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Producing Silage from the Industrial Waste of Fisheries

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Abstract
The aim of this study was to highlight the potential economic benefits of fisheries industrial waste silage by the dint of its ability to be recycled efficiently in animal feed. Fish silage was produced by acid hydrolysis. The fish silage was ripened and became half-liquid, at room temperature in 12 days. Its odour became less pungent and was deemed to have an acceptable malt smell. The silage cost was found to be 0.72 TL/kg. The results of this study established that, the use of silage instead of fish meal, reduces the cost of feed by 21%. Therefore fish waste products, previously considered as a refuse and causing environmental pollution, can be reintegrated into the economy.
Keywords: Fish meal, fish silage, silage composition, sustainability.

Su Ürünleri İşleme Sanayi Atıklarından Silaj Yapılması
Özet
Bu çalışmada su ürünleri işleme sektörünün yıllardır sorunu olan ve defedilmesi için ekonomik maliyetlere katlanılan işleme sanayi atıklarından silaj yöntemiyle yem hammaddesi üretilip-üretilemeyeceği araştırılmıştır. Silajlamada asit hidrolizasyonu yöntemi kullanılmıştır. Silaj oda sıcaklığında 12 günde olgunlaşmış ve yarı sıvı bir hale gelmiştir. Silajın kokusunun rahatsız etmeyen ve kabul edilebilir hoş malt kokusu olduğu tespit edilmiştir. Silajın maliyeti 0,72 TL/kg olarak hesaplanmıştır. Bu çalışmanın sonuçları, silajın balık unu yerine kullanılması halinde yem maliyetini %21'e kadar azaltabileceğini ortaya çıkarmıştır. Bu çalışmayla, çöp olarak kabul edilen ve çevre kirliliği oluşturan su ürünleri işleme atıkları ekonomiye kazandırılabilecektir.
Anahtar Kelimeler: Balık unu, balık silajı, silaj kompozisyonu, sürdürülebilirlik.

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INTRODUCTION

Nowadays, effective improvement of existing and potential resources is the first priority in every field. Waste management is an important research field addressing ecological balance through the diminution of environmental problems and provision of sustainable production and economic benefits. The waste of fish processing plants and factories are of particular interest as these wastes, including mostly shells, visceral organs, heads, skins, fish bones and little pieces of meat (Jaswal 1989), are thrown away as garbage without being recycled and thus have a negative effect upon the environment. Recycling of these wastes must be a matter of some urgency for both the fishing industries and the environment.

In 2011, fish production amounted to 703.545 tons in Turkey, including 514.755 tons through capture and 188.790 tons through aquaculture (Anonymous 2012). Approximately, 168.000 tons of this fish production was used in fish meal and/or fish oil production (Anonymous 2010), and 98.476 tons used by the processing industry (Anonymous 2010). Currently, nearly 60% of the processed fish in the fish processing plants becomes waste product. The waste materials are comprise of: 75-80% oysters, 70-75% crabs, 50-55% shrimp, 40-50% tuna, and 30-35% salmon (Espejo-Hermes 1998, Caklı and Kılınc 2004). In a study investigating the possibility of increasing the industrial added value of pearl mullet, *Chalcalburnus tarichi* (Pallas 1811) caught in Lake Van (Turkey) and processed in processing plants, Gullu (2007) reported that approximately 10.000 tons of pearl mullet were captured annually in the Lake. If half of this amount was processed in the same area, waste would be almost 3,000 tons.

It is widely accepted that packing and storing fish waste in accordance with legislation is costly for processing plants. Such waste develops micro-organisms and deteriorates quickly even when not transported in suitable form, because of the lipid

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and protein content. Although, this process could have negative effects on human health and the environment due to the potential spread of disease, discarding such rich feeding resources leads to economic loss.

Most of the fish meal used is imported from Chile and Peru and as these countries are experiencing a decrease in their stock, it is becoming increasingly difficult to meet the World's demands for fish meal. Hence, many studies searching the potential of raw material feed as an alternative to fish meal have been undertaken. In order to reduce the consumption of fish meal in feed, agricultural raw materials are supplemented to some extent, however, the use rate of these raw materials is limited due, in part, to increased prices of agricultural products resulting from biodiesel production.

The processing of the fisheries industrial waste, to be used in fish meal production, is very low because, as suggested by Hassan and Health (1986), the quality of the fish meal produced from this source is lower than that made directly from fish. Moreover, it is very difficult to obtain savings and improvements with regard to the technological costs and the use of wastes in fish meal production. In order to supply this, cost-effective methods for utilization of wastes and alternatives to fish meal production are required. Fish silage is a product obtained by adding acid to the waste and liquefying it with enzymatic activities (Tatterson and Windsor 1974). The two main methods currently used in the production of fish silage are: 1 a ripening method which uses fermented bacteria (Omay and Guvenilir 2011) and the other is the method of ripening using acid. This one is the most common methodology (Lovell 1978, Tatterson and Windsor 1974, Raa et al. 1983) and also the one used in this research. Gullu and Guzel (2003) provided silage produced from the whole pearl mullet as an alternative raw material to the feed industry. However, when the edible products fell out of favour, the use of the fish itself was replaced by post-processing non-human consumption waste silage (e.g. heads, fins, skins, fishbone, and visceral organs). The main aim of this study, therefore, was to focus heavily on the silage production for utilizing industrial wastes from the fisheries. In this contest, the study assumes a notable importance because it provides new alternative scenarios for the utilization of the industrial wastes of fisheries processing and, in addition, it will represent a precious references for studies on this topic.

MATERIAL AND METHODS

Fish Silage Production, Ripening and Storage

In this study, two different silages were produced. In the first batch, a mixture of processing wastes (visceral organs, fin, head, fishbone, skin, etc.) of some marine fish such as sea bream, sea bass, grey mullet, red mullet, blue fin tuna, and the Lake Van pearl mullet (*Chalcalburnus tarichi*, Pallas 1811), were used as raw material. For the silage produced from the processing wastes a total of 80 kg of waste, 25 kg from marine fish and 55 kg from pearl mullet waste, was used. In the second batch, 35 kg of unprocessed entire pearl mullet mince was used. While marine fish were provided fresh by a fishing company, pearl mullet were supplied by a fisheries cooperative in Gevaş (Van, Turkey).

Firstly, fresh fish were filleted in the laboratory and the residual processed waste was then stored for silage. The silage from pearl mullet was prepared as a whole and the waste was minced separately by means of an ordinary electrical mincer with a 10 mm mirror diameter hole. Then, in accordance with Turkish Food Regulations, 85% formic acid (Tekkim, Borkim, İzmir, Turkey) and 98% sulphuric acid (Tekkim, Borkim, İzmir, Turkey) were added at 1.5% of weight so 1200 mL of organic acid 1200 mL of sulphuric acid was added to the first batch and 525 mL of organic acid and 525 mL of sulphuric acid was added to second batch and then homogenized with a mixer. The pH of the resulting mince was reduced to below 4 and maintained at this level. The acid was blended in the mince homogenously to achieve dispersion of acid in all parts of the waste. Also, at this phase, 300 ppm of butyl hydroxy toluene (BHT) was added to the mince as an antioxidant (Tatterson and Windsor 1974, Beveridge 1987). The two obtained mixtures were then put separately into tight-head acid proof 60L plastic storage containers and kept at room temperature. The silages were left to ripen and only stirred with an ordinary wooden stick once a day for the first 10 days. The silage pH was measured and recorded daily and acid was added as required in order to maintain pH levels below 4 (Tatterson and Windsor 1974).

To compare the chemical composition of silages, samples were drawn on day 0, 30, 60, 90, and 150 for protein, lipid, dry matter, and ash analysis.

Silage storage at room temperature was checked daily and pH and physical characteristics (colour, odour, and texture) of the silage observed and recorded periodically. In addition to the retail unit price of acids and whole pearl mullet being included in the calculated cost of the silage, an estimated transportation price per kilogram was also included as a base to cost the processing wastes.

Pellet Feed Production

After the characteristic evaluation between the produced silages, they were intermixed before pellet production. Samples were drawn from this mixture for chemical analyses (protein, lipid, ash, and moisture) and this mixture was used as a raw material in pellet production.

In this study 4 different pellet feed groups were produced. Commercial feed formulation of the Sibal Company was used in the feed production. One was a control group and the others were 25%, 50%, and 100% silage used instead of fish meal. The only change in these groups was the quantity of used silage and fish meal. The substances used in the feeds and their percentages are shown in Table 1.

The amount of silage for each feed was calculated by proportioning the silage and fish meal's dry matter content. The dry matter content of the fish meal was 2.5 times greater than dry matter content of the silage. Consequently, the amount of silage used in each group of feeds was found by taking 2.5 times the amount of fish meal with which it was replaced (Table 1).

The same feed formulation was used in the preparation of all feeds and only the rates of silage and fish meal in the ration were changed. The other raw materials used in the pellet feed (Table 1) were provided by a commercial company. Large pulps of soybean and sunflower seed were required to be floured by grinding in a mill. When the group feeds were made, the dry raw materials, in powdered form, were stirred in the mixer of the pelletizer until they became homogeneous. Other liquid (of high moisture) substances (fish oil and molasses, 64% moisture silage) (Table 1) were added and stirred into the homogeneous mixture. This mixture was then transferred to the pelletizing unit of the machine via an outlet pipe in the mixer. A 3 mm diameter pellet outlet mirror hole was placed in the pelletizing unit. A shearing knife was also placed and adjusted according to the length of pellet. Feeds sieved through the pellet unit were left to dry in the pan (Lovell 1978, New 1987). After being dried in a ventilated area, the pellet feed was bagged and preserved for use in fish feeding. The same manufacture process was followed for all group feeds. For each treatment, 50 kg of feed was produced from each one of the group feeds. From each batch, 2 kg of samples were drawn for chemical (protein, lipid, dry matter, moist, cellulose, and ash) analysis. Powdered amounts of pellet feeds were determined by percentage. Observations were conducted with regard to the physical appearance of the pellets.

The Calculation of Unit Cost of the Silage Pellet Feed:

Market prices of other raw materials and additives included in rations were added to the cost of the silage. The price of 1 kg of feed was calculated by dividing the total value by 50 (Table 4). Labour cost and other operating costs were not included in the feed cost.

Chemical Composition Analysis of Produced Silage and Pellet Feed:

For crude protein and crude ash analyses AOAC methods were used (Anonymous 1984). Crude lipid was determined according to Bligh and Dyer (1959) and moisture was determined according to Ludorf and Meyer (1973). The analyses were conducted in the laboratory of the Agriculture Faculty of Yüzüncü Yıl University according to specified methods with the aim of determining the chemical composition of silages and pellet feeds. The FAO method was used for the calculation of gross energy values (New 1987).

Statistical Analysis

All statistical analyses were accomplished by means of SPSS 19 software. The differences between the two silages and among the feed groups were tested with the Kruskal-Wallis Test and Mann-Whitney Test to analyze the severity of these differences (Ozdamar 2011).

RESULTS

The ripening process of the silage was completed in 12 days. The temperature of the store ranged from 10-23°C and the pH of the silage was 3.2 – 4.2. The colour of the ripened silage was seen as brown or light brown and its odour was deemed to be acceptable malt.

The results of the chemical composition of the

Table 1. Composition of feed groups (control, 25%, 50%, and 100% silage used) and their amounts of use.

Used raw material and additive (kg)	Control feed	25% silage feed	50% silage feed	100% silage feed
Fish meal	19	14,25	9,5	---
Silage	---	11,87	23,75	47,50
Soybean pulp	13,5	13,5	13,5	13,5
Fish oil	7,112	7,112	7,112	7,112
Wheat flour	5,731	5,731	5,731	5,731
Corn gluten	2,232	2,232	2,232	2,232
Sunflower seed pulp	1,5	1,5	1,5	1,5
Wheat gluten	0,5	0,5	0,5	0,5
Vitamin	0,2	0,2	0,2	0,2
BIOMOS	0,075	0,075	0,075	0,075
Mineral	0,05	0,05	0,05	0,05
Selplex + Bioplex Zn	0,0375	0,0375	0,0375	0,0375
MYCO AD A - Z (toxin binder)	0,0025	0,0025	0,0025	0,0025
Total	50 kg	50 kg	50 kg	50 kg

fish mince used and the raw material of whole pearl mullet silage and those obtained from the processing waste are shown in Table 3. The gross energy values of silage made from whole pearl mullet and the silage made from the fisheries processing industry wastes were calculated as 4805 kcal/kg and 5034 kcal/kg respectively. The chemical composition of the silage mixture (obtained by mixing 30% whole pearl mullet silage and 70% processing wastes silage before pelleting) was; moisture 64.04%, crude protein (CP) 16.84%, crude lipid (CL) 10.81%, and crude ash (CA) 3.95%, with a gross energy value of 5312 kcal/kg.

The kilogram cost of the silage mixture used as a raw material in the pellet feed production was calculated as 0.72 TL (Table 2).

The chemical analyses of the feed groups are shown in Table 5. The crude protein content of the control feed made using only fish meal, and replaced with 25, 50, and 100% silage instead of fish meal were found as 46.68%, 46.34%, 44.03%, and 44.41% respectively. Their crude lipid rates were found as 17.97%, 19.25%, 22.99%, and 24.96% respectively. The rates of powder obtained as a result of sifting

Table 2. Unit cost of mixture silage produced in this study and used in feed production.

	Unit price	Amount used	Cost (TL)
Whole pearl mullet	1,50 TL/kg	35 kg	52,50
Processing waste	0,20 TL/kg	80 kg	16,00
Sulphuric acid	4,13 TL/L	1,725 L	7,12
Formic acid	5,31 TL/L	1,725 L	9,16
BHT*	0,00	300 ppm	0
Cost of 1 kg silage			0,72

*BHT (Butyl Hydroxy Toluene) cost was ignored because it was used at the amount of trace.

were determined for the four groups (control, 25% SF, 50% SF, and 100% SF) as 5.58%, 8.07%, 7.53%, and 5.47% respectively. The observed colour of the pellet feed was light brown and the pellet surface appearance of some granules was rough whilst others were smooth.

The cost of pellet feed production for the control feed was reduced by increasing the percentage of silage added to the feed and was calculated as 2.01 TL/kg, 1.91 TL/kg, 1.80 TL/kg, and 1.59 TL/kg for 25%, 50%, and 100% silage containing feed

Table 3. Chemical analyses results from the beginning till the 150th day of silage.

	Mince silage of the whole unprocessed pearl mullet				Silage of fisheries processing wastes			
	Moist. (%)	CP (%)	CL (%)	CA (%)	Moist (%)	CP (%)	CL (%)	CA (%)
Beginning	66,97±0,10^{f}	17,30±0,06^{g}	8,85±0,22^{a}	3,50±0,12^{a}	59,22±0,82^{a}	15,17±0,20^{bc}	12,32±1,43^{b}	4,19±0,96^{ab}
30th Day	65,36±0,32^{d}	16,34±0,04^{e}	9,02±0,10^{a}	3,55±0,01^{a}	60,90±0,32^{b}	14,13±0,13^{a}	11,98±0,30^{b}	6,54±0,20^{d}
60th Day	65,72±0,02^{e}	16,25±0,06^{e}	9,12±0,12^{a}	3,37±0,11^{a}	60,82±0,06^{b}	15,10±0,06^{b}	12,42±0,10^{b}	5,96±0,94^{bcd}
90th Day	67,04±0,17^{f}	16,94±0,00^{f}	9,15±0,03^{a}	3,28±0,47^{a}	62,70±0,15^{c}	15,20±0,03^{c}	12,47±0,00^{b}	5,45±0,02^{c}
150th Day	64,41±0,73^{d}	15,82±0,07^{d}	9,23±0,08^{a}	3,59±0,17^{a}	62,09±0,78^{c}	14,18±0,12^{a}	12,40±0,40^{b}	5,15±0,18^{b}

CP: Crude protein, CL: Crude lipid, CA: Crude ash

Table 4. Unit costs of produced pellet feed (TL/kg).

Raw materials	Raw material price (TL/kg)	Cost of control feed (TL)	Cost of feed, 25% silage was used (TL)	Cost of feed, 50% silage was used (TL)	Cost of feed, 100% silage was used (TL)
Fish meal	2,90	55,10	41,32	27,55	0
Silage	0,71	0	8,50	17,00	34,01
Other raw materials		45,57	45,57	45,57	45,57
Total		100,67	95,40	90,13	79,58
Cost of 1 kg feed*		2,01	1,91	1,80	1,59

*As 50 kg feed was made from each group of feed, the price of 1kg feed was calculated by dividing total value at the table by 50.

Table 5. Chemical analysis results and gross energy (GE) values of pellet feed made of silage .

Parameters (%)	Control feed	25% silage feed	50% silage feed	100% silage feed
Moisture	8,16±0,02^{d}	5,75±0,20^{a}	6,66±0,06^{b}	7,72±0,06^{c}
Crude Protein	46,68±0,11^{b}	46,34±0,90^{b}	44,03±0,68^{a}	44,41±0,30^{a}
Crude Lipid	17,97±0,01^{a}	19,25±1,69^{a}	22,99±0,10^{b}	24,96±0,14^{c}
Crude Ash	6,32±0,05^{b}	6,76±0,12^{d}	6,53±0,10^{c}	5,82±0,05^{a}
Crude Cellulose	5,59±0,39^{a}	5,42±0,62^{a}	5,57±0,44^{a}	5,00±0,20^{a}
Nitrogen Free Ext.	15,28±0,26^{c}	16,48±0,19^{d}	14,22±0,48^{b}	12,09±0,67^{a}
Gross Energy (kcal/Kg)	5259	5279	5459	5646

respectively (Table 4).

DISCUSSION

The results of this study demonstrated that the reduction of the pH of the silage to below 4 was a crucial step to offset long term silage decomposition. Also, silage was stored at a wide temperature range (10-23°C) without requiring a special cooling or heating system. Some previous studies about this subject reported that it could be stored for a long time at higher or lower temperatures (Tatterson and Windsor 1974). No further information could be found suggesting that heat had a negative effect in extending or shortening the ripening time. With this information, it could be asserted that long time storage of a perishable material without being subject to any cooling-heating process was one of the most significant advantages of this product. Since the odour may be a problem during fish meal storage, another important advantage of silage storage is that it had an acceptable malt odour that did not affect the environment.

The nutrient compositions (protein, lipid, ash, and moisture) of the two silages were different ($p<0.05$). These differences may be considered as a result of the material produced by the silage. The composition of silage was very similar to the composition of the substance from which it is made up (Kompiang et al. 1980, Mach 2009) and storage affects some parameters of the silage composition ($p>0.05$) (Table 3). Protein and lipid are notably important components in the feed industry. The crude lipid content of the silage was higher than the values in literature. However, the crude protein content was lower in the fish meal. Heras et al. (1994) found the CP rate of silage as 14.9%, while Gullu and Guzel (2003) reported a CP rate of 18.20% for a silage made of a whole pearl mullet. Ristic et al. (2002) found a CL rate of 14.84 %, Disney et al. (1976) reported a value of 12.20%, while a CL rate of 3.44% was found by Gullu and Guzel (2003) for silage made of whole pearl mullet. The differences in CL and CP rates between the present study and the data reported are probably due to the different structures of the raw materials used in the silage. The CP and CL rates obtained in the present study suggested that the silage could be used as an alternative substitute for fish meal in the fish feed industry and it could also be used as a raw material in factories producing pet food. Since the moisture content of silage was higher than that of fish meal, the expense of silage transportation could be more than for fish meal. However, if silage were used as a raw material in the areas where it was produced, this transportation expense could be minimized. Furthermore, as closed storage places are not needed for the storage of silage, the high moist rate of silage, which is a disadvantage in comparison to fish meal, may prove to be an advantage in terms of storage. Hence, the cost of storage for silage should be lower.

Apart from transportation costs, no extra expenses are required for fisheries processing industry wastes used in silage production. Hence, the raw material cost of silage is lower. Considering the method, instruments, and systems used, the production of fish meal is more expensive than the production of silage. The machines used in fish meal factories are very expensive, whereas, the equipment used in silage production is cheap and easily provided. While fish meal is produced as a result of engineering and technical processes, silage can be made easily by regular, non- specialized, workers. The kilogram cost of fish meal for the feed industry is almost 2.90 TL. Cost per kg of silage produced during this study was calculated as 0.72 TL. When this calculation was corrected after considering that the moist rate of silage was higher than the fish meal's, the cost per kg of silage, (with the same moisture rate of fish meal) resulted in 1.79 TL. While calculating the cost of silage, labour cost was not included. Nonetheless, the price for raw materials used in silage production was paid and the cost of acids was included in the retail price. If silage is made by mass-production under commercial terms, transport cost of raw materials will be reduced, and acids will be bought cheaper on a wholesale basis, therefore, cost per kilogram of silage will consistently decrease. Since smell is a significant problem in fish meal production, special machines are used for deodorizing. Silage does not have an obnoxious smell and it emits a nice malt aroma during storage. Therefore, investments such as deodorizing machines or equipment are not needed during storage and production. Also, as silage has an acidic structure, its storage life is longer than that of fish meal. On the other hand, as the moisture rate of silage is higher, bigger storage facilities are required. Yet, unlike fish meal, silage does not need closed areas for storage and storage costs can be balanced or reduced accordingly. Fish meal (5512 kcal/kg) and the silage of industrial wastes (5034 kcal/kg) were found to be similar in terms of gross energy values. It is suggested that having gross energy values as high as fish meal, silage from the fisheries processing industry wastes can be used instead of fish meal in the feed industry.

Feeds produced by using fish meal had some parallels with feeds produced using silage. There was no differences found in the crude protein and crude lipid component of the control feed and 25% silage feed ($p>0.05$). The crude protein component of the 50% and 100% silage used feeds also was found similar ($p>0.05$). The crude cellulose component of all feed groups was also similar ($p>0.05$) but the other components of feeds (Table 5) were found different ($p<0.05$). This may be a result of the increasing percentage of silage in the feeds. While the statistical differences found among the control group and the other feed groups could be due to the nutrient component of the raw material of fish meal and silage produced (Kompiang et al. 1980, Mach 2009). Due to the characteristics of the raw feed materials used in the ration, the colours of the pellet feeds produced during this study were light brown. The colour of feeds produced was similar to that of commercial feeds. As feeds were produced in a laboratory environment by an industrial pelletizing machine which was not fabricated, it was very normal that some physical deformities and dust formations were observed in the produced feeds. Such results may be negated through technological means that should be adopted by the feed industry following the results of this study. The closest feed to that made of fish meal (46.68%) was the feed in which 25% silage was used instead of fish meal in terms of crude protein (46.34%). It was observed that as the amount of silage in the feed increased, the lipid content of the feed also increased. Owing to the fact that the moisture rates of feed were similar to those of commercial feed, high moisture rates in silage fish meal did not constitute a problem with regards to feed production.

The gross energy value of the fish meal feed was lower than that of the feed made by using silage and this value of the feed also enhanced with the increasing silage rate. These results could be explained by the high lipid rate in the silage. Gross energy value is one of the indicators of efficiency in fish feeding. It is considered that feed produced from silage can be used as other commercial feed in fish feeding (Goddard and Al-Yahyai 2001).

In this study, the costs of the feed made by replacing fish meal with 25%, 50%, and 100% silage were reduced at the rate of 5.25%, 10.5%, and 21% respectively. Gullu et al. (2003) at the end of their study suggested that for trout feeding, silage could be used instead of fish meal at the rate of 50%. If silage produced in this study can be used instead of fish meal at the rate of 50% in feed production, trout feed expenses of a fish culturing firm can be reduced by a rate of 10.5%. This value is an important ratio for feed costs which constitute the biggest input (60%) in farming.

The results of this study suggested that it is possible to recover all processing wastes from the fisheries industry. Currently, the utilization of some fisheries waste materials from the production of fish meal requires expensive technology (Hassan and Health 1986). This method of silage production should result in wastes being processed more easily and cheaply, and the storage life of the product being prolonged with reduced storage costs.

The nutritional and digestibility values of silage are high (Goddard and Al-Yahyai 2001) and it can be used as an alternative rather than supplementary raw material feed or it can be used as a raw material in factories producing pet food. Silage production is an affordable and easy method for the utilization of industrial wastes of a fisheries processing plant. Utilization of the industrial wastes of fish processing carries both economic interest and environmental protection. Hence, silage production, silage storage, and silage use can be acknowledged as a contemporary, sustainable, and profitable method which can fulfil totally, instead of partially, the needs of fish meal production.

As a conclusion, currently the wastes of the fisheries processing industry are considered as garbage and a threat for human health. Present disposal fees paid for fisheries processing industry wastes will be reintegrated into the economy by silage production (Fagbenro and Jounjey 1995, Goddard and Perret 2005, Borghesi et al. 2008). In this context this study is noteworthy in the way that it not only brings a new dimension to the field of utilization of the industrial wastes of fisheries processing but also it draws attention to this subject for interested researchers.

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REFERENCES

Anonymous (1984) Official methods of analysis. Association of Official Analytical Chemists, Washington DC.

Anonymous (2010) Fishery statistics. Turkish Statistical Institute, Ankara.

Anonymous (2012) Fishery statistics. Turkish Statistical Institute, Ankara.

Beveridge M (1987) Cage aquaculture. Fishing News Books Ltd., Farnham.

Bligh EG, Dyer JW (1959) A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology 37: 911-917.

Borghesi R, Arruda LF, Oetterer M (2008) Fatty acid composition of acid, biological and enzymatic fish silage. Boletim do Centro de Pesquisa de Processamento de Alimentos 26(2): 205-212.

Çaklı Ş, Kılınç B (2004) Kabuklu su ürünleri işleme artıklarının endüstriyel alanda değerlendirilmesi. Ege Üniversitesi Su Ürünleri Dergisi 21(1-2): 145-152.

Disney JG, Tatterson IN, Olley J (1976) Recent developments in fish silage. In: Proceedings of the Conference on the handling, processing and marketing of tropical fish, Ministry of Oversea Development, 5-9 July 1976, London, 321- 340.

Espejo-Hermes (1998) Fish processing technology in the topics. Waste Management Chapter 17: 272-279.

Fagbenro O, Jauncey K (1995) Water stability, nutrient leaching and nutritional properties of moist fermented fish silage diets. Aquacultural Engineering 14: 143-153.

Güllü K, Güzel Ş (2003) İnci kefali (*Chalcalburnus tarichi*) silajının pelet yem yapımında kullanımı üzerine bir araştırma. Ekoloji 12(48): 19-23.

Güllü K, Güzel Ş, Güner Y, Tekinay AA (2003) Balık silajı kullanılarak yapılmış pelet yemin gökkuşağı alabalığı (*Oncorhynchus mykiss*, W., 1792) beslenmesinde kullanımı üzerine bir araştırma. Süleyman Demirel Üniversitesi, Eğirdir Su Ürünleri Fakültesi Dergisi 2 (10): 39-43.

Güllü K (2007) İnci kefali balığı işleme ünitesi-kurulumu ve işletilmesi- projesi sonuç raporu. Avrupa Birliği, Doğu Anadolu Kalkınma Programı, Tarım ve Kırsal Kalkınma Bileşeni, Proje Sonuç Raporu, Van.

Goddard JS, Perret JSM (2005) Co-drying fish silage for use in aquafeeds. Animal Feed Science and Technology 118: 337-342.

Goddard JS, Al-Yahyai DSS (2001) Chemical and Nutritional Characteristics of Dried Sardine Silage. Journal of Aquatic Food Product Technology 10(4): 39-50

Hassan TE, Heath JL (1986) Biological fermentation of fish waste for potential use in animal and poultry feeds. Agricultural Wastes 15: 1-15.

Heras H, Mcleod CA, Ackman RG (1994) Atlantic dogfish silage vs. herring silage in diets for atlantic salmon (Salmo salar): growth and sensory evaluation of fillets. Aquaculture 125: 93-106.

Jaswal AS (1989) Methodology investigations for the production of amino acid hydrolysate from shrimp waste. Canadian Institute of Food Science and Technology Journal 22(5): 460-463.

Kompiang IP, Arifudin R, Raa J (1980) Nutritional value of ensilage by-catch fish from Indonesian shrimp trawlers. In: Conell JJ (ed.), Advances in Fish Science and Technology, Fishing News Books Ltd., Surrey, 349-352.

Lovell RT (1978) Practical Fish Diets. Food and Agriculture Organization of the United Nations Publications, Rome.

Ludorf W, Meyer V (1973) Fische und fischerzeugnisse. Paul Parey Verlag, Berlin.

Mach DT (2009) Utilisation of fish or crab silage protein for cobia (*Rachycentron canadum*) effects on digestion, amino acid distribution, growth, fillet composition and storage quality. Phd thesis, University of Bergen, Bergen.

New MB (1987) Feed and feeding of fish and shrimp: a manual on the preparation presentation of compound feeds for shrimp and fish in aquaculture. Food and Agriculture Organization of the United Nations Publications, Rome.

Omay D, Güvenilir Y (2011) Yemekhane atıklarından fermantasyonla laktik asit üretimi. Ekoloji 20(80): 42-50.

Ozdamar K (2011) Paket Programlar ile İstatistiksel Veri Analizi 1. Kaan Kitabevi, Eskişehir.

Raa J, Gildberg A, Strom T (1983) Silage production -theory and practice. In: Leedward DA, Taylor AJ, Lawrie RA (eds.), Upgrading Waste for Feed and Food, Butterworths, London, 117-132.

Ristic MD, Filipovic SS, Sakac MLJ (2002) Liquid protein feedstuffs from freshwater fish by-products as a component of animal feed. Romanian Biotechnological Letters 7(3): 729-736.

Tatterson IN, Windsor ML (1974) Fish silage. Journal of Science Food Agriculture 25: 369-379.