Mar. Sci. Tech. Bull. (2021) 10(3): 251-257
e–ISSN: 2147–9666
info@masteb.com

dergipark.org.tr/en/pub/masteb
www.masteb.com
DOI: 10.33714/masteb.922865

Marine Science and Technology Bulletin

RESEARCH ARTICLE

# The effect of different processing methods on fishmeal element quality: Evaporator system

Barış Bayraklı[1*] • Hünkâr Avni Duyar[2]

[1] *Sinop University, Vocational School, Department of Aquaculture, 57000, Osmaniye, Sinop, Turkey*

[2] *Sinop University, Faculty of Fisheries, Department of Fishing and Fish Processing Technology, 57000, Akliman, Sinop, Turkey*

**ARTICLE INFO**

Article History:
Received: 20.04.2021
Received in revised form: 21.06.2021
Accepted: 21.06.2021
Available online: 25.06.2021

Keywords:
*Anchovy*
*Black Sea*
*Elements*
*Evaporator*
*Fishmeal*

**ABSTRACT**

Anchovy (*Engraulis encrasicolus* L., 1758) is the main source of fishmeal in Turkey. The research was carried out in 3 fishmeal factories where anchovy is processed in the Black Sea during the 2007-2008 fishing season. Factories A and B have an evaporator system, while factory C does not have an evaporator system. In the study, it was aimed to reveal the effect of the evaporator system on the mineral substance quality of the fishmeal produced in fishmeal oil factories. As a result of this study, the elements in fishmeal are listed in descending order as Ca>P>K>Na>Mg>Fe>Zn>Mn>Cu. According to the results of the research, it was determined that the phosphorus, sodium, potassium, calcium and zinc values of fish fishmeal produced in A and B factories using evaporator system were higher than the C factory without an evaporator system, and the difference between factories was statistically significant ($P<0.05$). It is recommended that all factories have an evaporator system in order to produce fishmeal of higher quality (protein and mineral substances) in fishmeal-oil factories.

**Please cite this paper as follows:**

Bayraklı, B., & Duyar, H. A. (2021). The effect of different processing methods on fishmeal element quality: Evaporator system. *Marine Science and Technology Bulletin*, *10*(3), 251-257. https://doi.org/10.33714/masteb.922865

## Introduction

The consumption rate of seafood, which is very significant in the healthy food of people, is constantly increasing (Bayrakli & Duyar, 2021). Fish is one such source that provides 17% of animal protein to the world's population (Halden et al., 2014). Given the forecasted 9 billion in world population by the year 2050, fish becomes an indispensable reliable source of nutrients as aquaculture is also fast-growing (Halden et al., 2014; FAO 2014). In this increase, the contribution of aquaculture is too much to underestimate (Tidwell & Allan, 2001; Duyar & Bayraklı, 2005).

In the world, approximately 96.5 million tons/year of aquaculture is obtained by fishing (FAO, 2020). While it is assumed that there will be a reduction due to both overfishing

* Corresponding author
E-mail address: bbayrakli@sinop.edu.tr (B. Bayraklı)

and pollution in the coming years; it is thought that the nutritional needs of people will be met by aquaculture obtained through aquaculture. The aquaculture sector has caught the amount of fishing today by catching a rapid rise after the fish and shrimp producers used fishmeal and oil in their feed mixes in the 1980s (Ruiter, 1995; Bayraklı & Duyar, 2019a). The increase in aquaculture also increases the demand for fishmeal and oil (New & Wijkströem, 2002).

The composition of commercial feeds used in feeding cultured fish also affects the mineral composition of the fish. Minerals represent a minor proportion in the feeds' composition. However, they are required in almost every aspect of animal metabolism. Minerals are classified as macro elements that the body needs in large quantities or microelements that the body needs in small quantities (FAO, 2017). Macro elements include phosphorus, calcium, potassium, magnesium, sodium, chlorine, and sulfur, while microelements are composed of copper, zinc, manganese, iron, cobalt, and iodine, among others (Antony et al., 2016; FAO, 2017).

Minerals such as calcium, phosphorus, magnesium, sodium, potassium, sulfur, chlorine, iron, copper, cobalt, iodine, manganese, zinc, molybdenum, selenium, and fluorine play a role in biological functions as elements or compounds (Makwinja & Geremew, 2020). If these mineral substances are not taken with the feed, they may be the cause of development and disease in the fish that are fed (Bilal & Dryer, 2021).

Minerals in food are present depending on salt and proteins (such as phosphorus in phosphoproteins and metal ions in enzymes). Minerals in foods are very important not only in terms of nutritional physiology but also in terms of taste (Telefoncu, 1993). Mineral composition in marine organisms varies according to seasonal and biological differences (species, height, black and white muscle, sex, sexual maturity), fishing area, processing method, food source, environmental impact (water chemistry, salinity, temperature, and contamination) (Rodrigo et al., 1998; Alasalvar et al., 2002). Fish meats are a valuable source of calcium and phosphorus, as well as zinc, iodine, potassium, iron, copper, magnesium, and selenium (Pigott & Tucker, 1990; Sikorski et al., 1990).

Each year, about 20 million tons of raw materials come from whole fish, shellfish, wild fish by-products, and farmed fish by-products. These raw resources can produce about 5 million tons of fishmeal, about 1 million tons of fish oil (Bayraklı & Duyar, 2019b).

Almost all fishmeal is made by cooking, pressing, drying, and grinding the fish in machinery designed for the purpose. Although the process is simple in principle, considerable skill and experience are necessary to obtain a high yield of high-quality products and to make the plant efficient. A typical process is shown diagrammatically in Figure 1.

In fishmeal oil factories, first separation and then evaporation processes are carried out in order to separate the aqueous, oily, and solid parts from each other after the pressing process (Figure 1). The evaporator required for this process may not be integrated into factories or sometimes not operated due to its high cost and high operating fee (Bayraklı & Duyar, 2021). It is thought that these different applications can change the element structure of fishmeal.

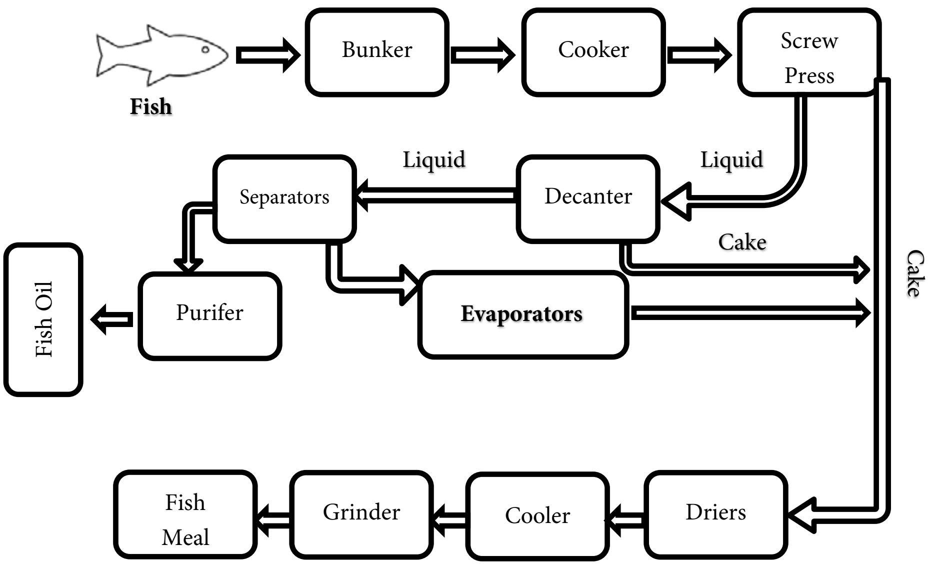


**Figure 1.** Process diagram of the fish meal-oil production line

**Table 1.** Minerals detected in fishmeal and some literature (mg $kg^{-1}$)

| | | Fishmeal | Ca | Na | K | P | Mg | Fe | Zn | Mn | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| In research | A | AM | 7114 | 10105 | 29458 | 26644 | 264.83 | 2525 | 247.62 | 16.78 | 2.20 |
| | B | AM | 6391 | 10940 | 29360 | 24608 | 324.12 | 2146 | 253.04 | 20.12 | 2.21 |
| | C | AM | 4578 | 8087 | 26774 | 23976 | 291.68 | 2032 | 232.76 | 18.35 | 2.21 |
| Satoh et al. (1987) | | SA | 44300 | 3200 | 3500 | 27300 | 2000 | 239 | 141 | 11.1 | 5.4 |
| | | Fb-PM | 52200 | 8400 | 3100 | 29300 | 2800 | 97.3 | 71 | 5.2 | 11.5 |
| | | BHM | 34400 | 8300 | 13400 | 24700 | 2000 | 289 | 141 | 11.1 | 5.4 |
| Moghaddam et al. (2007) | | SM | 39700 | 8300 | 5200 | 26100 | 2700 | 229 | 74.5 | 3.7 | 6.2 |
| | | HM | 22900 | 6100 | 10900 | 17000 | 1500 | 140 | 132 | 5 | 6 |
| | | AM | 37300 | 6500 | 6900 | 24300 | 2400 | 220 | 103 | 10 | 9 |
| | | MFM | 51100 | 6500 | 6500 | 28800 | 1600 | 440 | 147 | 33 | 11 |
| Storebakken et al. (2000) | | HM | 23900 | 14500 | 12200 | 22100 | 2640 | 155 | 121 | 5 | 3.26 |
| Cho et al. (1987) | | AM | 6772 | 20630 | 7143 | | 2222 | 3598 | 167 | | 6 |
| | | KFM | 10900 | 8801 | 7453 | | 2954 | 4092 | 190 | | 163 |
| Zarkadas et al. (1986) | | HM | 19500 | 4200 | 12000 | 15000 | 1100 | 100 | 100 | 30 | |
| Irungu et al. (2018) | | FWSM | 3932.4 | 21246.1 | 10065.2 | 4385.8 | 2191.5 | 922.2 | 454.9 | 1932.1 | 1512.5 |
| | | ACM | 1600.7 | 22633.6 | 6542.5 | 6542.5 | 1467.7 | 931.9 | 566.4 | 3126.1 | 1628.8 |

***Note:*** AM: Anchovy meal, Fb-PM: Fish by-products meal, BHM: Brown fish meal, SA: Sardine meal, SM: Shrimp meal, HM: Herring meal, MFM: Menhaden fish meal, KFM: Kilka fish meal, HFM: Hake fish meal, FWSM: Freshwater shrimp meal, ACM: Adult cricket meal.

It is very important to know the element structure of fishmeal, which is the raw material of fish feed, which is essential especially in aquaculture. In this study, the effect of the evaporator system found in some fishmeal-oil factories on the mineral amount of fishmeal produced was investigated.

## Material and Methods

### *Material*

The research was carried out in 3 fishmeal factories that process anchovy (*Engraulis encrasicolus L.*), which were caught in the Black Sea during the 2007-2008 fishing season. Factories A and B have an evaporator system, while factory C does not have an evaporator system. Factories operate in the same area. Since anchovy is a type of fish that feeds, wintering, and breeding in the north-south and east-west directions in the Black Sea (Özdemir et al., 2010), the fish used in the research are also the material that is caught from the same region.10 pieces of 1 kg fishmeal samples were taken from each factory on the same day and delivered to the laboratory for analysis.

### *Analytical Technique*

For mineral substance analysis, homogenized fishmeal samples were weighed 0.1 g in high pressure resistant teflon containers (10ml volume, 200 psi pressure-resistant), then 4ml nitric acid (65%) (Merck, 1.00452) was added to them. Wet combustion was applied to Teflon containers in a closed system microwave oven. In the first 15 minutes, a temperature of 150°C was reached gradually, and it was kept at this temperature for 5 minutes. After the pressure dropped below 50 psi, the temperature was allowed to reach 250°C within 15 minutes and it was kept for 5 minutes under these conditions. After waiting for cooling at the end of wet burning, the burned samples were washed with ultrapure water, taken into 14 ml falcon tubes, and completed with ultrapure water. Then, readings were made on the Perkin Elmer ICP-OES Optima 2100 DV spectrometer as stated in EPA (1994).

### *Experimental Plan and Statistical Analysis*

A wholly randomized experimental design was used. Data were exposed to analysis of one way variance and Duncan's multiple range tests using the SPSS version 15 statistical package adapted to a personal computer.

## Results and Discussion

The composition of commercial feeds used in feeding the cultured fish affects the mineral composition of the fish (Çaklı, 2007). In this study, the element content of fishmeal obtained from 3 factories was determined

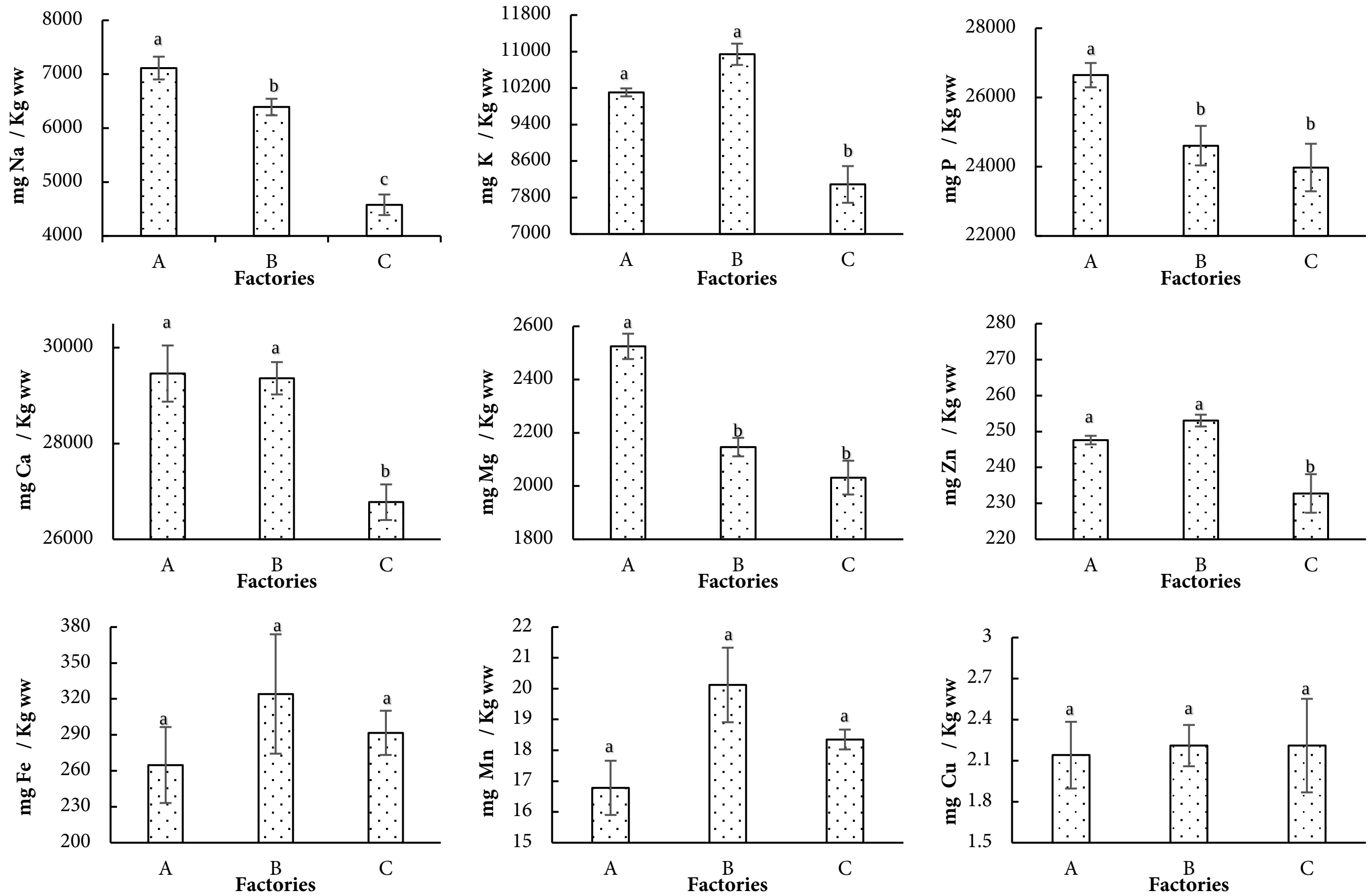


**Figure 2.** Mineral maters were detected in A, B, and C fishmeal factories (Different lowercase letters (a - c) in succession indicate significant differences ($p<0.05$) between A, B, and C factories that process fishmeal by different methods)

(Ca>P>K>Na>Mg>Fe>Zn>Mn>Cu). The findings of the researchers who reported the mineral substance values obtained in the study and the mineral substance amounts in fishmeal obtained from different raw materials are shown in Table 1. All researchers reported that there are the most calcium and phosphorus minerals in fishmeal, followed by sodium, potassium, and magnesium minerals. These results are similar to our study. The reason why different researchers find the same mineral values different is because of the seasonal and biological differences (species, height, dark and white muscle,sex, sexual maturity, breeding time, water chemistry, salinity, temperature) in marine organisms, the method of processing, fish (Bayrakli, 2021). It can be said that the fishmeal varies depending on whether it is made from whole fish or from processing waste.

As seen in Figure 2; from the mineral matter analysis results of fish meal produced in A, B and C factories for P (26644.25±351, 24608.38±570, 23976.38±686 mg kg$^{-1}$ ww), Na (7114.42±211, 6391.44±153, 4578.31±190 mg kg$^{-1}$), K (10104.75±870, 10939.75±233, 8086.88±402 mg kg$^{-1}$ ww), Ca (27256.36±586, 29360.65±337, 26774.74±372 mg kg$^{-1}$ ww), Zn (247.62±120, 253.04±1634 and 232.76±536 mg kg$^{-1}$ ww) were found, respectively. As a result of the mineral matter analyzes performed on fish meal produced in A, B, and C factories, Ca, P, K, Na, and Zn elements in A and B factories with an evaporator system were found to be significantly higher than the C factory. The difference between factories with and without evaporator systems was found to be statistically significant ($p<0.05$). Cu element was found similar in all three factories, statistical difference between factories was found to be insignificant.

The statistical difference between the factory groups of the average Fe, Mn, Cu elements (average 293.55±20.343, 18.42±0.565, 2.18±0.142 mg kg$^{-1}$ ww, respectively) in fishmeal produced in A, B, and C factories was found to be insignificant ($p>0.05$).

Especially in A and B plants using evaporators, phosphorus, sodium, potassium, calcium, and zinc were found to be of high quality compared to C factory, which does not use an evaporator system, as much as the difference between the couple is statistically significant ($p<0.05$). While the cake piece goes directly to the dryer as a result of the press operation from the fishmeal processing stage, the liquid cake part goes to the evaporator and the solid release is included after the


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evaporation. Due to this process, more information on sodium, potassium, calcium, and zinc is obtained in factories with evaporators. In the factory that does not use an evaporator system, these minerals are left as waste after oil is taken. P, Na, K, Ca, and Zn elements that dissolve in water and have nutritious properties remain on the cake as a result of the evaporation of the water in the evaporator and are added to the fishmeal. In this way, the evaporator system contributes 3.5-4% to the total fishmeal (Duyar & Bayraklı, 2005).

## Conclusion

Fishmeal is also a valuable source of the minerals sodium, calcium, phosphorous, magnesium, potassium and of trace elements, notably zinc, iron, copper and manganese. The significance of trace minerals as essential ingredients in diets, although in small quantities, is also evident in fish. Minerals are required for usual life processes, and all animals, with fish, need these elements. Fish may derive these minerals from the diet and also from ambient water. The minerals are accountable for the skeletal formation, conservation of colloidal systems, regulation of acid-base equilibrium, and biologically important compounds such as hormones and enzymes. Mineral deficiencies can cause biochemical, structural, and functional pathologies which depend on some factors, including the duration and degree of mineral lack (Watanabe et al., 1997).

Marine resources used to produce fishmeal and fish oil are finite resources that have been fully utilized for decades. Aside from higher recovery and utilization of seafood processing byproducts, there is no prospect of increasing fish meal and fish oil production from wild stocks of marine fish (Naylor et al., 2009). Fish meal is a complex material containing a wide array of essential nutrients and biologically active compounds, many of which are absent in plant proteins.

It is getting harder and harder to reach raw materials every day. There is an obligation to process our raw materials in a more efficient and beneficial way for consumers by using constantly developing technologies (Bayraklı & Duyar, 2019b). Phosphorus, potassium, calcium, sodium, and zinc minerals detected in fishmeal were found to be high in factories operating with evaporator systems. It has been determined that the evaporator system increases both the amount and quality of the final product obtained from the raw material for fish meal and oil factories. For these reasons, it is recommended that all fish meal oil factories have and use an evaporator system.

## Acknowledgements

This study was supported by the Technical Research Council of the Turkish Republic (TUBITAK, Project no: TOVAG-108O0087).

## Compliance With Ethical Standards

### *Authors' Contributions*

Author HAD designed the study and wrote the first draft of the manuscript, BB performed and managed statistical analyses. All authors read and approved the final manuscript.

### *Conflict of Interest*

The authors declare that there is no conflict of interest.

### *Ethical Approval*

For this type of study, formal consent is not required.

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