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# Evaluation of Fish By-Products Meal Emerging as a Result of Aquaculture and Fish Processing Industry by using the Flash Dryer System

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## ABSTRACT

In this study, convertibility of the fish by-products (FBP) emerging after processing the trout (*Oncorhynchus mykiss*), sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*) produced by aquaculture into a raw material that can be used in fish feed ingredient by means of a system called flash dryer has been researched. Before being subjected to drying and grinding in the flash dryer system, the FBP have been passed through the press and decanter, and it has been endeavored to separate the liquid part to the extent possible and to store them separately. At the end of the study, the fatty acids content in the liquid part, the nutrient content, amino acid and fatty acid profile in the solid part have been analyzed. According to the results obtained, it was observed that the solid part could not be used commercially by substituting the fish meal in a rate of one-to-one, and that it could be included in the formulation as a second class raw material although it is not as valuable as fish meal in terms of amino acid balance.

## INTRODUCTION

Aquaculture has become a very important industry in the world. The total world fish production has reached 167.2 million tons and 73.8 million tons of this amount is produced by aquaculture. Whereas 146.3 million tons of the total production amount can be used for human nutrition, the 20.9 million-ton part of it cannot be classified as food. It is stated that the non-food quantity is used as fish meal and oil at a rate of 75 % (FAO, 2016).

In aquaculture, the activities related to fish feed and feed supply constitute more than half of the expenses of a business (Rana *et al*., 2009). Among the most important reasons of this, the presence of oil resources containing high crude protein requirement and a balanced fatty acids profile that should be included in the feeds of the species such as trout, sea bream and sea bass which possesses a carnivorous nutrition property (Glencross *et al*., 2007). The most important of the raw materials that bring together these two features are the fish meal and fish oil (Tacon and Metian, 2008). The fish meal and oil used in the aquaculture studies and feed production activities carried out in many countries of the world are largely imported from the South American countries such as Peru and Chile. Nevertheless, the significant increase in the world population and human's need for cheap protein sources has increased the necessity of using more fish and aquatic species in human nutrition, and while the tonnage of the products allocated to make fish meal and fish oil has decreased, their prices have shown a significant increase (Hardy, 2010). The scientists working on fish feed continue to examine the new products that can be used instead of these two raw materials; however, both fish meal and fish oil continue to maintain their current importance (Hasan, 2001; Gatlin *et al*., 2007).

Fish processing technology, which continues its development in parallel with aquaculture, can provide different forms and sensory features by making the products gain substantial added value except for use as fresh and frozen fish (Merkle *et al*., 2016). Nevertheless, in the cleaned, fillet and smoked fish species, FBP emerge in a rate of 30-45% depending on the style of the process, as well and it is the non-economical and residue part of the industry (Alder *et al*., 2008). Generally, the structure of FBP is explained that it must consist of non-rendered, clean undecomposed portions of fish (such as, but not limited to, heads, fins, tails, ends, skin, bone and viscera) which result from the fish processing industry (Tacon *et al*., 2009). As a result of various ways of processing this FBP arising from fish processing technology can be used instead of fish meal and oil to some extent (Hirai, 2001; Li *et al*., 2004; Bell and Waagbø, 2008).

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As can be seen from the descriptions above, a significant amount of FBP emerge as a result of the activities arising from aquaculture and processing technology. Removal of them from the facility gives rise to loss of both time and money, and at the same time, brings with it a series of significant adherence to government mandated legislation. In these business facilities continuing an intense production work, re-usability of the FBP as a raw material of fish feed by recycling them seems to be possible (Westendorf, 2000; Huntington and Hasan, 2009; Ming-Hung *et al*., 2016). At the present day, the most important of these systems creating this recycling and providing a gain to the economy by enabling the reuse of the rest products are the systems called Flash Dryer (Ezhil, 2010; Jangam, 2011; Jangam and Mujumdar, 2015). This system is an easily installed and low cost recycling system that can convert the waste products emerging from both processing technology and also production in different fields of aquaculture into flour and oil form with no need to make any classification.

Within the scope of this study, the operation principles of the flash dryer system have been given, and comparisons of the meal and oil form obtained by using this system with the nutrient profile of commercial fish meal and fish have been made.

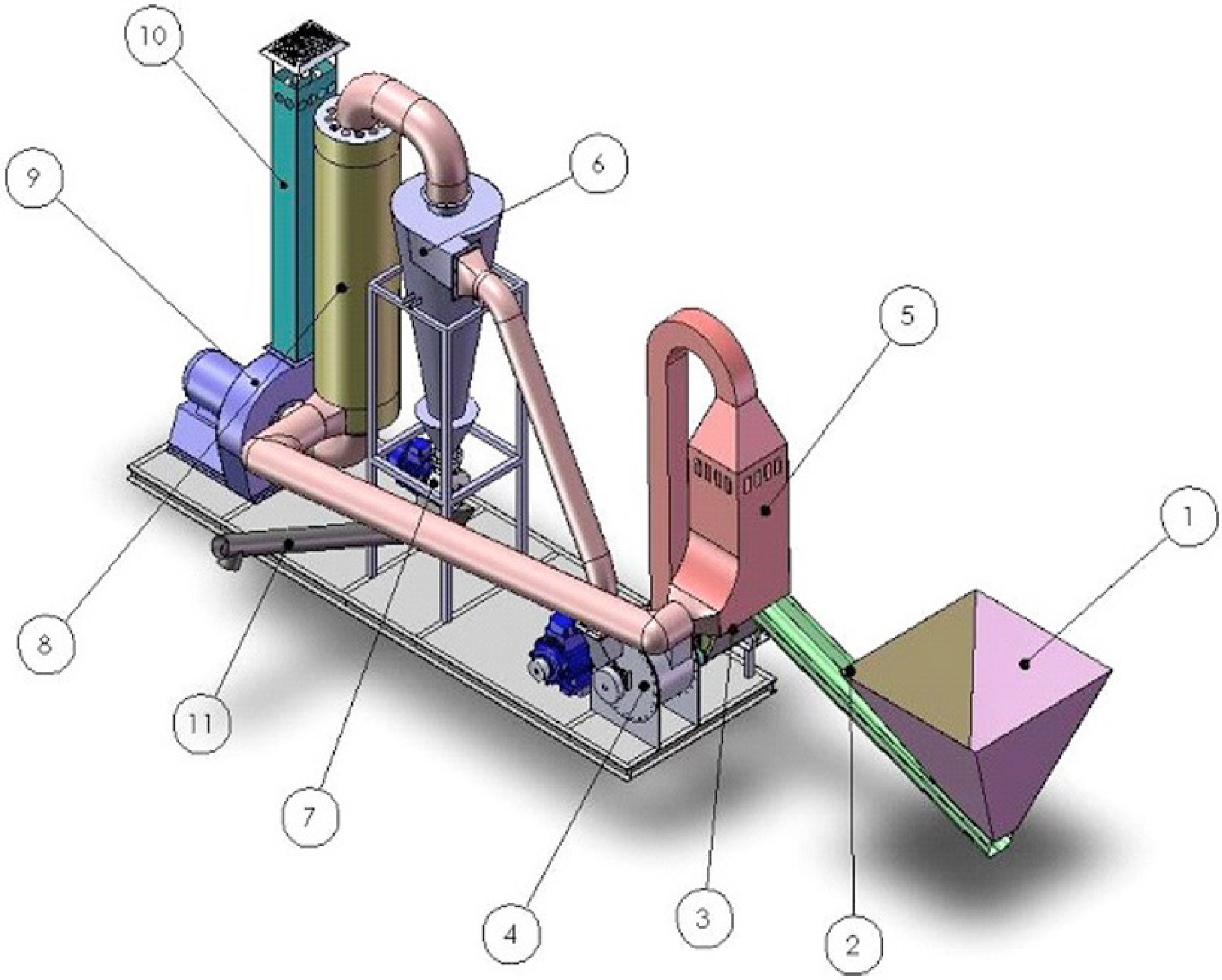


Fig. 1. The principle of operation of the flash dryer system. The fish wastes are poured into the bunker slurry **(1)**. After that, they are carried into the drying system with a double helix **(2)**. They are taken into the dehydrator for drying of the product **(3 and 4)**. Hot air intake is provided into the system with the help of a burner **(5)**. Decomposition of the dried product and its being dropped is ensured **(6)**. The entrance of air into the system from outside is prevented and the drying efficiency shall be brought to an upper level **(7)**. The hot air that is dormant in the system is taken into circulation again and the moist air is thrown out **(8, 9, and 10)**. Finally, carrying the dried product to the desired point is ensured **(11)**.

## MATERIAL AND METHODS

*General working principle of the flash dryer system*

The overall appearance of the flash dryer system used within the scope of this study was manufactured by KTS Drying Systems Co. Ltd., Izmir, Turkey and parts of the system are given in Figure 1. Daily product processing capacity is 6,000 kg. A 250-KW burner has been used to provide the heat energy requirement of the system, and the energy that can be given by this unit is 215.000 kcal.

*Drying the rest of seafood processing and transforming them into raw materials*

The studies within the scope of drying the FBP and converting into raw material in the flash dryer system have been carried out in a private aquatic products processing plant operating in the Province of Adana - Turkey. The fish whose excess have been used in this study are rainbow trout (*Oncorhynchus mykiss*), gilthead sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*). When we look at the overall rate of the products being processed, sea bass has been used at a rate of 50%, sea bream at a rate of 30% and trout at a rate of 20%. The total amount of rest products used in the experiments is 25 tons. The residual products remaining from the process were kept at 0°C in the cold storage depot of the business enterprise for a period of 1 week. The FBP were divided into 600 kg batches for the drying and grinding process in the flash dryer system. The drying and grinding temperature of the system has been set to 300°C. Firstly, the products were passed through a decanter to separate the liquid/oil content of the waste products, after that, they were pressed, and finally, the cake product was conveyed to the flash dryer system. This separation process both ensures the final product to be dried faster and more easily, and also a by-product like a fish oil is obtained by separating the liquid and oil part from the FBP. The time that passes from pouring the FBP to the processing chamber until they are brought into the form of a flour is 75 seconds in total. The dried and grinded products were taken into a cold air unit at +4°C, and they were stored here for a period of one week. One kg of sample was taken for each of the lots that were stored under the same conditions before and after the processing, and that were passed through the flash dryer system under the same conditions, and these samples were blended and mixed in the laboratory. Out of the mixture, 1 kg was sent to the laboratory for sample food substance analyses (moisture, crude protein, crude fat, crude ash, calcium and phosphorus), 1 kg for sample amino acid analyses and 1 kg sample for fatty acids analyses.

All of the analyses within the scope of the study were made in Adana Directorate of Food Control Laboratory of the Turkish Ministry of Food, Agriculture and Livestock. The method determined by AOAC (2005) was used for the nutrient analyses, the method used by Boonyoung *et al*. (2013) was used in the amino acid analyses, and the method specified by Kabeya *et al*. (2014) was used in the fatty acids analyses.

## RESULTS AND DISCUSSION

Nutrient content of the meal form obtained from the products which are processing FBP are moisture (8.7%), crude protein (65.2%), crude fat (5.6%), ash (13.7%), Ca (1.29%) and P (1.49%). According to the results obtained, crude protein content of the meal produced from the FBP was found to be 65.2% in average. This value is lower than the average crude protein content of the fish meal produced from anchovy (66.7%), herring (67.7%), mackerel (72.7), tuna fish (65.4%), sardines (62.2) and cod (68.1%), respectively (NRC, 1983; Tacon, 1987; Anderson *et al*., 1993; Fenucci, 2007; Weimin and Mengqing, 2007; Catacutan, 2012). However, it is higher than the average crude protein values of the meal form produced from the residuals emerging from processing the salmon fish farmed (63.5%), those of the flour produced from the residuals of the shrimp heads (46.6%), and those of the squid liver meal (50.3%) (Hertrampf and Pascual, 2000; Williams *et al*., 2005; Sumagaysay-Chavoso, 2007; Weimin and Mengqing, 2007).

When the crude fat content of the products which are the processing FBP is examined, the value found is 5.6% in average. This value is lower than the value of crude fat which is the subject of other commercial fish meal (NRC, 1994; Yavuz, 2001). Separating the liquid part from the solid part substantially by using decanter and press before starting the meal production in the flash dryer system can be shown among the most important reasons for this. Despite the fact that this study means drying the meal form faster and it's being packed, it also means that the product's crude oil content is reduced.

Calcium and phosphorus contents of the meal form obtained from the product which is the processing FBP have been found 1.29% and 1.49%, respectively. It can be said that these values are much lower than the fish meal obtained from anchovy (3.89% and 1.95%), herring (5.73% and 3.15%), mackerel (2.12% and 1.55%), tuna fish (7.86% and 4.21%) and sardines (4.44% and 2.72%). As known, calcium is a very important element in the skeletal system of fish. Hence, compared with the efficiency of the raw material of commercial fish, this product will have to be reinforced in terms of calcium content. Phosphorus is an element that plays an important role in sustainable aquaculture production today. In the primary production, it is one of the basic building blocks of plant-based foods. In intensive aquaculture, the existence of the plant-based creatures in the environment must be reduced as much as possible to provide superior water quality to fish, in particular, to provide high dissolved oxygen values. For this reason, the meal produced from FBP can help the integration of aquaculture with the environment (Tacon *et al*., 2009).

The essential amino acid contents of the meal form have been given in Table I. The essential amino acid contents of the meal form produced from the FBP have been found to be low compared with the amounts of amino acids obtained from other commercial fish meals except histidine and tryptophan.

**Table I.- Comparison of amino acid profiles of the FBP meal obtained from fish processing and commercial fish meals (%) (Tacon *et al*., 2009*).**

| Amino Acid | FBP meal | Anchovy* | Menhaden* | Herring* |
|---|---|---|---|---|
| Arginine | 3.05 | 3.75 | 3.66 | 4.48 |
| Cystine | 0.62 | 0.62 | 0.56 | 0.72 |
| Methionine | 1.18 | 1.96 | 1.76 | 2.13 |
| Threonine | 2.22 | 2.79 | 2.46 | 2.99 |
| Isoleucine | 2.05 | 3.05 | 2.84 | 3.18 |
| Leucine | 2.97 | 4.98 | 4.56 | 5.32 |
| Lysine | 3.51 | 5.06 | 4.71 | 5.50 |
| Valine | 2.10 | 3.49 | 3.24 | 4.19 |
| Tyrosine | 0.85 | 2.21 | 1.95 | 2.22 |
| Tryptophan | 1.44 | 0.76 | 0.66 | 0.80 |
| Phenylalanine | 1.53 | 2.72 | 2.43 | 2.77 |
| Histidine | 2.10 | 1.57 | 1.44 | 1.70 |

The fatty-acid content of liquid-oil part of the FBP separated by passing through decanter and press before putting into flash dryer system has been given in Table II.

According to the analysis results obtained and the detectable fatty acids content of the liquid part separated from the FBP, the content of the saturated and polyunsaturated fatty acids has been found high, the content of the mono-saturated fatty acids, however, have been found low compared with commercial fish oils.

## CONCLUSIONS AND RECOMMENDATIONS

Cleaning of the fish species obtained by means of aquaculture breeding in a significant amount in processing facilities, putting them on sale by preparing them as fillets and smoked, ensures the generation of products with more value-added compared to fish consumed as fresh and contributing to the national economy to a considerable extent. Contrary to the economic satisfaction brought by the subject, removal of the FBP emerging as a result of these processing activities and generating almost 40% of the processed products from the facilities is seen as a major problem. The problem can be turned over in an advantage with the flash dryer systems. Indeed, the information in the literature reviewed supports the fact that the use of this system is one of the most viable options in terms of transforming the aquatic products processing technology residuals into raw material.

**Table II.- Comparison of fatty acid contents of the liquid/oil part separated from the FBP and commercial fish meals (g/100g) (Tacon *et al*., 2009*).**

| Fatty acid | FBP oil | Herring oil* | Menhaden oil* | Sardine oil* |
|---|---|---|---|---|
| Saturated (total) | 35.69 | 19.71 | 26.88 | 27.16 |
| Lauric (C12:0) | 0.06 | NR | NR | 0.10 |
| Tridecanoic (C13:0) | 0.07 | NR | NR | NR |
| Miristic (C14:0) | 6.80 | 7.19 | 7.96 | 6.52 |
| Pentadecanoic (C15:0) | 1.19 | NR | NR | NR |
| Palmitic (C16:0) | 20.70 | 11.70 | 15.15 | 16.65 |
| Heptadecanoic (C17:0) | 1.59 | NR | NR | NR |
| Stearic (C18:0) | 3.76 | 0.82 | 3.77 | 3.89 |
| Arachidic (C20:0) | 0.91 | NR | NR | NR |
| Heneicosenoic (C21:0) | 0.32 | NR | NR | NR |
| Behenic (C22:0) | 0.29 | NR | NR | NR |
| Monosaturated (total) | 0.7 | 13.62 | 1.33 | 5.99 |
| Miristoleic (C14:1) | 0.25 | NR | NR | NR |
| Gadoleic (C20:1) | 0.34 | 13.62 | 1.33 | 5.99 |
| Nervonic (C24:1) | 0.11 | NR | NR | NR |
| Polyunsaturated | 35.69 | 11.63 | 23.88 | 22.81 |
| Elaidic (C18:2n6) | 2.64 | 1.15 | 2.15 | 2.01 |
| Eicosadienoic (C20:2) | 1.94 | NR | NR | NR |
| Eicosatrienoic (C20:3n6) | 0.34 | NR | NR | NR |
| Decosadieonic (C22:2) | 0.32 | NR | NR | NR |
| Eicosapentaeonic (C20:5n3) | 10.83 | 6.27 | 13.17 | 10.14 |
| Decosahegsaenoic (C22:6n3) | 19.62 | 4.21 | 8.56 | 10.66 |

In addition to this, it can also be predicted that the meal form which is the subject of raw material transformation can reduce the use of fish meal to a certain extent with its nutrient content, although it cannot completely replace fish meal. When we examine the essential amino acid contents of the raw material obtained along with this, lower levels than commercial fish meal are encountered. As it is known, no matter how high the crude protein content of a raw material is, if the amino acid balance does not have the balance needed by the fish, the percentage of utilization of the protein content will remain in low levels. This situation is an issue that can bring up the use of the flour produced from the rests instead of the fish meal, or addition of a synthetic amino acid in cases where fish meal will be substituted up to certain proportions.

In this type of recycling systems, thanks to passing the FBP through the decanter and press first before being sent to the flash dryer system, not only a raw material close to fish oil can be obtained by separating the liquid and oil part in the product, but also the time that passes for drying and grinding the product can be significantly reduced. In the results of the study, the fact that the ratio of polyunsaturated fatty acids in the liquid part was found higher when compared to the commercial fish oils supports this idea.

Flash dryer is a fast and economical system that can be used in recycling the FBP; however, the most important issue to keep in mind while using this system is the fact that the nutrient contents of the recycled raw materials to be produced will constantly change depending on the type and amount of the rest products entered into the system at the beginning. For this reason, if the recycled raw materials are to be used by a fish feed factory, they will need to be used in the formulation after each recycled raw material that enters into the factory after it is analyzed up to its basic building blocks.

Up to the present day, no work has been carried out regarding the shelf life of the raw materials recycled with the flash drier system. Therefore, studies related to their shelf life and the period of availability of the product will need to be given weight with the use of such raw materials becoming widespread.

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*Statement of conflict of interest*

Authors have declared no conflict of interest.

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