensile, and flexural strengths (Wang, P. & Liu, X. 2011; Fan et al. 2017; Wang et al 2020). In addition to the acceleration of the cement hydration reaction, high temperatures exceeding 40°C change the properties of hydration products and lead to a porous structure within the cement matrix (Gallucci et al. 2013; Daneshvar et al. 2021). Similar results were reported by Wang and Liu (2011), who researched the impacts of curing temperature on activated coal gangue/fly ash-cement blends and concluded that cement hydration, pozzolanic reaction, and concrete strength were enhanced by increasing the curing temperature up to 40 °C, but when the curing temperature reached 60 °C, the pore structure deteriorated and the strength values decreased. They also reported that the acceleration effect of temperature was more significant on cementitious supplementary materials than on cement clinker. According to the EN 634-2 standard (2009), the minimum MOR and MOE requirements for cement-bonded particleboards are 9 N/mm^2 and 4500 N/mm^2, respectively. Therefore, the modulus of rupture (15,49 N/mm^2 – 16,02 N/mm^2) and modu-

lus of elasticity (8037 N/mm^2 – 9160 N/mm^2) of all the board groups satisfied the standard requirements mentioned above.

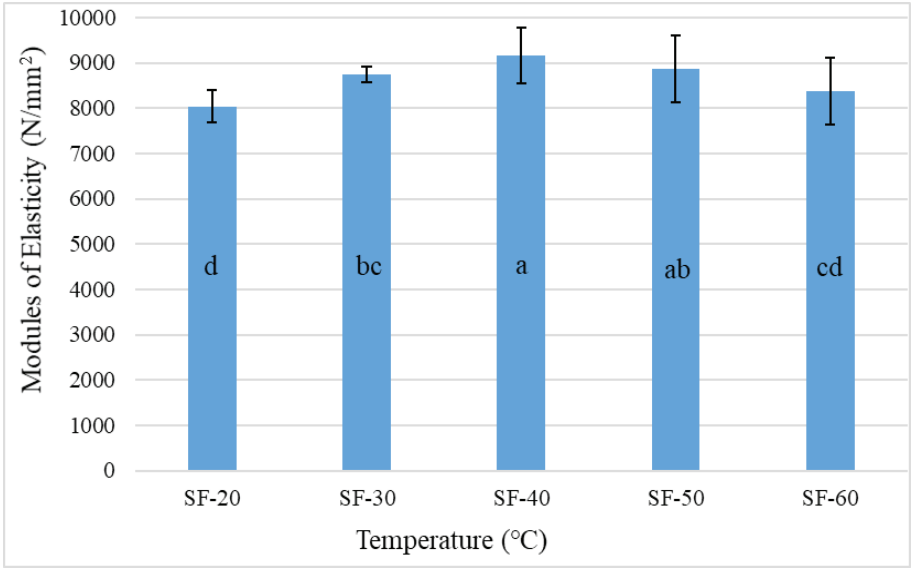


Figure 4. *Modulus of elasticity of the cement-bonded wood boards (Error bars show the standard deviations, and the letters on the columns refer to the homogeneity groups)*

The experimental boards' screw withdrawal resistance (SWR) and internal bond strength (IB) mean values with homogeneity groups and standard deviations are presented in Figure 5 and Figure 6 below. Based on the statistical analysis results, it was concluded that the temperature applied during the first 24 hours of cement curing significantly affected the IB and SWR values of the boards produced from Portland cement substituted by 10 wt.% of silica fume. The SWR values of the boards ranged from 112 N/mm to 138,7 N/mm, while the internal bond strength values ranged from 1,35 N/mm^2 to 1,68 N/mm^2. Moreover, the screw withdrawal resistance values were highest in the boards (SF-50) produced at 50 ℃ and lowest in the boards (SF-20) produced at 20 ℃, while the internal bond strength values are highest in the boards (SF-40) produced at 40 ℃ and lowest in the boards (SF-20) produced at 20 ℃. It was seen that the SWR and IB values of the boards were improved as the temperature rose up to 50 °C and 40 °C during the first 24 hours of cement curing, respectively. On the other hand, the test results indicated that the screw withdrawal resistance and the internal bond strength values were reduced as exceeding these temperatures (50 °C for SWR and 40 °C for IB). It was thought that the elevated curing temperature up to 40 °C and 50 °C significantly enhanced IB strength and SWR values because increasing the curing tempera-

ture stimulated the Portland cement and silica fume's pozzolanic reactions, which resulted in forming more calcium silicate hydrate gels and stronger interfacial bond strength (Daneshvar *et al*. 2021; Lu *et al*. 2022). However, IB strength and SWR values tended to reduce as the curing temperature rose above 50 °C, due to higher porosity and more heterogeneous distribution of hydration products (Wang and Liu 2011; Daneshvar *et al*. 2021). According to the EN 634-2 standard (2009), the minimum internal bond strength value must be 0,5 N/mm^2 for cement-bonded particleboards. All the board groups yielded internal bond strength values over the related standard requirement.

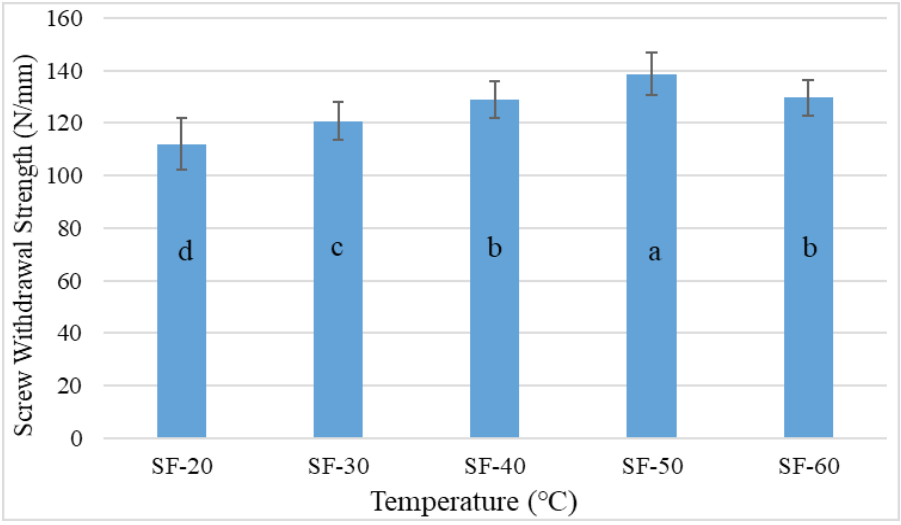


Figure 5. *Screw withdrawal resistance of the cement-bonded wood boards (Error bars show the standard deviations, and the letters on the columns refer to the homogeneity groups)*

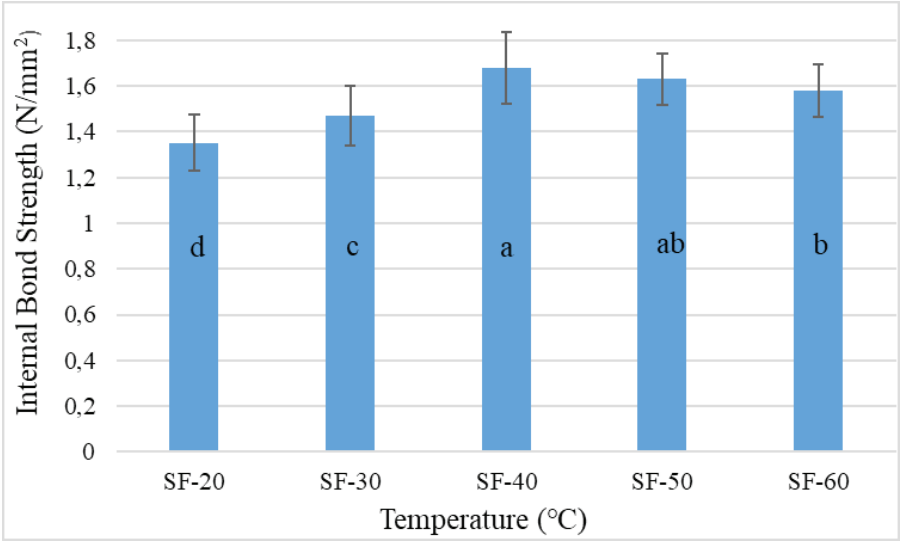


Figure 6. *Internal bond strength of the cement-bonded wood boards (Error bars show the standard deviations, and the letters on the columns refer to the homogeneity groups)*

CONCLUSION

This work investigated the impact of the variation of curing temperatures (20 °C, 30 °C, 40 °C, 50 °C and 60 °C) on some technological properties of cement-bonded wood boards made of Portland cement added with 10 wt.% silica fume. The key conclusions to be drawn from the findings are set out below:

- The temperature applied during the first 24 hours of cement curing significantly affected the properties of cement-bonded wood boards produced from Portland cement substituted with 10 wt.% silica fume.

- Raising the temperature led to a slight increase in the density values of the boards. As the temperature increased up to 40°C, the moisture content of the boards increased and then decreased.

- Both WA and TS values of the boards were remarkably reduced as the curing temperature rose from 20 °C to 60 °C. In addition, thickness swelling values (in the range of 1,05% - 1,38%) of all the board groups, except for the boards (SF-20) produced at 20 °C, satisfied the minimum thickness swelling requirement (<1,5 %) specified in the EN 634-2 standard (2009).

- The MOR, MOE, and IB values were highest in the boards (SF-40) produced at 40 °C while SWR values were highest in the boards (SF-50) pro-

duced at 50 °C. Moreover, the lowest mechanical properties were found in the boards (SF-20) produced at 20 °C.

- MOR, MOE, and IB values of the cement-bonded wood boars produced at all the temperature levels exceeded the minimum standard requirements (9 N/mm^2 for MOR, 4500N/mm^2 for MOE, and 0,5 N/mm^2 for IB) stipulated in the EN 634-2 standard (2009).

- Generally, it was concluded that the temperature applied during the first 24 hours of cement curing significantly improved the properties of cement-bonded wood boards produced from spruce planner shavings and Portland cement substituted with 10wt.% of silica fume, and the optimal temperature is 40 °C for the production of these type boards.

- Further research is needed to determine the impacts of curing temperature on the performance of cement-bonded wood boards manufactured at different wood/cement/water ratios and temperature duration by using other tree species and supplementary cementing materials.

REFERENCES

Aras, U. & Yel, H. 2023. The effect of press parameters on the physical and mechanical properties of cement-bonded particleboards produced from veneer wastes, *Journal of Anatolian Environmental and Animal Sciences* 8(3): 300-305, https://doi.org/10.35229/jaes.1296776

Aras, U., Yel, H., Kalaycıoğlu, H. & Kuştaş, S. 2022. Investigation of some technological properties of cement-bonded particleboards manufactured from planer shavings of CCA-treated scotch pine woods, *Artvin Çoruh University Faculty of Forestry Journal* 23(1): 65-73, http://dx.doi.org/1017474/artvinofd.1068053.

Aras, U., Kalaycıoglu, H., Yel, H. & Kustas, S. 2022. Utilization of olive mill solid waste in the manufacturing of cement-bonded particleboard, *J. Build. Eng.* 49:104055. https://doi.org/10.1016/j.jobe.2022.104055.

Dana Daneshvar, Karl Deix, Agathe Robisson. 2021. Effect of casting and curing temperature on the interfacial bond strength of epoxy bonded concretes, *Constr. Build. Mater.* 307: 124328. https://doi.org/10.1016/j.conbuildmat.2021.124328

Das, A., Kumar, S., Sharma, P.&Sharma, N. 2023. Environmental effects of cement production: A review. In: Shukla, A.K., Sharma, B.P., Arabkoohsar, A., Kumar, P. (eds) Recent Advances in Mechanical Engineering. *FLAME 2022. Lecture Notes in Mechanical Engineering*. Springer, Singapore. https://doi.org/10.1007/978-981-99-1894-2_51.

Deschner, F., Lothenbach, B., Winnefeld, F. & Neubauer, J. 2013. Effect of temperature on the hydration of Portland cement blended with siliceous fly ash, *Cem Concr. Res.* 52, 169–181. http://dx.doi.org/10.1016/j.cemconres.2013.07.006

De Weerdt, K., Haha, M.B., Le Saout, G., Kjellsen, K., Justnes, H. & Lothenbach, B. 2012. The effect of temperature on the hydration of composite cements containing limestone powder and fly ash, *Materials and Structures* 45: 1101-1114. https://doi.org/10.1617/s11527-011-9819-5

EN 322, Wood-based Panels, determination of moisture content, Brussels, 1993.

EN 323, Wood-based Panels, determination of density, Brussels, 1993.

EN 317, Particlepanels and fiberpanels, determination of swelling in thickness after immersion, Brussels, 1993.

EN 310, Wood-based panels, determination of modulus of elasticity in bending and bending strength, Brussels, 1993.

EN 320, Particleboards and fibreboards, Determination of resistance to axial withdrawal of screw, Brussels, 2011.

EN 319, Particlepanels and fiberpanels, Determination of tensile strength perpendicular to the plane of the board, Brussels, 1993.

EN 634-2, Cement-bonded particlepanels - specifications - part 2: requirements for

OPC bonded particlepanels for use in dry, humid, and external conditions, Brussels, 2009.

EN 634-1, Cement-bonded particle panels- specification- part 1, general requirements, Brussels, 1999.

Fan, L. Zhang, Z., Yu, Y., Li, P. & Cosgrove, T. 2017. Effect of elevated curing temperature on ceramsite concrete performance, *Constr. Build. Mater*. 153: 423–429. http://dx.doi.org/10.1016/j.conbuildmat.2017.07.050

Gallucci, E., Zhang, X., Scrivener. K.L.2013. Effect of temperature on the microstructure of calcium silicate hydrate (C-S-H), *Cem. Concr. Res.* 53: 185-195, http://dxdoi.org/10.1016/j.cemconres.2013.06.008

Humbert, P.S., Castro-Gomes, J.P. & Savastano, H. 2019. Clinker-free CO_2 cured steel slag based binder: optimal conditions and potential applications, *Constr. Build. Mater.* 210(20): 413–421, https://doi.org/10.1016/j.conbuildmat.2019.03.169

Ji, X.&Takasu, K. 2023. Hiroki Suyama and Hidehiro Koyamada. The Effects of curing temperature on CH-based fly ash composites, *Materials* 16: 2645. https://doi.org/10.3390/ma16072645

Kaleta-Jurowska A, Jurowski K. 2020. The Influence of ambient temperature on high-performance concrete properties. *Materials* 13(20):4646. http://dx.doi.org/10.3390/ma13204646

Lu, B., Drissi, S., Liu, J., Hu, X., Song, B. & Shi, C. 2022. Effect of temperature on CO_2 curing, compressive strength and microstructure of cement paste, *Cem. Concr. Res*. 157: 106827, https://doi.org/10.1016/j.cemconres.2022.106827

Ma, D., Zhang, W., Wang, X., Zhang, R., Zhou, Z., Yang, Y. & Shi, Y. 2023. Effects of curing temperature on mechanical properties and pore size distribution of cement clay modified by metakaolin and basalt fiber, *J. Build. Eng.* 68:10623. https://doi.org/10.1016/j.jobe.2023.106232

Mohamad, N., Muthusamy, K., Embong, R., Kusbiantoro, A.& Hashim, M.H. 2022. Environmental impact of cement production and Solutions: A review, *Materialstoday: Proceedings* 48(4): 741-746. https://doi.org/10.1016/j.matpr.2021.02.212.

Na, B., Wang, Z. & Wang, H. 2014. Xiaoning LuWood-cement compatibility review, *Wood Research* 9 (5): 813-826.

Ramzi, S. & Hajiloo, H. 2023. The Effects of supplementary cementitious materials (SCMs) on the residual mechanical properties of concrete after exposure to high temperatures—review, *Buildings* 13(1): 103. https://doi.org/10.3390/buildings13010103.

Snellings, R., Li, X., Avet, F. & Scrivener, K. 2019. Rapid, robust, and relevant (R3) reactivity test for supplementary cementitious materials. *ACI Mater. J.* 116:155–162. https://doi.org/10.14359/51716719.

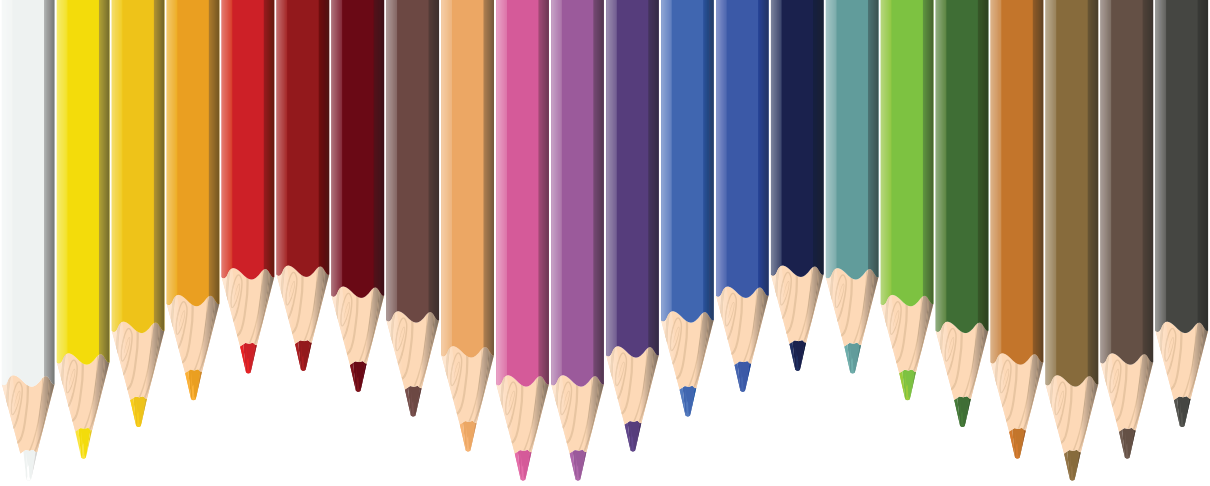
Yel, H., Donmez Cavdar, A. & Boran Torun, S. 2020. Effect of press temperature on some properties of cement bonded particleboard, *Maderas Cienc. Tecnol.*

22(1): 83–92, https://doi.org/10.4067/S0718-221X2020005000108

Wang, P. & Liu, X. 2011. Effect of temperature on the hydration process and strength development in blends of Portland cement and activated coal gangue or fly ash, *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering),* 12(2): 162-170, http://dx.doi.org/10.1631/jzus.A1000385

Wang, X., Saifulah, H.A., Nishikawa, H. & Nakarai, K. 2020. Effect of water–cement ratio, aggregate type, and curing temperature on the fracture energy of concrete, *Constr. Build. Mater.* 259: 119646. http://dxdoi.org/10.1016/j.conbuildmat.2020.119646

Wang, Y., Xiao, R., Lu, H., Hu, W., Jiang, X. & Huang, B. 2023. Effect of curing conditions on the strength and durability of air-entrained concrete with and without fly ash, *Cleaner Materials*, 7:100170. https://doi.org/10.1016/j.clema.2023.100170.



Chapter 15

THE GENERAL CHARACTERISTICS OF BENTHIC MACROFAUNA IN RIVER ECOSYSTEMS[1]

Eylem AYDEMİR ÇİL[2]

1 Note: This study is derived from a section of the doctoral thesis titled 'Taxonomic and Ecological Assessment of Macro Benthic Fauna of Karasu Stream (Sinop)' by the author Eylem AYDEMİR ÇİL (YÖK thesis no: 380573; Department of Hydrobiology, Faculty of Fisheries, Sinop University -2014).

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We have not fully explored the biological richness in the world and in our country. Although numerous studies have been conducted on this subject, they are still not sufficient. Nevertheless, these riches are under threat of extinction due to the boundless desires of humanity. Both globally and in our country, intensive agricultural activities and industrialization rapidly deplete natural resources, limiting the living conditions of various taxa. Many living taxa are harmed, and their populations are endangered due to the increasing negative impacts every day. The harm or disappearance of any taxon in an ecosystem also affects other organisms in the life cycle. Therefore, every study aimed at revealing biological richness becomes much more crucial from this perspective (Kalafat, 2008).

Approximately 1.8 million years ago, when the glacial periods began, fauna elements from Central and Northern Europe and Western Siberia started migrating southward (to Anatolia). Fauna elements from Siberia passed through the Caucasus to reach the Iran-Caspian refuge, while those from Central and Northern Europe, including the Balkans, reached the Macedonia-Thrace refuge. Subsequently, over time, or directly from these two refuges, they began to spread towards Anatolia. Balkan fauna elements spread to Anatolia through two routes. The first one is the Aegean route followed by freshwater forms from Southern Europe. The current Aegean Sea was a landmass at that time, and a large freshwater river named Egeopotamus flowed through it, reaching the Mediterranean. Many primary freshwater forms of European origin spread to Anatolia through the branches of this river originating from Europe. The presence of an internal lake consisting of many lakes scattered across the region of present-day Central Anatolia, occasionally allowing the passage of freshwater elements, is one of the most important factors facilitating this spread. Freshwater elements arriving in Anatolia through the Tuna Route via the Bosphorus and the Marmara route, reaching the internal lake, spread to all of Anatolia through rivers and streams (Kazancı, 1991; Demirsoy, 2002).

Aquatic systems are divided into lotic and lentic ecosystems. Life in both water systems depends on the presence of various taxa. The discharge of waste that can harm the lives of organisms and restrict their habitats into receiving environments such as the sea, rivers, lakes, bays, and gulfs changes and disrupts the physicochemical structure of these systems, causing significant changes in the substrate structure as well. As a result of all these adverse effects, water environments under intense pollution become limited areas for living organisms and also restrict the self-cleaning abilities of these systems. Any pollution in the aquatic environment negatively affects many taxa and leads to the loss of our still not fully known inland biological diversity, especially (Kocataş, 1996; Arslan, 1998; Ulukütük, 2009).

Invertebrates that inhabit the benthic region are important links in the food chain of aquatic ecosystems. Research has shown that these organisms

are consumed by fish and some crustaceans, containing essential nutrients, especially protein. In addition, some researchers have used these organisms as bioindicator organisms based on their different characteristics (Şahin, 1991).

Figure 1. *Some of the organisms in the river ecosystem (Aydemir, 2014)*

Most of the terrestrial ecosystem debris mixes in the river ecosystem. Pollutants such as excessive nitrite, nitrate, and phosphate that enter the river ecosystem in large quantities break down organic matter along with inorganic nutrient salts. Organic enrichment in rivers can lead to oxygen deficiency and diseases in organisms. This condition is called organic pollution. Inorganic enrichment disrupts the balance of oxygen by causing an increase in primary production. It leads to excessive development of plants and algae, considered as pollution, and its impact on macroinvertebrates is similar to the effect of organic pollution (Hawkes, 1979; Kırkağaç and Köksal, 2014).

At the taxonomic level, Plecoptera is the group with the lowest tolerance to organic pollution, while Oligochaeta members have the highest tolerance. Tolerance levels in other orders vary at the taxonomic level. Many leeches are tolerant to organic pollution and can survive in oxygen-deprived environments for extended periods. However, the most critical factor affecting their distribution in polluted waters is the presence of hosts or prey in the environment. For example, Piscicola geometra is a fish parasite and cannot be found in fishless environments. Glossiphonia complanata feeds on aquatic snails, while *Helopdella stagnalis, Asellus aquaticus*, and *Erpobdella octoculata* feed on Oligochaeta and Chironomid larvae.

From the Crustacea class, *Gammarus pulex pulex* and *Asellus aquaticus* can only live in shallow and fast-flowing areas of rivers exposed to or-

ganic pollution, while Asellus aquaticus is tolerant to low oxygen conditions. Ephemeroptera (except Ephemerellidae and Caenidae) and Trichoptera are groups that cannot tolerate organic pollution. Members of the Odonata order are found in slow-flowing areas and are tolerant to organic pollution. The tolerance of Hemiptera, Coleoptera, and Diptera orders to organic pollution varies at the taxonomic level. Among mollusks, Lymnaea and Physa are the most tolerant genera to low oxygen conditions (Hawkes, 1979; Kırkağaç and Köksal, 2014).

Macroinvertebrates, plankton, algae, macrophytes, and fish are determined as important indicators in assessing water quality in the Water Framework Directive accepted by European Union member countries (WFD, 2000). Among these groups, macroinvertebrates attract the most attention. These organisms are often preferred in water quality studies due to their longer life cycle compared to macrophytes and algae, their quicker response to environmental changes compared to fish, ease and cost-effectiveness of collection, and sufficient diagnosis at the genus and family level (Bonada et al., 2006; Zeybek and Kalyoncu, 2012).

With pollution in rivers, community diversity decreases, and as pollution increases, more sensitive taxa replace tolerant ones. The data obtained from studies are used to calculate various measurements for comparing sampled stations or determining the responses of macroinvertebrates to pollution. The most commonly used of these measurements are biotic or diversity indices (Zischke et al., 1992; Kırkağaç and Köksal, 2014).

Natural water sources are more important as they are used for drinking and irrigation water. Hosting many organisms that are important in the food chain and sensitive to environmental changes also increases their importance. Rivers, as one of the natural water sources, are rich in oxygen due to their shallow depths and continuous flow. Rivers are sensitive to organic matter pollution. Bacterial activity during decomposition leads to a decrease in oxygen in the water. Pollution of rivers in this way or chemically is one of the most significant problems of industrial areas with a high population. Organic materials from pollutant sources accumulate over time at the bottom of the water, forming pollution in sediments. This negatively affects organisms living at the bottom.

In determining the pollution of rivers, biological assessments should be considered along with chemical parameters. Macroinvertebrate communities can be used as indicators in biological assessments since they are sensitive to ecosystem changes and pollution. Macroinvertebrates living in polluted water are stressed in clean water, and those living in clean water are stressed in polluted water and cannot become dominant taxa. This situation facilitates interpretations about pollution. Macroinvertebrates provide information about the

extent of pollution because they cannot easily escape from pollution (APHA, 1998; Demir, 2005). In river ecosystems, the general characteristics of some taxa of macroinvertebrate fauna, which spend their entire life or a part of it, are given below;

1. Planariidae: General Characteristics

Planaria species belong to the phylum Platyhelminthes and generally represent a class comprising small and free-living members.

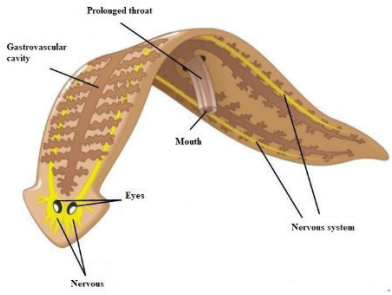


Figure 2. *General appearance of Planaria (Aydemir, 2014).*

Flatworms are worm-like organisms with unsegmented bodies, mostly flat, and often leaf-shaped. Their bodies are covered with epidermis and a muscle sheath beneath it (Demirsoy, 1998). They move using cilia. The majority of them are carnivorous. While many taxa are found in oceans and freshwater environments, some taxa can also inhabit moist areas. Planaria, being hermaphroditic, can reproduce sexually and, at the same time, asexually through regeneration. Planaria also have a central nervous system. They lack circulatory fluid in their bodies, and the movement of substances in the body cavity is facilitated by the motion of muscles.

2. General Characteristics of Nematoda

Roundworms, also known as nematodes, constitute the most abundant phylum of invertebrates globally, featuring a cylindrical body shape. Many taxa within this phylum cause significant damage to both animals and plants.

Anatomically and morphologically, roundworms are relatively simple organisms. Their sizes range from 0.25 to 3 mm, with diameters varying between 1 and 20 µ. They lack some of the complex systems found in higher animals, such as respiratory, circulatory, and skeletal systems. Their nervous and excretory systems are composed of simple cell structures. The most developed systems among them are the digestive and reproductive systems. Their bodies

are elongated, cylindrical, and exhibit bilateral symmetry. False coeloms are present in their anatomy.

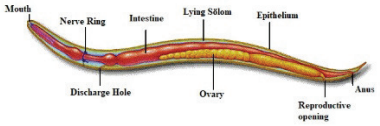


Figure 3.*The general appearance of Nematoda (Aydemir, 2014).*

Reproduction is exclusively asexual, yet in numerous taxa, population growth occurs when environmental conditions are favorable, and reproduction takes place through parthenogenesis, with females laying eggs shortly after the inclusion of a female individual. Males are present in the population at very low frequencies (Anonymous, 2014c)

3. General Characteristics of Oligochaeta

Oligochaeta exhibits both terrestrial and aquatic forms, with some forms, especially members of Enchytraeidae and Lumbricidae, being found in both soil and aquatic systems. The faunal distributions and densities of aquatic Oligochaeta taxa are utilized as indicators of water quality. The bodies of Oligochaeta are typically homonomous segmented, possessing a pre-oral prostomium, bilateral symmetry, a spacious coelom, and hermaphroditic worms. They have thin-skinned, transparent, and small bodies. Their sizes generally range from 0.5 mm (some Chatogaster taxa) to 400 mm (Haplotaxis gordioides), with certain soil forms capable of reaching much larger sizes. The bodies consist of numerous segments separated by dissepiments. The number of segments in the body varies according to subfamilies and taxa.

Segments are separated by ring-like grooves, which are more pronounced and visible externally in some taxa (Sperber, 1948; Brinkhurst and Jamieson, 1971; Rüzgâr, 2010).

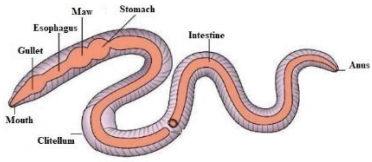


Figure 4. *General appearance of Oligochaeta (Aydemir, 2014).*

In Oligochaeta taxa, both mating and reciprocal fertilization are observed. Most of them inhabit moist soils or freshwater environments, with some found in marine ecosystems. Those residing in freshwater are predominantly found in shallow waters, residing in mud and among algae on the floors of lakes and streams. The distribution of taxa is influenced by factors such as food size, biotic factors, and the characteristics of water and sediment (Yıldız, 2003).

4. General Characteristics of Gastropoda

Snails are mollusks belonging to the Gastropoda class, with spiral dorsal shells, herbivorous and carnivorous habits, and a broad foot consisting of strong muscles, enabling them to move or swim. They are found in our seas, on land, and in freshwater habitats. In terrestrial species, the mantle has evolved into a lung, while in aquatic species, it has transformed into gills. Snails are asymmetrical and mostly have a single-shelled structure that coils around a non-symmetrical center or forms a column. Their shells contain varying numbers of coils, with the top of the shell being flat and narrow, and the final coil being broad, circular, oval, or open at the edges.

The head of snails is distinct, with two eyes on their tentacles. The flat and well-developed foot on the ventral side facilitates crawling movement, and internal organs are located within a twisted shell on the dorsal side. The respiratory organs and anus are situated in the cavity formed by the change in the mantle on the dorsal side. In aquatic species, there is water circulation in this cavity. The mantle cavity is positioned on the anterior side of the dorsal region. The shell is attached to the body from the beginning of the last coil emerging from the back of the foot to the columella and is secured with the help of the columellar muscle. Through this muscle, the body can be retracted into the shell. Many gastropods can completely retract their head and foot into the shell. To seal the opening, they use an operculum, a horn-like structure made of chitinous and calcareous material, which grows concentrically or spirally.

Most gastropods are hermaphroditic, while some are dioecious. The reproductive organs of hermaphrodites exhibit a more complex structure. (Hyman, 1967; Demirsoy, 1998; Rüzgâr, 2010).

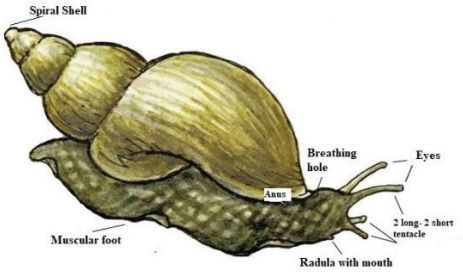


Figure 5. *The general appearance of Gastropoda (Aydemir, 2014).*

Snails are animals that can be found in freshwater, oceans, and various environments. They inhabit moist areas and are consistently visible in the fall months when there is abundant rainfall and the air has not cooled completely. They produce a shiny, mucous-like fluid that allows them to leave a trail wherever they go. The dried mucous between their shells and bodies prevents them from losing moisture.

During winter, they reduce their activity by burrowing underground or into tree hollows. Similarly, in extremely hot summer conditions, they exhibit similar behavior. While primarily herbivorous, they can also be carnivorous or omnivorous. Snails are most active when it rains. Numerous animals feed on snails, including birds, small mammals, lizards, frogs, centipedes, insects, and certain larger snail taxa (Anonymous, 2014ee).

5. General Characteristics of Bivalvia.

They belong to the phylum Mollusca and constitute a class within it. They feed on waterborne particles by filtering water. Their body is enclosed within two shells that are hinged together. They are commonly known as bivalves, characterized by their symmetrical, two-shelled structure. The entire class comprises approximately 30,000 taxa, inhabiting either freshwater or marine environments.

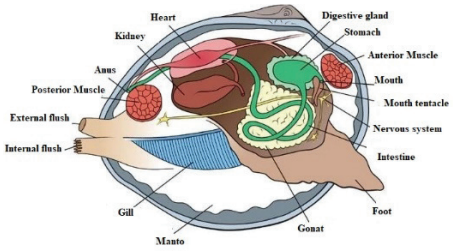


Figure 6. *The general appearance of Bivalvia (Aydemir, 2014).*

The movement of the shells is akin to a lock against each other. The projections (teeth) on one shell and the sockets (grooves) on the other shell are arranged to interlock. The structure of this hinge is used as a taxonomic feature (Demirsoy, 2003). The shell embryonically forms as a uniform plate and later transforms into a two-part structure. Calcification begins from a pair of points on the hinge (junction point) and progresses towards the edge of the shell. The tips of the shell grow by the accumulation of new material. The addition of these rings at the outer part results in the formation of growth rings often used for age determination (Demirsoy, 2003).

The reproductive glands come in pairs. These typically branch, filling the spaces between intestinal folds and occasionally extending into the interior of the foot and mantle lobes. Therefore, a mussel can produce up to 1,000,000 eggs.

Many bivalves live attached, either partially or entirely, exhibiting a sedentary (sessile) lifestyle, while some are capable of swimming. There are taxa that bury themselves in the substrate, and the depths of burial vary. Most are found in marine environments, with a small portion occurring in freshwater; however, they do not have terrestrial forms. Some taxa are consumed by humans. As members of the lower levels of the food pyramid, they are economically important not only as a food source but also for forming pearls and serving as intermediate hosts in the life cycles of some parasites in parasitological contexts (Demirsoy, 2003).

6. General Characteristics of Pseudoscorpionida

Their external appearance closely resembles true scorpions. Their sizes range from 0.8 to 8 mm, and their bodies are flattened. The cephalothorax, in some cases, may be divided into three regions by two transverse lines. In scorpions, the opisthosoma is divided into mesosoma and metasoma. Pseudoscorpions lack the metasoma (tail) region. The first abdominal segment lost in scorpions is distinct in these taxa. Similar to scorpions, the abdomen is attached to the cephalothorax in its full width (Demirsoy, 1998).

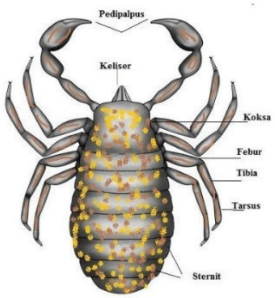


Figure 7. *Pseudoscorpionida'nın genel görünüşü (Aydemir, 2014).*

They have undergone significant modifications compared to scorpions. Their chelicerae emerge just below the anterior edge of the cephalothorax. The pincers consist of only two parts. Their pedipalps resemble those of scorpions; however, venom glands open to the outside from the tips of the pincers. They move slowly and keep their pedipalps in the air while in motion. After capturing their prey, they immobilize it with the venom from the pedipalp. The liquefied contents of the immobilized animal are then absorbed by inserting the head into the prey. Sexual dimorphism is minimal.

While they are found worldwide, their primary habitats are tropical and subtropical regions. They can live under the bark of trees, among leaf litter, in the soil, under rocks in arid areas, and even in the nests of some mammals (Demirsoy, 1998)

7. General Characteristics of Ostracoda

Ostracods, belonging to the extensive and significant class Crustacea, are bivalve organisms. Despite their microscopic size (0.2-2 mm, rarely 32 mm), they may not be conspicuous taxa, but with accurate sampling, a diverse range of taxa can be found in aquatic environments. To date, approximately 25,000 ostracod taxa have been identified, including fossil records. There are approximately 12,500 extant taxa, with 3,000 in freshwater and 9,500 in marine environments (Cohen et al., 2007; Paçal 2010).

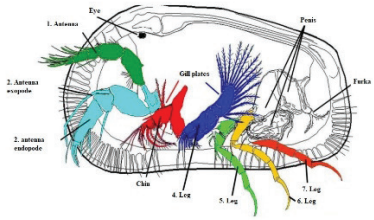


Figure 8. *General appearance of Ostracoda (Aydemir, 2014).*

Although some Ostracoda taxa inhabit terrestrial environments, they are found in various aquatic habitats, including oceans, seas, lakes, ponds, rivers, and marshes, from coastal regions to depths of 7000 m (in littoral, bathyal, abyssal, and hadal zones) (Pinto et al., 2005; Cohen et al., 2007; Pinto et al., 2008; Paçal, 2010). The majority are benthic, residing on various substrates such as rocky, gravelly, sandy, muddy, and algal-covered surfaces. They can live by swimming on the surface of the sea floor or by digging cavities beneath the surface sediment. Some ostracod taxa typically swim short distances above the seafloor at night for feeding and mating (Paçal, 2010).

The primary food source for these taxa consists of epiphytic algae growing on submerged macrophytes in the water (Altınsaçlı and Altınsaçlı, 2005; Paçal, 2010)

8. General Characteristics of Isopoda

Woodlice (Isopoda) are small to medium-sized organisms with lengths ranging from 1mm to 27 cm. Their general color is gray or brown. Their bodies are compressed dorso-ventrally and more or less oval-shaped. The chitinous cuticle covering the skin, especially in those living on land, has become a very hard structure. The abdomen is short compared to the thorax, and there is never a carapace. Compound eyes are located on the sides and are sessile. Woodlice are dioecious, and males and females are distinguished from each other in some species by significant external structural differences.

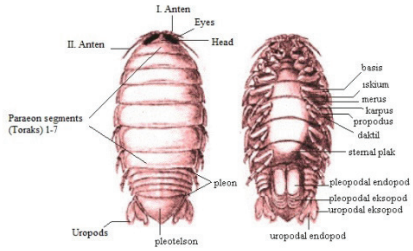


Figure 9. *General appearance of Isopoda (Aydemir, 2014).*

Most woodlice live in the seas, with a significant portion inhabiting terrestrial environments and a small number residing in freshwater; a few taxa are parasitic. Their movement can involve walking, crawling, or swimming, with only a few capable of continuous swimming. They can be carnivorous, herbivorous, or omnivorous in terms of nutrition, with some parasitic species feeding on blood. Typically, their lifespan is around 1-2 years (Demirsoy, 1998).

9. General Characteristics of Amphipoda

Woodlice have flattened bodies laterally. The number of body segments is always 14 in taxa. Eight of these segments are in the thorax, and six are in the abdomen region. All segments bear appendages. They possess a total of 7 walking legs (periopods), with the first 4 pairs directed forward and the last 3 pairs directed backward. The abdomen is divided into two parts: metasome and urosome, each consisting of three segments. The last part of the abdomen, which does not contain appendages and ganglia, is not considered a segment. This part is called the telson. The telson may remain simple or be partially or completely divided into two by a slit running through the middle. There is no carapace. Compound eyes are sessile and located on both sides of the head. The general shape and sizes of the compound eyes may vary among taxa. Some members, such as *Niphargus* sp., lack eyes (Gledhill et al., 1993; İpek, 2009; Özbek, 2011)

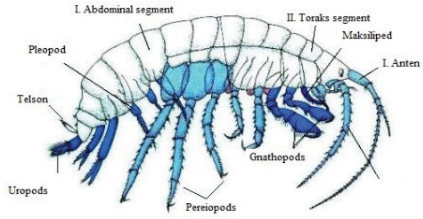


Figure 10. *General appearance of Amphipoda (Aydemir, 2014).*

Fertilized egg development takes place within the brood pouch. Their development is direct, and the newly hatched larvae resemble the adult in terms of major features and the number of appendages. However, the number of antenna segments and the shapes of the appendages differ from adults (Demirsoy, 1999; İpek, 2009; Özbek, 2011).

In aquatic habitats, gammarids are generally benthic inhabitants, although many can also move by swimming. The propulsive force for swimming is provided by the movement of pleopods and uropods. Movement on the substrate can also occur through the walking motion of the thoracic appendages and partially the pleopods. During this fast walking on the bottom, the animal typically moves sideways on one side of its body, a movement pattern specific to the family. Taxa living in fast-flowing waters are found under small stones and in the sand on the bottom (Gledhill et al., 1993; İpek, 2009).

Most amphipods feed on fragmented animal and plant matter (detritus). Only a small portion are predators. Residual material found in the mud at the bottom is collected using gnathopods with the help of the second antennae. Sometimes, they directly ingest food with their mouthparts. Some digging forms scrape detritus and diatoms from sand grains. In gammarids, daily detritus consumption can exceed 100% of body weight in juveniles and be up to 60% of body weight in adults. Predatory feeding is not common. While many eat small animals along with detritus, they are not considered predators.

Their bodies are slender, and the first antennae generally have a lateral flagellum. The second antennae are approximately the same length as the first. The basipod of the first four pairs of thoracic appendages is very wide. The last pair of abdominal extremities is either the same length as the others or longer. Their movement is generally in the form of swimming, occasionally using the setae filter on the gnathopods at the bottom. Some species also filter-feed by passing water through their first and second antennae. In rivers and streams with abundant aquatic plants and less current, Gammarus taxa are

more densely found in the lower parts of plants. Detritus-consuming stream Gammarus taxa play an important role in the feeding of large aquatic invertebrates and fish.

10. General Characteristics of Brachyura

Crabs have five pairs of legs. The first pair is modified into a pair of claws and is not used for movement. In most crabs, except for a few, they are concealed beneath the cephalothorax, below the abdomen (Aydemir, 2014).

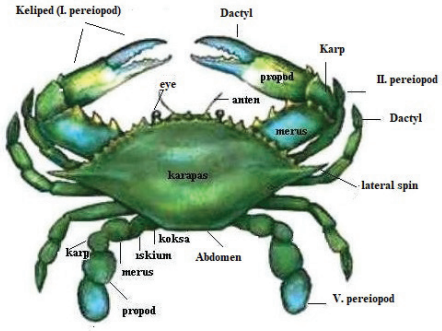


Figure 11. *General appearance of Brachyura (Aydemir, 2014).*

Crabs walk sideways because their legs can only bend in that direction. Muscles work in pairs, with one muscle pulling the leg and depending on another antagonistic muscle to extend it again. Additionally, this walking style is related to the density of water. Most crab taxa exhibit clear sexual dimorphism, and gender can be easily distinguished. The abdomen, located under the thorax, is narrower in males. Females, on the other hand, have numerous pleopods on their abdomen and are visibly wider. This is associated with the female crab carrying the fertilized eggs. In most arthropods, gonopores are located on the legs. Approximately 850 crab taxa (Sternberg and Cumberlidge, 2001) are found in freshwater or semi-terrestrial habitats, primarily in tropical and subtropical regions worldwide.

11. General Characteristics of Collembola

The taxa, which translates to “tube-bellied” in Greek, refer to organisms belonging to the Nematoda order, with lengths ranging from 0.25 to 9 mm (Tetradontophora). Typically measuring 1-2 mm, these animals can be observed in potted soils and even on the surfaces of certain water accumulations. They are widely distributed, reaching polar regions, and thrive particularly in

moist soils. Their significance lies in soil biology, where they play a crucial role in decomposition, serving as indicators and contributing to humus formation. Due to their ability to shape the soil into a form beneficial for plant growth, they hold considerable economic importance.

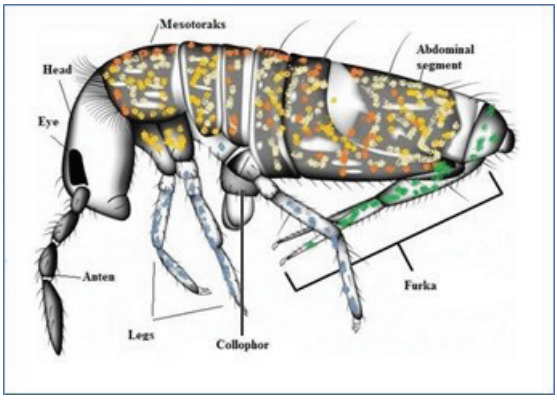


Figure 12. *General appearance of Collembola (Aydemir, 2014).*

Their abdomens consist of 6 segments, lacking terminal extensions and cerci. The first, third,

and fourth abdominal segments undergo special modifications to form legs with specific functions on the ventral side. A tubular extension called "ventral tube" serves for water intake, respiration, and attachment. The third segment features a grasping organ known as "retinaculum," while the fourth segment's posterior edge exhibits a structure called "furca" (Demirsoy, 2003). The cuticle is thin, regularly hairy, or, as seen in many genera, scaly. Their antennae, typically four-segmented (rarely six-segmented secondarily) and almost always equipped with sensory hairs and receptors, are well-developed and muscular. The "posternal organ," likely a moisture sensor, is unique to this group, often sensitive to light but lacking eyes; some species may have simple eyes or compound eyes composed of dot eyes and 8 ocelli. The tracheal system is simple, with two stigmata opening outward between the head and thorax. Many species respire through their skin, utilizing air trapped among the hairs, especially in moist soils. They undergo approximately 50 moltings in their lifetime, during which they can regenerate lost body parts. Their lifespan is around one year (Demirsoy, 2003).

12. General Characteristics of Ephemeroptera

Nymphs belonging to the order Ephemeroptera can be easily distinguished from all other aquatic insects by the presence of tracheal gills on their abdomens, single tarsal claws, a well-developed mesothorax with five, and at

the end of the abdomen, three setae, two cerci, and one paracercus (Edmunds, 1959; Harker, 1989; Williams, 1980; Aydınlı, 2008).

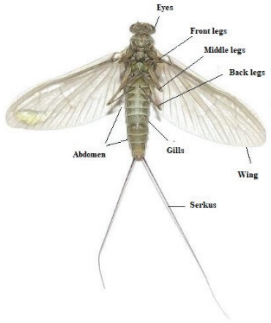


Figure 13. *General appearance of Ephemeroptera (Aydemir, 2014).*

The name Ephemeroptera is derived from the fact that adult individuals of this order have a very short lifespan, ranging from a few hours to a few days, leading to the term "mayflies" or "one-day insects." In Turkish, they are known as Mayıssinekleri, Birgünlükler, or Birgünsinekleri (Elliott and Humpesch, 1983; Lodos, 1983; Tanatmış, 2002; Aydınlı, 2008).

Ephemeroptera is considered one of the oldest known insect taxa, and its significance in zoogeographic studies stems from factors such as their extremely short adult lifespan, weak flying capabilities during this period, and the limitation of their distribution due to factors such as nymphs being entirely aquatic (Brittain, 1982; Kazancı, 2001b; Aydınlı, 2008).

Nymphs of Ephemeroptera constitute 10-25% of all macrozoobenthos in clean natural waters. Given that the majority of Ephemeroptera nymphs are herbivorous, feeding on detritus and algae, and their ability to inhabit various aquatic environments such as rivers or stagnant waters worldwide throughout the year, they play a crucial role in the secondary production of aquatic food chains (Zelinka, 1984; Brittain and Sartori, 2003; Aydınlı, 2008). Additionally, various organisms, including Gastropoda, Trichoptera larvae, and many other small animals, consume Ephemeroptera eggs, while freshwater fish, frogs, numerous birds, Odonata, Plecoptera, Trichoptera larvae, and Coleoptera and Hemiptera among many aquatic insects feed on both the larvae and adults of Ephemeroptera (Harker, 1989; Aydınlı, 2008).

13. General Characteristics of Odonata

Dragonflies (Odonata) constitute an order within the class Insecta, and the common name for the taxa classified in this order (Anonymous, 2014).

While there are approximately 5700 known taxa of the Odonata order worldwide, Europe is reported to have 120 known taxa, and in Turkey, a total of 115 taxa belonging to 39 genera have been documented (Kalkman et al., 2003; Dijkstra and Lewington, 2006; Akkuş, 2012)

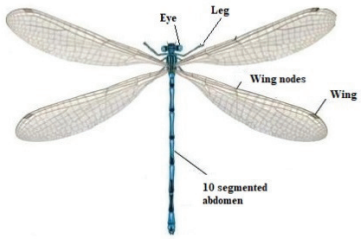


Figure 14. *General appearance of Odonata (Aydemir, 2014).*

Adult individuals of the order Odonata are found in rivers, streams, brooks, natural lakes, ponds, reservoirs, irrigation channels, marshes, and small water pools. They deposit their eggs in the water, and the development of their nymphs is completed within the aquatic environment (Corbet, 1999; Akkuş, 2012). Taxa belonging to this order live as predators in both nymph and adult stages, attacking even individuals of their own kind. Nymphs inhabit aquatic environments and feed on nymphs of other insect taxa, fish eggs, as well as worms like annelids and nematodes. Adults are proficient fliers and primarily feed on flying insects from almost every group. Due to their predation on harmful insects, taxa belonging to the Odonata order are beneficial for agriculture (Demirsoy, 1995; Akkuş, 2012).

14. General Characteristics of Plecoptera

They are typically found on rocky, sandy, or gravelly freshwater shores. Although they have well-developed wings, they generally prefer to inhabit rocks, plants, and trees. They exhibit the typical delicate, slender, and elongated body structure characteristic of insects (Demirsoy, 2008).

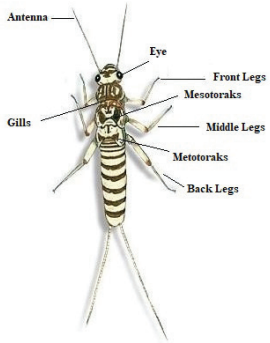


Figure 15. *General appearance of Plecoptera (Aydemir, 2014).*

They are typically found on the edges of freshwaters, on rocks, plants, and trees. They have a pair of compound eyes on both sides of their head and 2-3 simple eyes in the frontal region. Just in front of their eyes, a pair of slender antennae emerge. They possess two pairs of transparent wings with reduced venation. The cerci at the end of the abdomen are thread-like and multi-segmented in primitive taxa. During the mating season, males produce a drumming sound by rapidly striking the tip of their abdomen against objects. The larvae are released into the water and resemble adults but lack developed mouthparts and wings. Approximately 90% of their lifespan is spent in the egg or larval stages, and a pupal stage is not observed. Due to their consumption of mosquito larvae and their use as fish food, they hold economic significance. Moreover, they are considered indicators of water pollution levels (Aydemir, 2014).

15. General Characteristics of Hemiptera

The Hemiptera, or true bugs, are recognized by certain taxa within the group emitting foul odors, making these insects easily identifiable by humans.

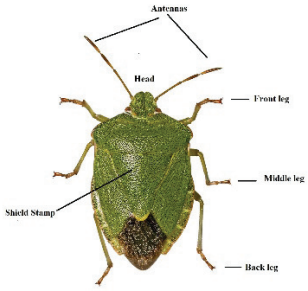


Figure 16. *General appearance of Hemiptera (Aydemir, 2014).*

They always have four wings, and they have adapted to various body structures, spreading across all habitats. Typically, they possess a proboscis that emerges from the lower front part of their head, which, during rest, is folded backward underneath the body, often into a longitudinal groove. The size of their bodies and shapes is quite diverse, with their generally flattened, oval bodies ranging in length from 1 mm to 10 cm. Some may have a stick-like shape (Ranatra), while others are short and hemispherical (Plataspidae). They are rarely vividly colored (Sphaerocoris), with predominant colors being black, brown, grayish, and greenish (Aydemir, 2014)

16. General Characteristics of Trichoptera

Trichoptera taxa are nearly ubiquitous, having spread to almost every habitat, with around 9,000-10,000 known taxa. The continuous discovery of new taxa in scientific research indicates a broader Trichoptera fauna worldwide (Wiggins, 1998; Rüzgâr, 2010). The Trichoptera order is a close relative of Lepidoptera, and like Lepidoptera, Trichoptera can weave silk to construct webs. This adaptation has contributed to their success in adapting to nature. Silk is used in constructing silk cases, gathering food by building webs, creating shelters, anchoring to substrates, and spinning cocoons during the pupal stage. Most Trichoptera larvae live inside a case. Trichoptera taxa are important for aquatic ecosystems as they constitute a significant food source for fish and contribute to organic matter (Bouchard, 2004).

The two well-known subfamilies, Annulipalpia and Integripalpia, are distinctly differentiated based on their use of silk. They use adhesive to construct various types of portable cases or to bind together sand, small gravel, leaf fragments, and thin twigs. Each genus or even taxa constructs its case in a unique style. The larva has a distinct head, thorax, and abdomen. The larval head capsule is well-developed and chitinized (Holzenthal et al., 2007;

Rüzgâr, 2010).

The majority of adult individuals are winged, with free-moving, often densely hairy bodies, small heads in proportion to body length, and antennae of regular length. Their compound eyes are quite large and bulging. Mouth-parts serve only to lap up plant sap (Demirsoy, 1998).

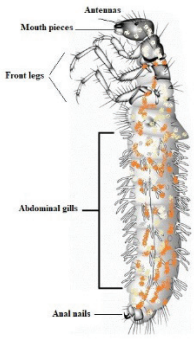


Figure 17. *General appearance of Trichoptera (Aydemir, 2014).*

Larvae with cases, residing in calm and warm waters, are generally large; however, those inhabiting cold and swiftly flowing waters carry very small tracheal gills (Demirsoy, 1998).

17. General Characteristics of Coleoptera

Coleoptera are an insect order within the class Insecta, characterized by their size ranging from 1 mm to 15 cm. This order is the most populous among insects, with approximately 350,000 known taxa. They exhibit diverse colors and forms, but a common characteristic is the transformation of their front wings into tough and thick elytra.

Their dorsal body is highly convex, while the ventral side is flat. The head is small and elongated forward. The eyes are not divided into dorsal and ventral portions. The labrum is transverse and quite short. Antennae are 11-segmented and filiform, with occasional segment expansions.

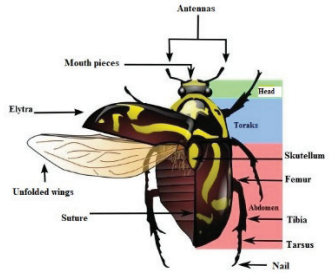


Figure 18. *General appearance of Coleoptera (Aydemir, 2014).*

Coleoptera antennae come in various shapes, and their mouths are adapted for biting and chewing. With the exception of those that live in caves, most of them have eyes. These insects fly with thin, membrane-like front wings and larger hind wings. When not in flight, the hind wings are folded and concealed beneath the elytra.

The larvae of Coleoptera exhibit a wide variety of forms based on their lifestyles. For example, there are predatory larvae with well-developed legs, as they rely on predation, and there are also larvae that are eyeless and legless, living within plants. Coleoptera feed on a diverse range of food sources, and many taxa within this order are predatory (Topkara, 2008).

18. General Characteristics of Simulidae

Worldwide, there are a total of 120,000 taxa gathered in 177 families. In the Palearctic region, there are 29,579 taxa belonging to 120 families, while in Turkey, there are more than 1,170 taxa distributed among 63 families.

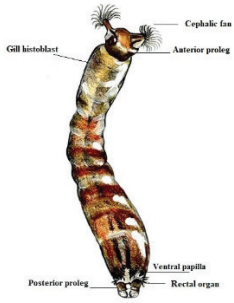


Figure 19.*General appearance of Simulidae (Aydemir, 2014).*

All of them possess piercing-sucking or licking-sucking mouthparts. Due to their complete metamorphosis (holometabolism), their larvae ("worm or caterpillar") are markedly different from adults both in appearance and life-style. Yellow, brown, green, or black colors are structural and pigment colors.

In many species, the eyes enlarge, covering a significant portion of the head. The size and location of the eyes vary among families and genders. While the compound eyes of females remain distinctly separated on the forehead, those of males are contiguous. The common color of the eyes ranges from red to dark brown, and these colors, divided by burgundy, dark green, or red bands, provide the eyes with a captivating coloring. Those dwelling in caves exhibit reduced eyes. The triangular arrangement of three ocelli is solely responsible for detecting light, although they cannot perceive shapes (Aydemir, 2014).

19. General Characteristics of Chironomidae

They constitute a family belonging to the Diptera order of the Insecta class. In everyday language, adults are referred to as "Non-biting Midges" or "Blind Mosquitoes," while their larvae are known as "Bloodworms." Chironomidae is closely related to Culicidae (Mosquitoes) and Ceratopogonidae (Biting Midges) families. Chironomids are commonly encountered in freshwater habitats and represent a worldwide family with over 10,000 taxa.

They can be found in diverse locations, ranging from the glaciers of the Nepal Mountains at 5,600 meters to the depths of Lake Baikal at 1,000 meters. Chironomidae larvae have also invaded seas and have been identified along the coasts of aquatic environments worldwide, including depths of up to 30 meters in the oceans. Additionally, there are taxa found in terrestrial environments (Armitage et al., 1995; Ulukütük, 2009).

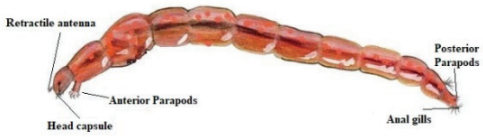


Figure 20. *General appearance of Chironomidae (Aydemir, 2014).*

Chironomidae larvae, pupae, and adults are crucial components of the food chain, serving as important links. They constitute a significant food source for invertebrates, fish, frogs, and birds. Chironomidae larvae have long been recognized by benthologists as a potential indicator of water quality.

Some genera or taxa are known to inhabit only high-quality waters, while others specifically prefer poor-quality waters. This makes them valuable indicators for assessing the health of aquatic ecosystems (Taşdemir, 2003; Ulukütük, 2009).

REFERENCES

Akkus, A. H. 2012. Investigation of the Odonata Fauna and Ecology of Çekerek District and Its Surroundings in Yozgat Province (Master's Thesis), Hitit University, Institute of Natural and Applied Sciences, 83, Çorum.

Altınsaçlı, S., Altınsaçlı, S. 2005. Ostracod Fauna of Ancient Eflatunpınar (Beyşehir, Konya, Turkey). Ecology, 14(54); 13-19.

APHA, 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition, American Public Health Association, Washington, DC.

Arslan, P. N. 1998. Taxonomic and Zoogeographic Study of the Naididae (Oligochaeta) in the Sakarya River Potamofauna (Ph.D. Thesis), Osmangazi University, Institute of Natural and Applied Sciences, 116.

Armitage, P., Cranston, P. S., Pinder, L. C. V. 1995. The Chironomidae: Biology and Ecology of Non-biting Midges. Chapman and Hall, London, 572.

Aydemir, E. A. 2014. Taxonomic ve Ecological Assessment of Macro Benthic Fauna of Karasu Stream (Sinop), *Sinop University Institute of Natural Sciences, Doctoral Thesis, Sinop, 290.*

Aydınlı, C. 2008. Limnofauna of Ephemeroptera (Insecta) in the Sultan Creek (Malatya) (Master's Thesis), Anadolu University, Institute of Natural Sciences, 89.

Bonada, N., Prat, N., Resh, V. H., Statzner, B. 2006. Developments in Aquatic Insect Biomonitoring: A Comparative Analysis of Recent Approaches. Annual Review of Entomology, 51; 495-523.

Bouchard, R. W. 2004. Guide to Aquatic Invertebrates of the Upper Midwest, University of Minnesota, 207.

Brinkhurst, R. O., Jamieson B. G. M. 1971. Aquatic Oligochaeta of the World, Oliver and Boyd, Edinburgh, 860. Stephenson, J., 1930, The Oligochaeta. -Clarendon Press, Oxford.

Brittain, J. E. 1982. Biology of Mayflies, Annual Review of Entomology, 27, 119-147.

Brittain, J. E., Sartori, M. 2003. "Ephemeroptera (Mayflies)" In: Encyclopedia of Insects (Ed: Resh, V. H. and Carde, R. T.), Academic Press, Amsterdam, 373-380.

Cohen, A. C., Peterson, D. E., Maddocks, R. F. 2007. Ostracoda, Intertidal Invertebrates from Central California to Oregon. In: James T. Carlton (Ed.), The Light and Smith Manual; Fourth Edition. University of California Press, Berkeley and Los Angeles.

Corbet, P. S. 1999. "Dragonflies, Behavior and Ecology of Odonata," Cornell University Press, 1-829.

Demir, Ö. 2005. Assessment of Water Quality with Sediment Macroinvertebrates, Harran University, Department of Environmental Engineering, Master's Thesis, Şanlıurfa, 2005.

Demirsoy, A. 1995. Fauna of Turkey, Odonata, TUBITAK Series; 8, Section; 4, Number; 8, 446.

Demirsoy, A. 1998. Principles of Life, Invertebrates (Except Insects), Volume II/Part I, Hacettepe University Publications, 518-572.

Demirsoy, A. 1999. Principles of Life (Invertebrates/Except Insects), Volume II/Part I, Metaksan A.S., Ankara, 879 – 890.

Demirsoy, A. 2003. Principles of Life, Invertebrates (Except Insects), Volume II/Part I, 5th Edition, Ankara, 1210.

Dijkstra, K. D. B., Lewington, R. 2006. Field Guide to the Dragonflies of Britain and Europe including Western Turkey and Northwestern Africa. British Wildlife Publishing, Milton on Stour, Gillingham, 320 p.

Edmunds, G. F. 1959. Fresh-Water Biology (Ed: Edmundson, W. T.), John Wiley and Sons Inc., New York, USA, 908-916.

Elliott, J. M, Humpesch, U. H. 1983. A Key to the Adults of The British Ephemeroptera, Freshwater Biological Association, London, No; 47.

Gledhill, T., Sutclife, D. W., Williams, W. D. 1993. British Freshwater Crustacea Malacostraca; A Key with Ecological Notes, Series Editor: Elliot, J. M., Freshwater Biological Association, Scientific Publication No. 52, 173.

Harker, J. 1989. Mayflies, Naturalist's Handbook 13, Richmond Publishing Co. Ltd., Slough, England.

Hawkes, H. A. 1979. Invertebrates as Indicators of River Water Quality. Chapter 2. In: A. James, L. Evison (Eds.) Biological Indicators of Water Quality, Wiley-Intersci. Publ., Great Britain, 27.

Holzenthal R. W., Blahnik R. J., Prather, A. L, Kjer, K. M. 2007. Order Trichoptera Kirby, 1813 (Insecta), Caddisflies. Zootaxa 1668; 639-698.

İpek, M. 2009. Research on Freshwater Gammaridea (Crustacea-Amphipoda) Fauna of Eskişehir and Its Surroundings (Master's Thesis), Eskişehir Osmangazi University, Institute of Natural and Applied Sciences, 75.

Kalafat, A. 2008. Studies on the Simuliidae (Diptera) Fauna of Afyon and Its Surroundings, Eskisehir Osmangazi University, Institute of Natural and Applied Sciences, Master's Thesis, Eskişehir.

Kalkman, V. J., Wasscher, M., Van Pelt, G. J. 2003. An Annotated Checklist of the Odonata of Turkey, Odonatologica, 32; 215-236.

Kazancı, N. 1991. Contribution to the Zoogeography of Asia Minor Based on the Distribution of Drunella Species (Ephemeroptera; Ephemerellidae). In: Overview and Strategies of Ephemeroptera and Plecoptera (Eds: ATercedor and S. Ortega, The Sandhill Crane Press. Gainesville, 271-276.

Kazancı, N. 2001. "Preliminary Study on the Ephemeroptera (Insecta) Fauna of Gümüşhane, Erzurum, Erzincan, Artvin, Kars Provinces," Turkey Inland Wa-

ters Research Series; V, Imaj Publishing, Ankara.

Kırkağaç, M., Köksal, G. 2014. Determination of the Response of Benthic Macroinvertebrates in Streams to Water Pollution and Use of Biotic and Diversity Indices, Ankara University, Faculty of Agriculture, Department of Aquaculture (compilation).

Kocataş, A. 1996. Ecology and Environmental Biology. Ege University Faculty of Science Books Series, No; 142. 564.

Lodos, N. 1983. Entomology of Turkey I (General, Applied and Faunistic) Volume I (Expanded 2nd Edition), Ege University Printing House, 131-134.

Özbek, M. 2011. An Overview of Gammarus Species Distributed in Turkey, with an Updated Checklist and Additional Records. Zoology in the Middle East, 53; 71–78.

Paçal, F. 2010. Seasonal Changes and Some Ecological Features of Ostracod (Crustacea) Fauna in the Bandırma and Erdek Bays (Sea of Marmara), Istanbul University, Institute of Science, Ph.D. Thesis, 156.

Pinto, R. L., Rocha, C. E. F, Martens, K. 2008. On the First Terrestrial Ostracod of the Superfamily Cytheroidea (Crustacea, Ostracoda); Description of Intrepidocythere ibipora n. gen. n. sp. from Forest Leaf Litter in São Paulo State, Brazil. Zootaxa, 1828, 29–42.

Pinto, R. L., Rocha, C. E. F., Martens, K. 2005. On New Terrestrial Ostracods (Crustacea, Ostracoda) from Brazil, Primarily from São Paulo State. Zoological Journal of the Linnean Society, Volume 145, Number 2, (29), 145-173.

Rüzgar, M. 2010. Determination of the Zoobenthic Potamofauna (Oligochaeta, Chironomidae, and Trichoptera) and Their Distributions in the Delice River (Kızılırmak) and Its Tributaries, Biology Department, Master's Thesis, Sinop.

Sperber, C. 1948. A Taxonomical Study of the Naididae. Zoologiska Bidrag fran Uppsala 28; 1-296. Sperber, C. 1950. A Guide for the Determination of European Naididae. Zoologiska Bidrag fran Uppsala 29; 45-78.

Sternberg, R., Cumberlidge, N. 2001. "On the Heterotreme-Thoracotreme Distinction in the Eubrachyura De Saint Laurent, 1980 (Decapoda; Brachyura)". Crustaceana, 74; 321–338.

Şahin Y. 1991. Chironomidae Potamofauna of the Inland Waters of Turkey. TUBITAK, TBAG-869 project, 88.

Tanatmış, M. 2002. The Ephemeroptera (Insecta) Fauna of Lake Ulubat Basin. Turkish Journal of Zoology, 26; 53-61.

Taşdemir, A. 2003. Taxonomic and Ecological Investigation of Chironomidae and Chaoboridae (Diptera) Fauna of the Inland Waters of the Aegean Region, Ph.D. Thesis, İzmir.

Topkara, E. 2008. Research on the Aquatic Coleoptera (Insecta) Fauna of the Western Black Sea Region and Its Surroundings (Ph.D. Thesis), Ege University, Institute of Natural and Applied Sciences, 398, İzmir.

Ulukütük, S. 2009. Determination of the Potamofauna (Chironomidae-Oligochaeta) of Lake Uluabat (Apolyont) Basin and Its Relationship with Water Quality. Eskisehir Osmangazi University, Institute of Natural and Applied Sciences, January 2009, 272.

WFD. 2000. EU Water Framework Directive (WFD) 2000/60/EC. 23. 10. 2000.

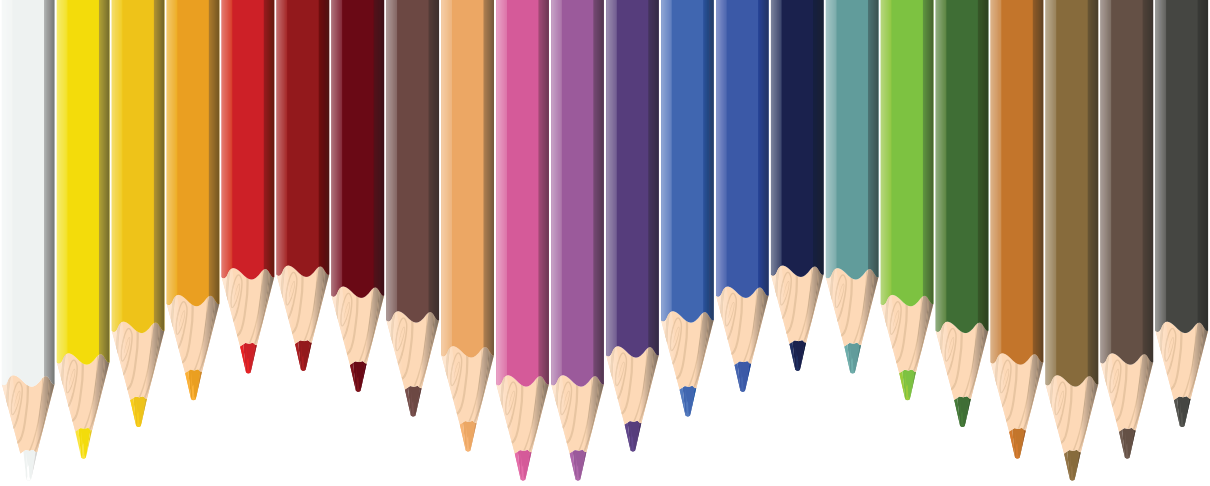
Wiggins, G. B. 1998. Larvae of the North American Caddisfly Genera (Trichoptera) Second edition, University of Toronto Press, 457.

Williams, D. D. 1980. "Applied Aspects of Mayfly Biology", Advances in Ephemeroptera Biology (Ed: J. F. Flannagan and K. E. Marshall), Plenum Pres, New York, USA, 1-17.

Yıldız, S. 2003. Taxonomic and Ecological Examination of the Oligochaeta (Annelida) Fauna of the Inland Waters of the Aegean Region (Ph.D. Thesis), Ege University, Institute of Natural Sciences.

Zelinka, M. 1984. "Production of Several Species of Mayfly Larvae", Limnologica, Berlin, 15, 21-41.

Zeybek, M., Kalyoncu, H., Ertan, Ö. O. 2012. Species Composition and Distribution of Mollusca in Relation to Water Quality, Turkish Journal of Fisheries and Aquatic Sciences 12; 719-727 (2012).



Chapter 16

INVESTIGATION OF NOISE LEVEL IN SOME PARKS IN BARTIN CITY CENTER

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Introduction

One of the important factors that negatively affects the quality of the environment we live in today and human health is noise. We can define noise as "unpleasant, unwanted, disturbing sound". Sound is an objective concept. In other words, it can be measured and its existence does not change depending on the person. Noise is a subjective concept. As can be seen from the definition, whether a sound is considered noise or not may vary depending on the person (Güremen et al. 2008). Music that some people enjoy listening to may disturb others. Especially in fast-growing cities, with the unplanned and intertwined development of residential and industrial areas, increased traffic density, and the increasing penetration of electrical, electronic and mechanical devices into our daily lives, noise disturbance increases and the places where our people can rest, work, in short, live peacefully are decreasing.

On the other hand, in cases where respect for others' right to rest and environmental sensitivity are not sufficiently developed, noise resulting from entertainment and other daily activities causes intense complaints and serious physical and mental disorders, especially hearing loss and sleep disorders (Belojevic et al. 2008). In daily life, the presence of sounds is necessary for people to feel good. Speech, music, and sounds in nature are indispensable for our lives (Aşcıgil 2009). However, noise, defined as unwanted sound, negatively affects human health. Today, the negative effects of noise are not examined only in cases of long-term noise-induced hearing loss in factories, as in the past. The research covers all types of noise in open spaces and indoors.

Noise sources can be grouped from different aspects. Depending on the way sounds are generated, noises arising in air and solid environments can be acoustically emitted from point, line and planar sources (Kamer 2005; Candemir 2008). Noises that create acoustic pollution; they can be divided into two groups depending on the location of the source and receivers in an environment and their propagation paths: Noise sources in open areas: these are the noises produced from sources outside the buildings and affect the people using both the volumes inside the building and the open areas outside the building (industrial noise, transportation noise, construction site noise, noise related to human activities, entertainment and commercial noise). Indoor noise sources: these are the sounds arising from sources located inside the buildings (sounds of conversation, footsteps, noise of household vehicles, loud music, door slamming, office noise).

Effects of Noise on Human Health

Human behaviors against the effect of noise are divided into two groups. The first is psychological discomfort, which can only be determined by explaining feelings and sensations, and the second is; It is a physiological disorder that can be determined by various measurement methods. For this reason,

noise control must be carried out at the architectural design stage in terms of human health and comfort conditions. When examining the effects of noise on humans, three important factors can be taken into consideration: 1. Annoyance, 2. Obstruction of communication, 3. Risk of permanent hearing impairment,

Daytime (Leq) (dBA) Effect; 55-60 noise disturbs, 60-65 discomfort increases markedly, above 65 behavioral inhibitions occur and harmful symptoms occur due to noise. Noise Level Exposure Range (dBA) Effects on Health: First degree noises (30-65) discomfort, anger, irritation, sleep disorder and concentration impairment. Secondary noises (65-90) physiological reactions, increased blood pressure, increased heart rate and breathing, decreased pressure in the cerebral fluid, sudden reflexes. Third degree noises (90-120) physiological reactions, headaches. Fourth degree noises (120-140) permanent damage to the inner ear, disruption of balance. Fifth degree noises (>140) severe brain damage, ruptured eardrum (Thompson 2002). The Regulation on the Evaluation and Management of Environmental Noise has been published in order to ensure that the necessary measures are taken to prevent people's peace and tranquility, physical and mental health from being disrupted as a result of exposure to environmental noise.

In most local governments, the issue of noise is not given due importance and the negative effects of noise on human health and behavior are ignored. In order to reduce the negative effects on urban people resulting from the chaos and pressure of urban life, physical, social and recreational planning is needed in the urban environment. Almost all cities should have spaces that allow society to live, work, have fun and relax. At this point, green areas become common use spaces with a high social role by meeting many needs in urban life. Spending time in a park reduces stress and increases the joy of life. It is thought to strengthen and be beneficial in protecting mental health. It has been observed that individuals living in cities with natural and cultural areas containing components such as green areas and water elements are less stressed than individuals living in cities that do not have such natural and cultural areas. It has also been shown that people who visit parks and green areas more often feel healthier than those who visit less often. Green areas and parks socialize people, calm them down, and it has also been shown to reduce aggression. Parks and green areas not only provide aesthetic and historical integrity and continuity, but also help people develop feelings such as knowing themselves, testing themselves, increasing their sense of trust, and belonging through their active experiences. City parks, which have aesthetic and historical activity value, increase the attractiveness of cities and provide new income and job opportunities by making them a place to visit for both urban people and tourists. In addition to providing economic benefits for the urban people with their social and psychological effects, trees also provide savings

in the management strategies and budgets of city administrations due to the air purification effect of trees. Likewise, it increases the value of the structures around it with its natural elements such as wood and water, and contributes to the national and local budget with the taxes obtained from those structures.

Noise pollution is one of the most important environmental problems of our cities. In parks in the city center, the noise problem becomes even more important. Because parks are one of the noise sensitive areas such as schools and hospitals. Cities are the places where noise pollution is most intense, especially due to the increasing number of vehicles. While noise pollution used to exceed the permissible limit values in big cities, today it emerges as an important environmental problem in small cities and almost everywhere in the city. Sources of noise are generally industrial noise, construction noise, commercial noise and transportation noise. Especially transportation noise is the type of noise we encounter everywhere. Land traffic noise is the dominant type of noise that affects human health the most.

Material and Method

Especially city centers are one of the places where the city is most dense in terms of noise. People coming to the center by both public transportation and private vehicles causes the vehicle density in the city center and therefore noise pollution to increase. The aim of this study is to examine the noise values of city parks in order to fulfill their aesthetic and functional functions and create a quality living environment in the example of Bartın province. Daytime noise measurements were made in eleven parks located 5-25 meters from the highway in the city center. Noise values were taken from a height of approximately 1.20 m above the ground. Measurements were made on rainless and windless days. TES 1353 noise meter device was used to measure noise levels in the research. The device can record measurements every second with a sensitivity of 1.5 dB and the recorded data can be transferred to the computer via RS232 output.

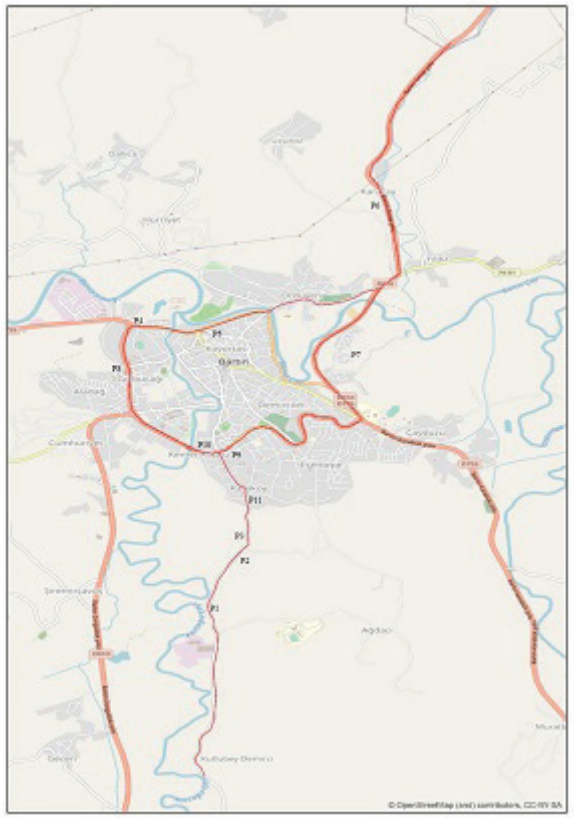


Figure 1. Location of measured parks

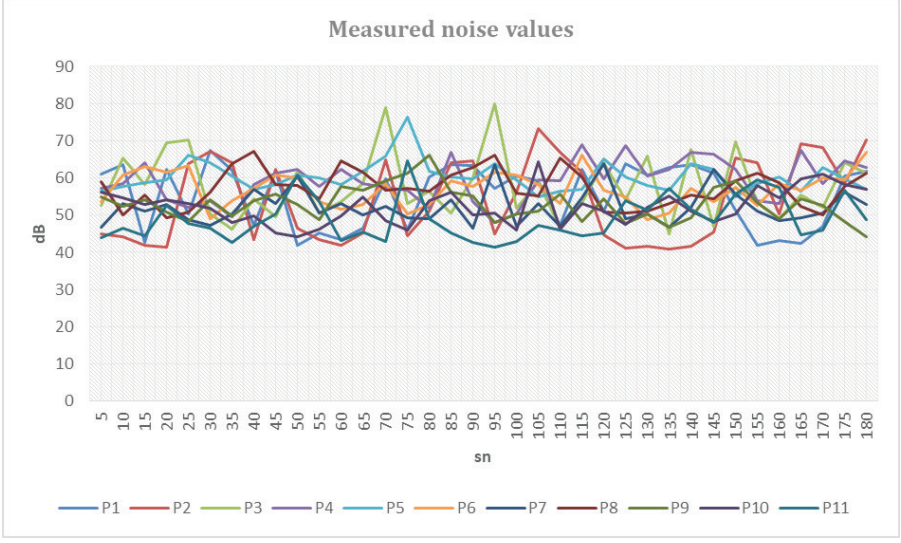


Figure 2. Noise values measured at 5-second intervals in parks

Differences between average noise levels (in decibels) in parks located close to and far from the road were examined with the Independent sample t-Test. The purpose of this analysis is to determine whether there is a statistically significant difference between the average noise levels of parks in two different categories.

Table 1. Independent Sample t-Test for Noise Levels in Parks by Distance from the Road

Distance to road	N	Mean	SS	t	sd	p
Near	3	57.35	3.17	1.326	9	0.218
Far	8	54.39	3.33			

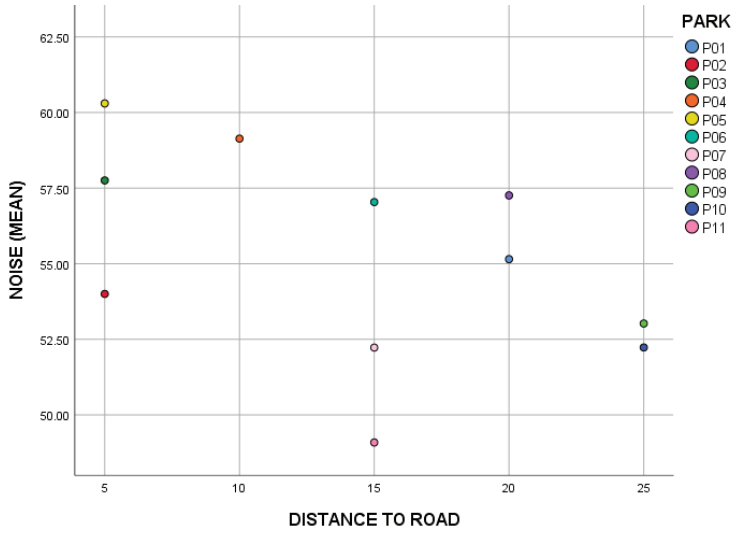


Figure 3. Distance to road and noise average

Independent Sample t-Test was applied to determine the average difference between parks' noise levels based on proximity to the road. While the average noise level for parks 'Close' to the roadside (N=3) was measured as 57.35 decibels, for 'Far' parks (N=8) this value was recorded as 54.39 decibels. The difference between the averages is calculated as 2.96 decibels.

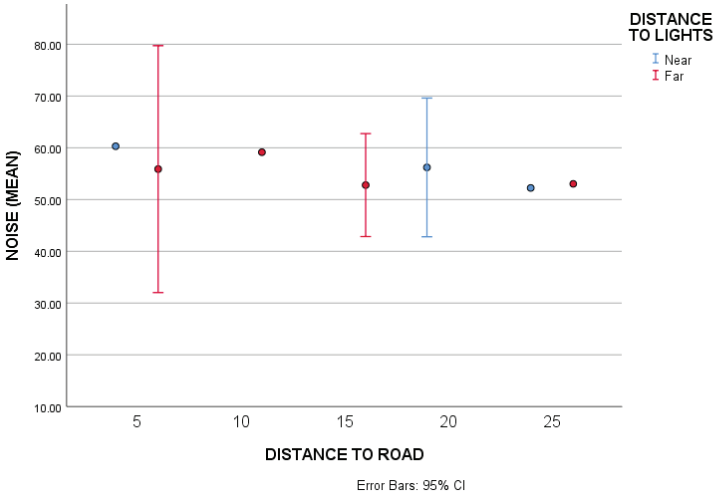


Figure 4. Noise average according to distance (meters) from the road

In the statistical analysis, a t-value of 1.326 was obtained with 9 degrees of freedom and the p-value was found to be 0.218. This p-value is above the generally accepted alpha level of 0.05. This result shows that there is no statistically significant difference in noise levels between parks 'Near' and 'Far' from the road. The fact that the average difference was not statistically significant in the analysis indicates that the difference in noise level between the two groups may be coincidental.

Conclusion

Noise pollution is one of the most important environmental problems of our cities. In parks in the city center, the noise problem becomes even more important. Because parks are one of the noise sensitive areas such as schools and hospitals.

It has been determined that long-term exposure to noise affects heart rate, blood pressure, breathing and the level of uric acid in the blood. As the noise level increases, the human heart rate also increases. This is also a symptom of human energy consumption. Therefore, as noise increases, fatigue increases.

Measures to reduce noise: Not driving a motor vehicle without a silencer and other sound-reducing parts. Avoid unnecessary use of horns or other sound-producing devices on or inside motor vehicles. Obeying speed limits. Adopting high gear and low rpm driving style. Establishing parks away from areas with heavy traffic, through good urban planning.

Most of the parks are under the influence of heavy vehicle traffic. In the measurements made in eleven parks, noise values did not exceed the limits

allowed by the Noise Control Regulation.

Designing and implementing barriers for noise reduction is a very expensive process, especially in built-up areas. Therefore it is important to consider noise estimates in land use planning. Noise control stages, which must be handled in a planned manner, gain importance in completely eliminating or minimizing the negative effects of noise, in other words, in keeping the noise below acceptable limits.

References

Güremen L., Altanlar A., Çelik C.T. (2008). Kent Parklarının Yaşam Kalitesi Üzerine Etkisi Yozgat Örneği, Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi 30. Yıl Sempozyumu Bildiri Kitabı, Adana.

Belojevic G, Jakovljevic B, Stojanov V, Paunovic K, Ilic J, (2008). Urban Road-Traffic Noise and Blood Pressure and Heart Rate In Preschool Children. Environment International.

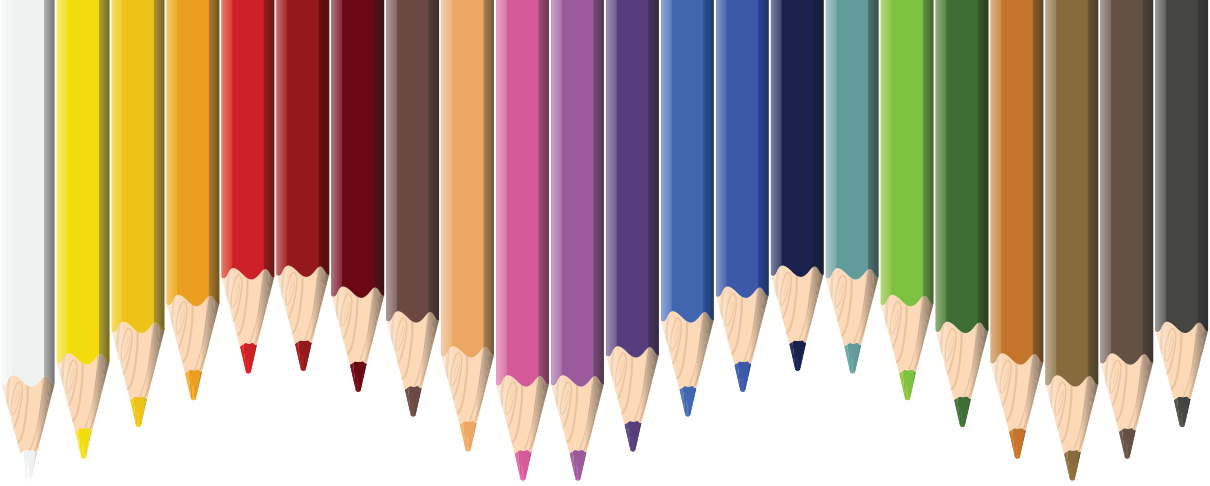
Aşcıgil M.(2009). Karayolu Gürültü Haritalarının Hazırlanması, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü.

Bursa Büyükşehir Belediyesi (2020). Çevre Koruma ve Kontrol Dairesi Başkanlığı.

Candemir N. (2008). D100 (E5) Karayolunun Gürültü Açısından Değerlendirilmesi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü.

Kamer H.A. (2005). Tarımsal mekanizasyon işletmelerinde oluşan gürültü düzeylerinin belirlenmesi ve ergonomik değerlendirme, Kahramanmaraş Sütçü İmam Üniversitesi, Fen bilimleri Enstitüsü.

Thompson, C.W., (2002). Urban open space in the 21st century. Landsc. Urban Plan. 60.



Chapter 17

BUFFALO BREEDING: HISTORY AND CURRENT SITUATION

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1. Introduction

Water buffalo is a species belonging to the "Bovidae" family, defined as "Water Buffalo" in English, which is raised primarily for milk yield, meat, leather and labour force (Sariozkan, 2011). Buffaloes constitute a suitable material for extensive breeding due to their ability to adapt to different environmental conditions, their resistance to diseases, their ability to consume cheap feeds with low quality and high cellulose content among roughages and to transform them into animal products, and their abstinence. In addition, it is a very economical form of animal husbandry that can be carried out in swamp and reed areas in regions where cheap roughages are available (Sahin et al., 2013).

The human population in the world and in our country is increasing day by day. In parallel with the increase in population, there is an increase in the nutritional needs of people. In order to provide animal production that can meet these needs of people, it is desirable to increase the number of animals and animal products obtained (Çelik, 2015). In addition, buffalo breeding has an important place in today's World where the demand for organic products and therefore organic animal husbandry is increasing (Sahin et al., 2013). However, while the number of buffaloes has been increasing in the world since the 1960s, the number of buffaloes in Turkey has been decreasing (FAO, 2023).

Buffalo breeding is a traditional branch of animal husbandry that has been going on for thousands of centuries and is widespread especially in Asia (96.4 %). In Europe, where buffalo breeding is carried out in small amounts, Italy is one of the model countries where buffalo breeding is carried out with modern techniques (Yilmaz and Kara, 2019).

Nowadays, with the nutritional needs of the increasing population and the increasing demand for organic products, buffalo farming plays an important role in both developed and developing countries. In this chapter, general information about buffalo breeding, its current situation in the world and in Turkey, the reasons for the significant decrease in number and yield, problems and solution suggestions will be emphasised.

2. Classification of Buffaloes in General

The classification of buffaloes is presented in Figure 1. In general, buffaloes are divided into two groups as African wild buffalo and Asian buffalo. Asian buffaloes originate from wild and domesticated forms and constitute 74 different breeds. Domestic buffaloes are also divided into two groups as swamp buffaloes and river buffaloes (Atasever and Erdem, 2007). There are many differences between these groups in terms of chromosome numbers, morphological characteristics and utilisation aspects. Swamp buffaloes have

48 chromosomes and river buffaloes have 50 chromosomes and they can produce fertile offspring when they unite among themselves (Yilmaz and Kara, 2019).

Swamp buffaloes, found in China and Southeast Asia, are not suitable for milk production and are mainly used for ploughing rice paddies. River buffaloes, which originate from India, are bred for milk and meat production. In addition, while there is only one breed of swamp buffalo, there are several breeds in the river buffalo group, such as Murrah, Nilli-Ravi, Kundi, Surti, Meksana, Jafarabadi, Nagpuri, Pandharpuri and Mediterranean buffalo. (Moioli and Borghese, 2005; Soysal, 2006). In some Asian countries such as China and Pakistan, breeding studies for buffalo breeds are being carried out (Soysal, 2006).

The buffaloes raised in Turkey are called "Anatolian buffaloes" and are reported to originate from Mediterranean buffaloes (Soysal et al., 2005). The breed registration of the Anatolian buffalo was carried out by the Ministry of Agriculture and Forestry, General Directorate of Agricultural Researches and Policies (TAGEM) in 2004 and it was identified (Gazette, 2004).

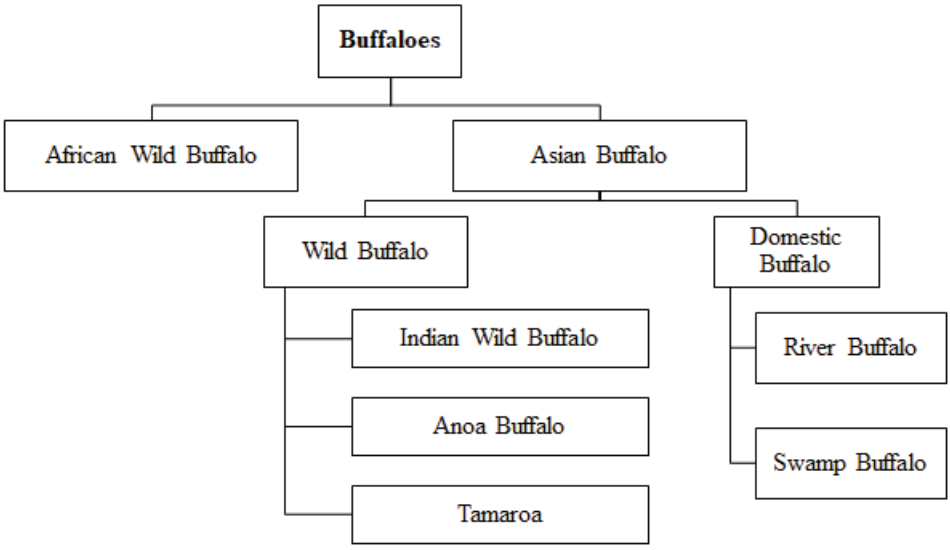

Figure 1: Basic grouping of buffaloes (Atasever and Erdem, 2007)

3. Water Buffalo in the World and Turkey

Although water buffaloes are intensively distributed in Asia, it is observed that they are cultivated in various countries under different socio-economic conditions, geographical structure and climatic conditions (Figure 2,

FAO, 2015). The fact that the Asian buffalo is distributed in such a wide area in the world is an indication that its adaptation ability is very strong (Khan and Coskun, 2018).

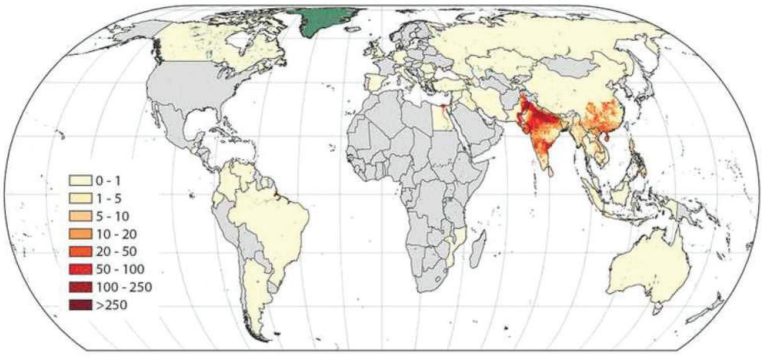

Figure 2: Number of water buffaloes per kilometre in 2015 (FAO, 2015)

When the ratios of the number of cattle and buffaloes raised in the world and in Turkey between 1961 and 2021 are analysed, it is seen that while the ratio of buffalo breeding in the world cattle breeding is increasing day by day, it has decreased considerably in Turkey (Figure 3, FAO, 2023).

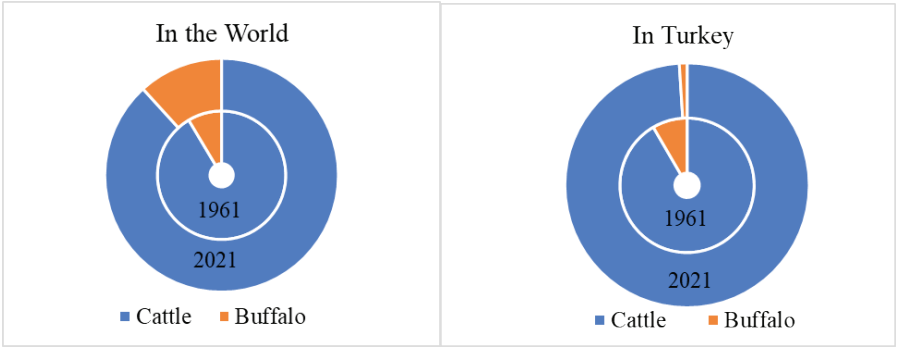

Figure 3: Ratios of cattle and buffalo in bovine assets in 1961 and 2021 (FAO, 2023)

In the 60-year period between 1961 and 2021, the number of water buffalo in the world increased continuously from 88 321 107 heads to 203 939 158 heads with an increase of 130.9 %. In Turkey, a decrease of 83.7 % was observed from 1 140 000 heads to 185 574 heads in this period (FAO, 2023). In relation to this significant decrease observed in Turkey, Turkey's share in the world buffalo population decreased from 1.29 per cent to 0.09 per cent (Table 1).

	1961	1981	1991	2011	2021	Değişim (%)
World	88 321 107	124 211 642	149 685 090	195 327 711	203 939 158	130.91
Turkey	1 140 000	1 031 000	371 000	84 726	185 574	-83.72
Share (%)	1.29	0.83	0.25	0.04	0.09	-93.02

Table 1: Changes in buffalo numbers in the world and in Turkey in 60 years (FAO, 2023)

Figure 4 shows the change in buffalo population in the world and in Turkey between 1961 and 2021. Accordingly, the number of buffalo in Turkey, which was over 1 million heads before 1970, showed a sharp decline in the following years (FAO, 2023). Until 2008, the number of water buffaloes decreased to 84 705 heads, suggesting that the species is in danger of extinction, which is extremely worrying (Sariozkan, 2011). In this process, the main reasons for the decrease in the buffalo population were stated as the decrease in the support given by the state to animal husbandry, the transition to modernisation in agriculture, the failure to promote the nutritional value of the products obtained from buffaloes, the disappearance of lands suitable for their cultivation, and the inability of producers to adapt to the intensive breeding of buffaloes, which have low yields compared to cattle. Although buffalo products vary according to the regions in Turkey, they have come to the forefront in terms of cream and cheese. However, the desired level of consumption preference has not yet been reached due to the lack of adequate promotion of buffalo products to consumers (Özkan et al., 2017).

The increase in the number of buffaloes in Turkey after 2008 has been promising. It is thought that the "Buffalo Breeding by People" project, which is one of the studies carried out to increase buffalo breeding and productivity, has a great contribution to this increase. In addition, encouraging the establishment of "Breeding Buffalo Breeders' Associations" in the provinces where buffalo breeding is carried out in 2008 in order to ensure the organisation of this branch of animal husbandry, and the establishment of "Turkey Breeding Buffalo Breeders' Central Union" in 2012 have been effective in the increase in the number of buffalo (Soysal, 2013). Until 2020, the number of buffaloes in Turkey increased and reached 192 489 heads. In the last three years, it has decreased by 3.59 %, 7.40 % and 3.93 % respectively compared to the previous year and decreased to 166 803 head buffalo in 2023 (TUIK, 2023).

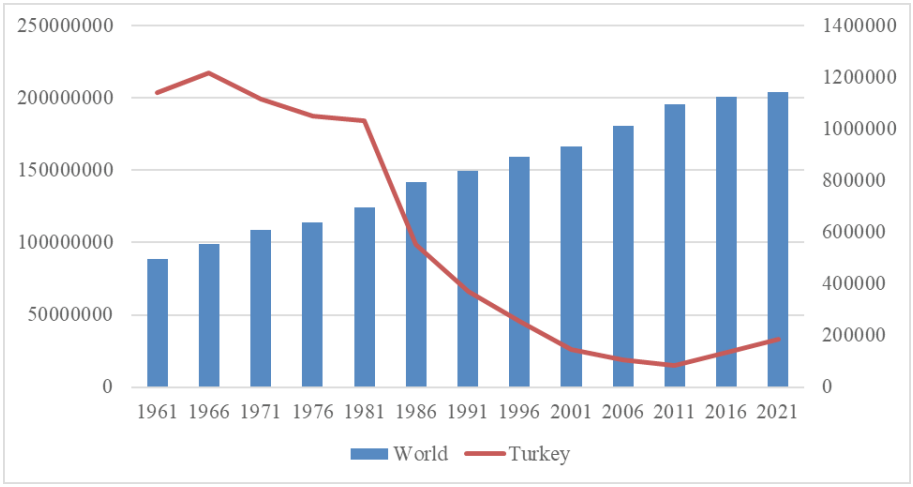

Figure 4: Change in buffalo population in the world and Turkey between 1961 and 2021 (FAO, 2023)

4. Buffalo Breeding Provinces in Turkey

Among the main forage consumed by buffaloes are reeds, reeds and grasses in wetlands. For this reason, they like wetlands, swamps and humid regions. The ideal temperature values for Anatolian buffaloes in Turkey are between 0-30 °C. In cases other than these values, they enter into heat stress and their productivity decreases. They have a tendency to get into water or mud against heat stress. In general, they like climates and regions where the annual temperature difference is not high (Soysal, 2013). According to the 2022 data announced by TUIK; the Black Sea region has the highest share in terms of buffalo presence in Turkey. This is followed by Marmara and Eastern Anatolia regions respectively. The regions with the highest buffalo breeding in Turkey and the provinces in these regions are listed below:

Black Sea region: Samsun, Tokat, Amasya

Marmara region: Istanbul, Balikesir, Bursa

Eastern Anatolia region: Bitlis, Muş, Iğdır

Central Anatolia region: Sivas, Kayseri, Yozgat

Southeastern Anatolia region: Diyarbakır, Şanlıurfa, Batman

Aegean region: Afyon, Kütahya, Manisa

Mediterranean region: Osmaniye, Hatay, Adana

Buffalo breeding is one of the most ideal animal husbandry activities for the Black Sea region. Because of the dominant climate and rugged land struc-

ture in the region, animal (especially ovine) and plant production activities can be carried out at a very limited level. Accordingly, mechanisation in agriculture has not been developed. In the Southeastern Anatolia region, most of the buffalo breeding and activities are carried out in Diyarbakır province. In the Marmara region, Istanbul province is important. In the Mediterranean region, the presence of buffaloes is low and not widespread due to the fact that the climate structure of the region (hot and humid) is not suitable for buffalo breeding conditions. In addition, the fact that the most important source of livelihood of the region is tourism can be considered among the reasons for the lack of interest in buffalo breeding (Dogdas, 2021).

According to the data of 2022, the ten provinces with the highest number of buffaloes in Turkey are indicated in the Table. Accordingly, Samsun ranks first with 20 671 heads. Samsun is followed by Diyarbakır with 15 333 heads and Istanbul with 12 990 heads (TUIK, 2023).

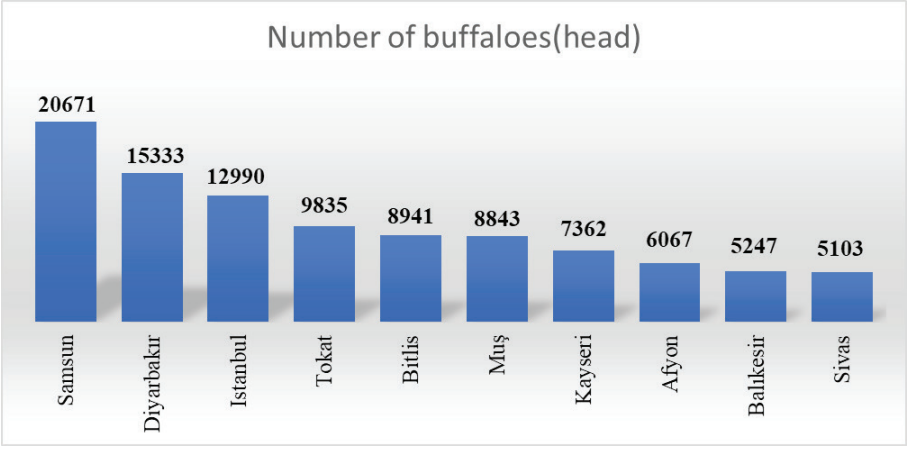

Figure 5: Top ten cities with the highest number of buffalo farming in Turkey (TUIK, 2023)

5. Buffalo Meat and Meat Products

Buffaloes are contented animals that can both survive on hay and crop residues as roughage sources and produce protein-rich, lean, low cholesterol meat. (Sarwar et al., 2009). Buffaloes can maintain their productivity for a longer time under poor care and feeding conditions than ruminant animals such as cattle and sheep. In addition, it is possible to utilise these animals, which are less competitive with humans in terms of nutritional resources, for sustainable meat production. However, until today, buffaloes have not been given enough importance and serious breeding and feeding studies have not been applied like other animals. The development of the Bufalypso breed on

the islands of Trinide and Tabaga to increase meat yield is the only known progress in this field. (Irurueta et al., 2008). Nevertheless, buffaloes show better growth than cattle in hot and harsh tropical climate and poor feeding conditions. If buffaloes are well cared for and fed, it is possible to increase meat yield and quality with lower rearing costs. (Astuti et al., 2019).

The buffaloes from which meat is obtained are old animals that have been culled from herds in rural areas in many countries and have reached the end of their productive period. (Nanda and Nakao, 2003). In Turkey, buffalo slaughtering has a non-industrialised structure. Most of the animals reaching the market for meat have reached the end of their productive period. Almost all of this meat obtained from older animals is used in sausage making. Compared to beef in Turkey, buffalo meat is about 10 per cent lower in price. (Şekerden, 2016) In fact, buffalo meat is not sold in markets and butchers. When buffalo meat was compared with beef, it was found to be more or less similar in terms of organoleptic, composition, nutritional, functionality and physico-chemical quality characteristics, and it was even reported that buffalo meat has advantages due to its leaner, lower calorie and cholesterol content. (Naveena and Kiran, 2014). It was also reported in another study that when buffaloes are slaughtered at an early age like cattle, their meat may be lighter in colour and meat quality characteristics may be higher. (Naveena and Kiran, 2014). In order to increase buffalo meat production, there is a need for studies to increase the awareness and consumption of buffalo meat in the society. (Adkinson and Konca, 2021).

Figure 6 shows the impact rates of animal species on the amount of meat produced in Turkey in 2023. Accordingly, it is seen that 71.8 per cent of the meat production is obtained from cattle and the lowest 0.6 per cent is obtained from buffaloes.

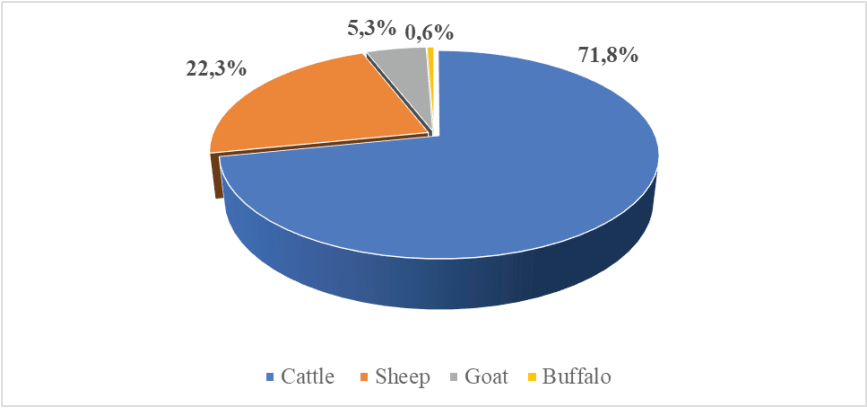

Figure 6: Effect of animal species on the amount of meat produced in Turkey (TUIK, 2023)

Figure 7 shows the number of water buffaloes slaughtered and the amount of meat produced in Turkey between 2001 and 2022 (TUIK, 2023). Between 2001 and 2012, the number of slaughtered buffaloes and the amount of meat obtained from buffaloes decreased due to the decrease in the number of buffaloes. From 2012 to 2020, an increase was observed in the number of slaughtered buffaloes with the increasing buffalo population. However, despite the decrease in the number of buffaloes in the two-year period after 2020 until 2022, the increase in the number of slaughtered buffaloes causes concerns that buffalo breeding will decrease further in the future if measures are not taken.

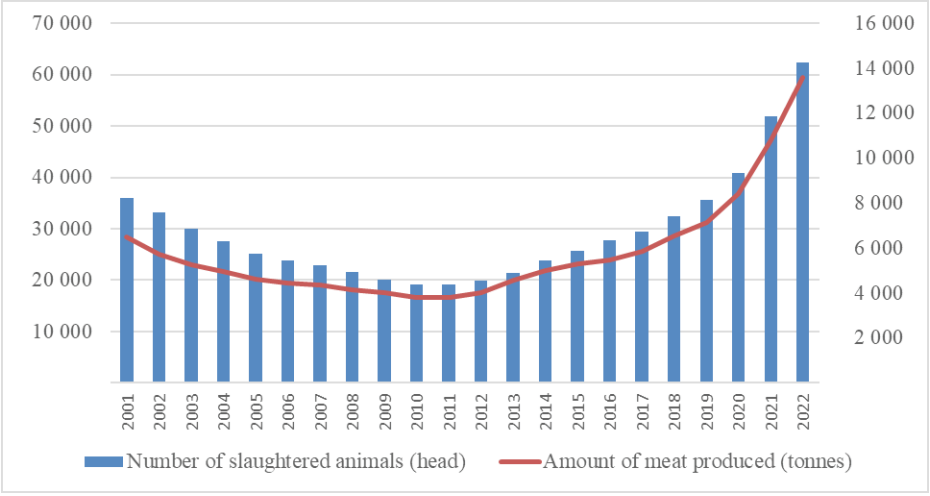

Figure 7: Number of water buffaloes slaughtered and amount of meat produced between 2001-2021 (TUIK, 2023)

6. Buffalo Milk and Dairy Products

Compared to cow's milk, buffalo milk is an important nutrient rich in high protein, fat, vitamin and calcium content. It is also a good source of important minerals such as magnesium, potassium and phosphorus (Abdel-Hamid et al., 2023; FAO, 2015). As shown in Table 2, buffalo milk contains higher dry matter and fat content compared to other species. The high fat and calorie content of buffalo milk is considered to be a superior and distinctive feature compared to other species (Atasever and Erdem, 2007, 2008). 100 and 70 calories per 100 grams of buffalo and cow's milk, respectively (Ermetin, 2020). Buffalo milk is healthier than cow's milk in terms of its lower cholesterol content and high content of unsaturated fatty acids (Khan et al., 2017). Although the fat content is already high, the low cholesterol value is due to the fact that it is rich in polyunsaturated fatty acids due to the small diameter of the fat globules

(Zicarelli, 2004).

In a study conducted in Turkey, it was reported that buffaloes are raised only in small family farms for milk and each breeder has 3-5 buffaloes on average and productivity per unit is low. It was stated that the number of buffaloes can increase up to 10-15 in some regions depending on natural feeding conditions. It is stated that producers do not tend to increase the number of buffaloes because they cannot market the milk they produce at a value price (Şekerden, 2016). Buffalo milk, like cow's milk, can be processed into many products such as butter, cream, hard and soft cheese, ice cream and yoghurt. In Afyon region, a type of dessert was obtained by wrapping the cream obtained in rolls. This type of dessert obtained from buffalo milk has gained world fame and created a separate market environment in terms of gaining value of buffalo milk (Atasever and Erdem, 2007). Approximately 350-400 g cream is obtained from 2.5 kg milk and can be sold at high prices. When buffalo milk is marketed without being transformed into any product, it can be sold at a higher price than cattle milk (Şekerden, 2016). In addition, the most important feature of the world-famous Mozzarella cheese produced in Italy is that it produced from buffalo milk (Atasever and Erdem, 2007).

Species	**Water**	**Dry Matter**	**Protein**	**Oil**	**Laktose**	**Mineral Matter**
Buffalo	82.0	17.7	4.15	7.85	4.8	0.77
Cattle	87.5	12.4	3.4	3.65	4.65	0.75
Sheep	82.9	17.2	5.4	6.25	4.55	0.88
Goat	87.1	13.0	3.7	4.1	4.45	0.8

Table 2: Comparison of milk content of some animal species (%) (Atasever and Erdem, 2007, 2008)

Figure 8 shows the number of water buffaloes milked between 1991-2019 and the amount of milk obtained until 2022 in line with the latest data announced by TUIK. Until 2008, there was a decrease in the number of water buffaloes milked and the amount of milk obtained in parallel with the decrease in the buffalo population, while an increase was observed in the following years until 2019 and 79 thousand tonnes of milk was obtained from 79 thousand head of water buffaloes milked in 2019. From 2019 to 2022, the sharp decline in milk yield is worrying. The reasons for this decline include the continuation of buffalo breeding with traditional methods, the restriction of pasture areas and the negative impact of increasing feed prices on the breeders.

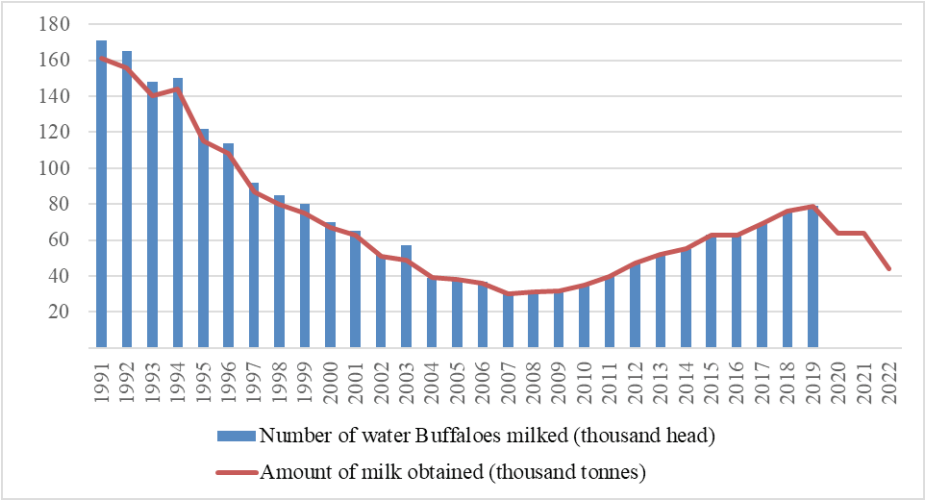

Figure 8: Number of water buffaloes milked between 1991-2019 and amount of milk obtained until (TUIK, 2023)

7. Buffalo Skin

Buffalo leather has an important place in the world market. According to 2003 data, the world buffalo leather production is 833 566 tonnes, which is a very high level and offers employment opportunities to many people. Since buffalo leather is quite thick, it is a sought-after product especially in the manufacture of shoes (leather) and bags (Atasever and Erdem, 2007).

In Figure 9, the amount of leather obtained from buffaloes raised in Turkey between 1991 and 2020 is shown in the graph. In 1991, approximately 66 thousand pieces of buffalo leather were produced, while it decreased considerably until 2019 and decreased to 338 pieces, and according to the data reported in 2020, it increased suddenly to 34 thousand pieces (TUIK, 2023).

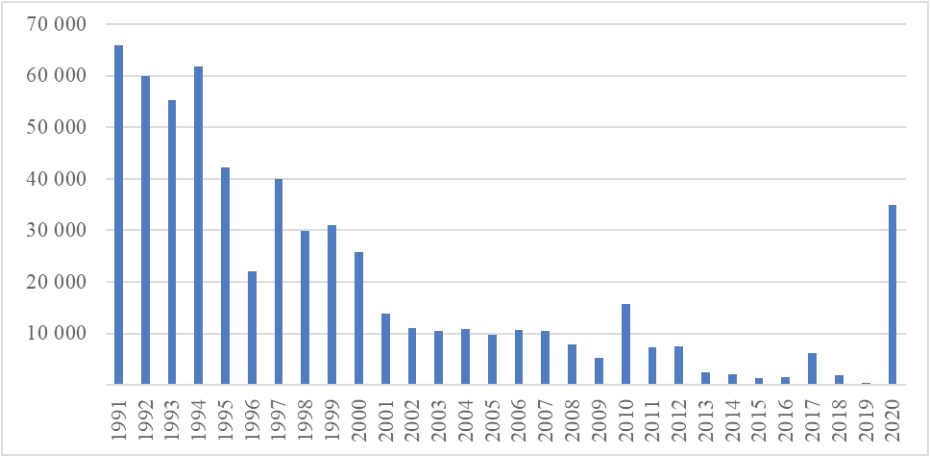

Figure 9: The amount of leather obtained from buffaloes reared between 1991 and 2020 (pieces) (TUIK, 2023)

8. Conclusion and Recommendations

In the last 60 years, buffalo population has been increasing day by day in the world, while in Turkey a rapid decline was observed until 2008. After 2008, the breeding projects implemented and the efforts to organise the breeders initially yielded successful results and an increase in the buffalo population was observed. However, in the last few years, it is worrying that buffalo presence and products have been decreasing again. Buffaloes come to the forefront as a sustainable livestock breeding branch due to their ability to utilise even poor quality roughage better than other animal species, their high adaptability to all kinds of climatic conditions, and the fact that they can be cultivated extensively (Atasever and Erdem, 2007; Şahin et al., 2013). It also provides an advantage in terms of consumers' expectation of organic products. In this direction, it is unlikely to be abandoned at once, but unless measures are taken, there is a danger that buffalo breeding will decrease day by day.

The data on buffalo and buffalo products in Turkey are well below the values reported for developed countries. Measures should be taken to increase the contribution of buffalo breeding in the country's animal husbandry and to raise it to the level of developed countries.

The data on buffalo and buffalo products in Turkey are well below the values reported for developed countries. Measures should be taken to increase the contribution of buffalo breeding in the country's animal husbandry and to raise it to the level of developed countries. The efforts to protect the buffalo population, which has been decreasing over the years, as a gene source should be accelerated.

The milk yield of buffaloes in Turkey is low. In order to increase the milk yield of buffaloes, the breeding activities initiated in the regions where buffalo breeding is intensively carried out should be extended.

In response to consumers' demand for organic products, the production of organic buffalo products should be encouraged and additional support should be given to the breeders producing these products. In particular, studies should be carried out to ensure that products such as milk and cream are labelled as organic brands and produced in accordance with food safety and find a market at their real value. In addition, products obtained from buffalo milk should be diversified (such as Italy's Mozerella cheese, Afyon's Turkish delight made from buffalo cream) and incentive supports should be provided to existing facilities that process buffalo milk into various dairy products or new enterprises to be established for this purpose.

The leather obtained from buffaloes has an important place in the leather industry due to its species-specific thickness. However, buffalo leather cannot be marketed at its real value in domestic and foreign markets. In this direction, additional premium supports can be given to encourage the producers, as well as the promotion and branding of the products made with buffalo leather will be effective to encourage the consumers.

Consumer awareness raising activities that can eliminate prejudices about buffalo meat should be increased. In order to increase the production of buffalo meat, which contains less saturated fat and lower cholesterol, consumer awareness raising policies should be implemented. The increase in studies on buffalo meat and especially the fact that the meat obtained from buffaloes can compete with beef has also added attraction to this sector of animal husbandry. However, today, buffalo meat is obtained from old animals that have reached the end of the milk yield period. It is true that directing the breeders to produce buffalo meat will add vitality to the buffalo meat sector.

Buffalo breeding is carried out under inadequate care and feeding conditions. On the one hand, while efforts are being made to increase the number of buffaloes and the products obtained per buffalo, on the other hand, the breeders should be trained on proper care and feeding.

9. References

Abdel-Hamid, M., Huang, L., Huang, Z., Romeih, E., Yang, P., Zeng, Q.,Li, L. (2023). Effect of Buffalo Breed on the Detailed Milk Composition in Guangxi, China. *Foods*, *12*(8), 1603.

Adkinson, A. Y.,Konca, Y. (2021). Manda eti üretimi ve kalite özellikleri. *Avrupa Bilim ve Teknoloji Dergisi*(31), 420-428.

Astuti, T., Sari, R.,Santoso, U. (2019). The effectiveness of forage and balanced concentrate feeding on the nutritional values and performance of buffaloes. *Buffalo Bulletin*, *38*(2), 285-290.

Atasever, S.,Erdem, H. (2007). Manda yetiştiriciliği ve Türkiye'deki geleceği. *Anadolu Tarım Bilimleri Dergisi*, *23*(1), 59-64.

Çelik, Ş. (2015). Türkiye'de büyükbaş hayvan sayıları ve nüfus arasındaki nedensellik ilişkisi. *Adıyaman University Journal of Science*, *5*(1), 80-93.

Doğdaş, İ. A. (2021). *Yozgat ilinde manda yetiştiriciliği, Yüksek Lisans Tezi, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara*

Ermetin, O. (2020). KOP bölgesinde manda yetiştiriciliği ve önemi. *Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *3*(2), 164-171.

FAO, (2015). Food and Agriculture Organization, *Buffaloes*. https://www.fao.org/livestock-systems/global-distributions/buffaloes/en/

FAO, (2023). Food and Agriculture Organization, https://www.fao.org/faostat/en/#compare

Gazete, R. (2004). Aralık 2004 Tarih ve 25668 Sayılı Resmi Gazete. *Yerli Hayvan Irk ve Hatlarının Tescili Hakkında Tebliğ*.

Irurueta, M., Cadoppi, A., Langman, L., Grigioni, G.,Carduza, F. (2008). Effect of aging on the characteristics of meat from water buffalo grown in the Delta del Paraná region of Argentina. *Meat Science*, *79*(3), 529-533.

Khan, A. A.,Coskun, M. (2018). Water buffalo production in Turkey part 1: global trend and geographical distribution. *Livestock*, *23*(1), 32-38.

Khan, I. T., Nadeem, M., Imran, M., Ayaz, M., Ajmal, M., Ellahi, M. Y.,Khalique, A. (2017). Antioxidant capacity and fatty acids characterization of heat treated cow and buffalo milk. *Lipids in health and disease*, *16*(1), 1-10.

Moioli, B.,Borghese, A. (2005). Buffalo breeds and management systems. *Buffalo production and research. Rome: Food and Agriculture Organization of the United Nations*, 51-76.

Nanda, A. S.,Nakao, T. (2003). Role of buffalo in the socioeconomic development of rural Asia: Current status and future prospectus. *Animal Science Journal*, *74*(6), 443-455.

Naveena, B.,Kiran, M. (2014). Buffalo meat quality, composition, and processing characteristics: Contribution to the global economy and nutritional security. *Animal frontiers*, *4*(4), 18-24.

Özkan, Z., Arslan, S., Uçum, İ., Canik, F.,Uzun, B. (2017). Yetiştiriciliği Faaliyetine Yer Veren İşletmelerin Mevcut Durum Analizi. *Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü*.

Sariozkan, S. (2011). Türkiye'de manda yetiştiriciliğinin önemi. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, *17*(1), 163-166.

Sarwar, M., Khan, M., Nisa, M., Bhatti, S.,Shahzad, M. (2009). Nutritional management for buffalo production. *Asian-Australasian Journal of Animal Sciences*, *22*(7), 1060-1068.

Soysal, İ., Kök, S.,Gürcan, E. (2005). Mandalarda alyuvar potasyum polimorfizmi üzerine bir araştırma. *Tekirdağ Ünivi Zir Fak Derg*, *2*(2), 189-193.

Soysal, M. (2006). Manda ve Ürünleri Üretimi: Ders Notları. *Tekirdağ Üniversitesi, Tekirdağ*.

Soysal, M. İ. (2013). Anatolian water buffalo husbandry in Turkey. Buffalo Bulletin, 32(Special Issue 1): 293-309.

Şahin, A., Ulutaş, Z.,Yıldırım, A. (2013). Türkiye ve dünya'da manda yetiştiriciliği. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*(8), 65-70.

Şekerden, Ö. (2016). Her yönüyle manda. *URL: http://www. ozelsekerden. com/yukleme/sr186. pdf (8 Aralık 2023)*.

TUIK, 2023: Türkiye İstatistik Kurumu, http://www.tuik.gov.tr.

Yilmaz, A.,Kara, M. A. (2019). Dünyada ve Türkiye'de manda yetiştiriciliğinin durumu ve geleceği. *Türkiye Tarımsal Araştırmalar Dergisi*, *6*(3), 356-363.

Zicarelli, L. (2004). Buffalo milk: its properties, dairy yield and mozzarella production. *Veterinary research communications*, *28*, 127.