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Solar Versus Sun Drying of Mixed-Species Fish Waste: Effects on the Nutrient Composition of Fish Meal

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Abstract – This study investigated the nutrient composition of fish meal produced from locally collected fish waste (a mixture of species) using two methods: a solar drier and open sun drying. The resulting meals were compared with Imported Fish Meal (IFM) and a locally produced Commercial Plant Fish Meal (CPFM). Moisture and protein content differed significantly ($p<0.05$) among the solar-drier, sun-dried, IFM, and CPFM samples. Ash content was significantly different ($p<0.05$) between CPFM and IFM but did not differ significantly between the solar-drier and open sun-dried samples. Fat content was significantly higher ($p<0.05$) in CPFM (12.82%) than in the open sun-dried, solar-drier, and IFM samples. Energy content also varied significantly among all sample types. Overall, fish meal produced using the solar dryer was superior to the open sun-dried meal in terms of protein, fat, ash, moisture, and energy content. Comparison with IFM and CPFM indicated that solar-dried fish meal is an acceptable protein source for poultry feed formulation. However, its inclusion in feed requires caution due to its higher ash content, which may affect the protein efficiency ratio in chicks.

Keywords- Ash, Energy, Fat, Poultry feed, Protein

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Introduction

The increase in the primary output from fish has created new opportunities with the resulting by-products (Roda et al., 2019). The term "fish by-product" refers to a variety of fish by-products, including fresh water fish by-products, which are utilized as raw materials for the production of fishmeal. Depending on the level of processing and the kind of fish, the quantity of waste let out during processing ranges from 20% to 80% (Dorea, 2006). It is predicted that the percentage of total fish meal produced from fish waste might increase from 22% to 28% between 2018 and 2030 (Food and Agriculture Organization [FAO], 2020). Fish meal is often used as the principal source of protein for aquaculture fish and shrimp and is also a popular supplement for the diets of farm animals i.e., in the raising of pigs, poultry and for other purposes. According to the International Fish meal and Fish Oil Organization (IFFO), the use of fish meal in aquaculture has been significantly expanding since 1960. In 2020, the aquaculture sector consumed 78 % of all fish meal generated globally. Fish meal's amino acid profile is a major selling point as a dietary protein supplement (Hall, 2010). Crude protein content in high-quality fish meal ranges from 60-70% by weight (Khan et al., 2012; Miles and Chapman, 2006). Typically, the mineral content of superior fish meal varies between 17 and 25 % (Khan et al., 2012). The majority of fish meal ash is composed of calcium and phosphorus (Hall, 2010). According to Guo et al. (2020), moisture content in fish meal varies from 7.7% to 9.6%.

The fish meal is produced through a heating, pressing, and drying process, and typically contains about 60–70% protein, 10–12% residual fat, and 8–11% moisture, with the other ingredients being bones and salt (ash) (de Koning., 2002). Drying is one of the important processes in the fish meal processing which affects the nutrition composition of fish meal and various drying methods are used from large scale commercial operations to the small-scale traditional operations. According to Obayopo and Alonge (2018), the moisture content varied from 13.97% to 15.68% under solar dried conditions while it varied from 17.0% to 21.7% under open sun-dried conditions during wet and dry seasons for different fish species. According to Islam et al. (2012), moisture, crude protein, lipid and ash content under open sun-dried condition were 26.6%, 50.03%, 12.16% and 12.19% respectively while under solar drier condition they were 12.8%, 62.53%, 18.36% and 7.52% respectively for the mola fish. Afore mentioned studies were for the drying of whole fish and not for fish waste. However, Akande and Simpa (1992) produced fish meal from herring offal and investigated them for moisture, crude protein, fat and ash content and found that they were 10.4%, 63.8%, 14.6% and 11.25% respectively under solar drier condition while 10.0%, 64.5%, 14.6% and 10.5% respectively under open sun-dried condition and the study used fish waste from a single species. However, for the local fish meal production, fish waste from mix of various species are used in Sri Lanka at large scale and as well as small scale operations and this fish waste is collected chiefly from fish selling stalls which include unwanted by-products i.e., skin, head, fins, viscera and trimmings. The small-scale producers at local level utilize the fish waste to produce fish meal under solar drier and open sun dry conditions. However, nutrient composition of fish meal produced from this fish waste that consists of mixture of species was not known yet to our knowledge. Hence, the present study was an attempt to investigate the nutrient composition of fish meal produced using the fish waste of mixture of fish species under open sun dry and solar drying conditions and also to compare them with two different fish meals available in the market.

Materials and Methods

Collection of Fish Waste

Sufficient quantity of fish waste was collected from Oluvil and Addalaichenai fish market areas that comprised a mixture of heads, fins and tails, scales, skins, bones, livers, roe, and viscera from different species to dry under different drying conditions. The rest of the processes for the collected fish waste were carried out at the laboratory of the Department of Biosystems Technology, South Eastern University of Sri Lanka.

Processing of Fish Waste to Produce Fish Meal

The fish waste was cut into small pieces to facilitate quick drying during drying process. After the cutting, the fish waste was cooked for about 30 minutes at a temperature of about 90 degrees Celsius to destroy the harmful bacteria in the fish waste, to liberate the oil from the fat depots of the fish, and to condition the material for the subsequent treatment in the various processing. The cooked fish waste was divided into two equal portions. The first portion was systematically placed in the solar dryer and dried for three days and the other portion was dried in an open area under direct sun in a raised mesh for that same three days, in both cases sufficiently dried fish waste materials for griding purpose were obtained. The solar dried and sun-dried fish wastes were ground separately to produce fish meal. A properly milled meal has an attractive appearance and is readily mixed into feed rations which require homogeneous blending (FAO, 1986).

Collection of Fish Meal Samples

Two types of fish meal samples available in the market were collected; one type was from the local CPFM located at Pehaliyagoda in the western province of Sri Lanka and the second type was an IFM from a medium scale poultry farm from Ninthavur located at the Eastern province of Sri Lanka.

Sample Analysis

All the fish meals samples i.e., solar dried (T1), sun dried (T2), CPFM and IFM (10 sample for each fishmeal type with three replicates, for each fishmeal type, replicate 1 – 03 samples, replicate 2 – 03 samples and replicate 3 – 04 samples) were analyzed for moisture, ash, protein, and fat by proximate analysis according to Association of Official Analytical Chemist International (AOAC, 2002) methods and the energy content was found out using bomb calorimeter.

Results and Discussion

Nutrient Composition of Various Fish Meal Samples

The data obtained from the laboratory analysis of fish meal samples on moisture, protein, ash, fat and energy was statistically analyzed (SPSS 25, Analysis of Variance (ANOVA) and the results obtained are shown in Table 1.

Table 1

Comparison of mean moisture, ash, protein, fat and energy content of various fish meal (M±SE)

Treatment/ sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Energy (kJ/kg)
CPFM	9.22 ± 0.17^{c}	24.8 ± 0.28^{c}	52.52 ± 0.25^{b}	12.82 ± 0.33^{a}	$20,381.0 \pm 10.55^{a}$
IFM	7.20 ± 0.50^{d}	26.88 ± 0.33^{b}	56.27 ± 0.39^{a}	8.86 ± 0.29^{b}	$19,307.80 \pm 9.39^{b}$
T1 (Solar dry)	10.20 ± 0.26^{b}	30.82 ± 0.39^{a}	48.49 ± 0.18^{c}	9.16 ± 0.09^{b}	$18,390.60 \pm 59.47^{c}$
T2 (Open sun dry)	11.44 ± 0.41^{a}	30.25 ± 0.38^{a}	45.93 ± 0.12^{d}	9.07 ± 0.29^{b}	$16,381.40 \pm 121.6^{d}$

Note: A comparison between different fish meal samples is made within column for each parameter and the different superscripts within a column indicate the significant difference ($p<0.05$). CPFM – Commercial Plant Fish Meal. IFM –Imported Fish Meal. T1 – fishmeal produced under solar drier. T2 – fishmeal produced under open sun dry conditions

According to Table 1, the moisture content was significantly different between CPFM, IFM, T1 and T2 fish meal samples and the highest mean moisture content (11.44%) was obtained for T1 (open sun dry sample). The moisture content is an important factor in causing spoilage of fish meal in storage/keeping, hence, the moisture from fish is removed using different drying methods in fish meal processing. Therefore, when considering the importance of drying, it has become necessary to find out a viable drying method to use at local level mainly by small scale producers. The moisture content in different fish meal samples investigated in the present study varies from 11.44% (open sun-dried samples) to 7.20% in the imported fish meal samples.

According to Burt et al. (1992), the moisture content of the fish meal varies between 5% and 10%. Whereas South African Law requires a maximum of 10% moisture in the fish meal (de Koning (2002). According to the specification of NorSeaMink and Norse-LT 94, the maximum moisture content of fish meal is specified as 10% (Einarsson, 2019). Having the aforementioned specifications and the recommendations, the maximum acceptable moisture in fish meal is expected to be 10%. In the previous studies moisture content in fish meal in sun-dried conditions were 10.0% for herring offal (Akande and Simpa, 1992), 26.6% in fish meal produced from whole mola fish (Islam et al., 2012), and 17.0% to 21.7% in fish meal produced from different fish species during wet and dry seasons (Obayopo and Alonge, 2018).

In the present study, moisture content was found with acceptable level for CPFM and IFM samples whereas it was higher than the acceptable level in solar dried and sun-dried fish meal samples. However, the moisture content in the solar dried fish meal (10.2%) is slightly higher than acceptable level and lower than the sun-dried fish meal in three days of drying. Previous studies found that open sun drying and solar drying process required 2 to 5 days (Abraha et al., 2017; Martunis, 2013). Thus, solar drying seems to be a better drying method than the open sun drying and can be utilized for fish waste drying by local producers. The present study may reveal that the solar drying has higher level of potential to dry fish waste to produce fish meal at the Eastern province of Sri Lanka which receives sufficient solar energy for seven months during a year (owing to its climatic and geographical conditions) and seem to be a viable method for small scale producers at local level.

The protein content was significantly different between T1, T2, CPFM, and IFM and the highest mean protein content (56.27%) was obtained for IFM samples (Table 1). Fish meal is utilized mainly in the poultry feed production as a protein source at local level. Though the fish waste is produced in large quantity at local level, the utilization of it for fish meal production is limited due to the lack of feasible drying methods. In the present study on drying methods, the protein content in solar dried samples was 48.49% whereas, it was 45.93% in sun-dried samples and the difference was significant. Further, the protein content in the sun-dried sample was the lowest compared to the solar dried, CPFM and IFM samples and the highest protein content was found in the IFM sample (56.27%) (Figure 2). According to previous studies, crude protein in fish meal produced from whole molar fish was 50.03% under sun-dried condition and 62.53% under solar dried condition (Islam et al., 2012) whereas for the fish meal produced from herring offal, the crude protein was 63.8% and 64.5% under sun-dried and solar dried conditions respectively (Akande and Simpa, 1992). Accordingly, protein content varies between sundry and solar dry conditions for fish meal produced from whole fish and fish waste. In the present study under solar and sun-dried conditions, crude protein content seems to be lower compared to previous studies. The present study utilized the fish waste collected to produce fish meal as it is without cleaning and sorting; this is how it is practiced by local producers and this could be the reason for having low level of protein in fish meal.

According to Figure 2, the fish meal produced by CPFM in the present study contained 52.52% of crude protein which is higher than the crude protein in solar and sundry conditions. From our field visit, it was noticed that the CPFM also utilized the fish waste as it is (without sorting and cleaning) to produce fish meal. However, for the CPFM fish meal production, drying method is different where electric dryer is used. Previous studies suggested that protein nitrogen retention takes place during the drying yielding higher protein percentage in fish meal (Farid et al., 2016; Foline et al., 2011). Further, the aggregation of protein may be caused by the dehydration of water molecules that present between protein molecules (Kim et al., 2020; Kumar et al., 2017). In the present study, authors did not have the knowledge about the fish species used for fish meal production although CPFM used fish waste. Though we found the highest protein content in the IFM sample, we have no idea about the processing method applied and the species used for fish meal production, because, the proximate composition in fish meal varies depending on the fish species and fish parts used and processing methods applied (Islam et al., 2012; Akande and Simpa, 1992; Obayopo and Alonge, 2018).

The protein content (typical) in fish meal, according to NorSeaMink and Norse-LT 94, is specified as 71% whereas the minimum was specified as 68% by Norse-LT 94 (Einarsson, 2019). According to de Koning (2002), South African Law requires the minimum protein content to be 60%. The available information on the requirements and specifications of protein indicates that the fish meal should contain minimum of 60% of protein. In the present study, protein in fish meal under solar dry and sundry conditions was lower than the required percentage. It should be noted that obtaining the aforementioned minimum protein content of 60% is hardly possible from the dried fish waste. The present study indicated that the protein in fish meal is higher under solar dry condition than the open sundry condition, therefore, fish meal can be produced feasibly under open solar dry condition at local level from fish waste. In Sri Lanka, although the import, manufacturing, sales, and distribution of animal feed are regulated by the Animal Feed Act No. 15 of 1986 (as amended in 2016) and the Guidelines for Registration of Animal Feed - Import (2012), no specific national standards for fishmeal itself could be found.

Further, fat content was significantly higher (12.82%) in CPFM samples compared to the T1, T2 and IFM samples whereas it was not significantly different between IFM, T1 and T2 samples (Table 1). The fat content in CPFM sample was significantly different from IFM, solar dried and open sun-dried fish meal samples while it was highest in CPFM (12.82%). Our observation and evaluation of the processing methods at the CPFM found that the oil is not extracted in the fish meal processing, as a result, it was found with a higher level of fat. Further, another reason could be that the crude fat increased during mechanical drying (Kumar et al., 2017) whole body moisture is inversely related to whole body lipid and decreases or increases as lipid is stored or utilized (Shearer, 1994). Previous studies using mechanical method for drying found varying amount of fat in fish meal produced from fish waste i.e., 13.56% (Farahiyah et al., 2015) and 11.3% (Akande and Simpa, 1992).

According to Figure 3, the fat content was lower in sun-dried (9.07%) and solar dried (9.16%) fish meal samples compared to CPFM samples, however, the fat content in solar dry and sundry fish meals were higher than the IFM (8.86%). The higher fat content in solar dry and open sun-dried samples was expected since there was no oil extraction performed during the processing. The lowest fat content was expected in the IFM samples because we assumed that the usual procedure is adopted in the processing of fish meal where oil extraction is performed. According to the specifications of NorSeaMink and Norse-LT 94, fat in fish meal is specified as maximum of 13% (Einarsson, 2019). According to de Koning (2002), South African Law requires a maximum of 12.0% of fat in fish meal. The aforementioned specifications show that fat in fish meal should be below 13%. However, de Koning (2002) stated that the lipid content in fish meal needs to be 10 -12%, therefore, the present study may indicate that the fat content of 9.16% in solar dry fish meal is found at the acceptable level.

The ash content was significantly different between CPFM and IFM samples whereas it was not significantly different between T1 and T2 samples. Further, the ash content of T1 and T2 samples were significantly different from CPFM and IFM samples. The highest mean ash content of 30.82% was found in T1 (Table 1). The highest ash content (30.82%) was found in solar dry sample (Figure 4) and the reason could be that fish waste mainly consists of head, fins, and trimmings which mainly consists of minerals contributing for higher ash content. According to Ramírez- Ramírez (2008), the ash content in mixture of fish waste was 19% whereas Farahiyah et al., (2015) found that fish offal meal produced from the fish waste collected from the fish market contained 19.88% of ash. The ash content in fish meal, according to the specifications provided by both NorSeaMink and the high-quality Norse-LT 94, is maximum of 14% without salt (Einarsson, 2019). Fitri et al. (2022) found that the fish that was sun-dried in the open space has been shown to have higher ash content than those dried in a closed system. In the present study, the ash content was much higher than the aforementioned previous studies and the specifications. According to Einarsson (2019), the composition of fishmeal made from trimmings is different from fishmeal manufactured from whole fish, i.e. the ash content in the by-product fishmeal is higher due to bone fractions in trimmings. Further, the fish waste collected locally for fish meal production in the present study was a left-over portion after cutting and cleaning the different species of small and medium size fish purchased by consumers for domestic cooking and these fish waste we found to have higher level of bone parts. The higher level of ash content may negatively affect the nutrient utilization. According to Johnson and Parson (1997), the meat and bone meal protein efficiency ratio is affected by ash content, where meat and bone meal with the low ash yields a higher protein efficiency ratio than the high ash meat and bone meal in poultry chicks. Therefore, precautions needs be taken in adding the level of fish meal produced from fish waste in poultry feed formulation.

With regard to the energy content, it was significantly different between T1, T2, CPFM and IFM samples and the highest mean value (20, 381kJ/kg) was obtained for CPFM samples (Table 1 and Figure 5). The results obtained (Figure 5), showed that the energy content of fish meal samples from CPFM, IFM, solar dried and sun dried were 20,381.0 kJ/kg, 19,307.80 kJ/kg, 18,390.60 kJ/kg and 16,381.40 kJ/kg respectively and the energy values were significantly different between all the samples. The highest energy value was obtained for the CPFM sample (2, 0381.0 kJ/kg) and the lowest value was obtained for the sun-dried samples (1, 6381.40 kJ/kg). From our field observation of fish meal processing, we noticed that fish oil extraction is not carried out at the CPFM plant. Hence, it is highly likely that the higher fat content in fish meal at CPFM samples (Table 1) resulted in higher energy level. In addition, species of fish used for fish meal production also might have contributed for higher energy. The energy level was low in IFM samples compared to CPFM sample and the reasons could be that the extraction of oil in imported samples during the processing and in addition to species of fish used. The reason for the lowest energy value in the sun dry fish meal samples may be due to the utilization fish waste which contains chiefly trimmings, bones etc. Farahiyah et al., (2015) determined the energy value of offal fish meal produced in oven dry condition at the laboratory and the energy value obtained was 18.5 MJ/kg and the value was similar to the energy value of solar dry sample in the present study. Patterson et al. (2018) found that fish under solar dry condition was better in nutritive value compared to the sun dry fish. Further, they found that the lipid which is the main precursor for energy in fish is higher in solar dry condition than the sun dry condition and also the lipid oxidation measured in terms of Thiobarbituric Acid (TBA) value was less in solar dry fish compared to sundry fish causing for higher energy level in solar dry fish.

Conclusion

The present study investigated the nutrient composition of fish meal produced from locally collected fish waste—a mixture of various fish species—under two conditions: using a solar dryer and open sun drying. The results were compared with IFM and CPFM. It was found that fish meal produced using a solar dryer was superior in quality to that dried under open sun conditions. Moisture levels under both drying methods exceeded acceptable limits, though solar-dried meal had lower moisture than sun-dried meal. Crude protein content in both was below the acceptable level, although solar-dried meal contained more protein than sun-dried. Ash content in both exceeded the acceptable range. Energy concentration was lower in both locally produced meals compared to standards. However, fat content in both was within acceptable limits. When solar-dried fish meal was compared with IFM and CPFM, it was deemed acceptable for use as a protein source in poultry feed. Based on these findings, it is recommended that the solar dryer method can be adopted to process fish waste into fish meal under local conditions. However, precautions should be taken when incorporating this solar-dried fish meal into poultry feed formulations due to its higher ash content.

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