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Comparative analysis of the chemical quality of fishmeal produced on the Northwest coast of Mexico

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ABSTRACT

Objective: To evaluate the physico-chemical quality of fishmeal produced by four companies in different states of the Republic (Baja California Sur, Jalisco, and Sinaloa).

Design/methodology/approach: The analyzed fishmeals were from six batches, sardine meal from California pilchard and Pacific thread herring (*S. sagax* and *O. libertate*), and skipjack tuna and (*K. pelamis*) processed by different Mexican companies. Proximal chemical analysis was carried out at the Centro de Investigaciones Biológicas del Noroeste (CIBNOR).

Results: The fishmeal's quality parameters analyzed in this study showed similar values to those reported in the literature. The variations observed in their proximate chemical composition allow them to be classified according to the results of the analyses.

Limitations on study/implications: Considering that four of the six flours were produced from the same raw material, *S. sagax*, the high variability in their physico-chemical quality parameters indicates a lack of standardization in both production methods and quality controls among the producing companies.

Findings/conclusions: *K. pelamis* by-products can produce meals of equal or better physico-chemical quality than those produced from *S. sagax*. The development of official regulations establishing quality standards to fishmeal production at national level is desirable for competitiveness.

Keywords: fishmeal, proximate composition, California pilchard, Skipjack tuna.

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INTRODUCTION

Fishmeal has been one of the most important agri-food products due to its extensive use in livestock, poultry, and aquaculture (Naylor *et al.*, 2009; Kaiser *et al.*, 2022). Therefore, the latter, these ingredients have been used in feeds for carnivorous fish and crustaceans due to their high protein content, good digestibility, palatability, and optimal balance between amino acids and lipids (Yen-Ortega *et al.*, 2021; Zlaugotne *et al.*, 2022). However, there have been efforts to replace fishmeal with alternative protein sources for more than two decades to reduce pressure on small pelagic fish stocks (Gaxiola and Cuzón, 2014; FAO, 2022).

Although alternative animal protein sources, such as soybean or insect meals (Martínez-Córdova *et al.* 2013), have allowed the gradual reduction of fishmeal in aquaculture diets, full substitution of traditional ingredients has not been possible (Hua *et al.*, 2019). Alternative meals often have lower digestibility, anti-nutritional factors, or poor palatability (Zlaugotne *et al.*, 2022). Consequently, it has been recommended that the quality of fishmeal be controlled and optimized as much as possible to ensure good diet performance (Cozzolino *et al.*, 2005; Boyd *et al.*, 2022).

Mexico is the world's fourteenth largest producer of fishmeal, which is mainly made from clupeids, whose fishing and processing are concentrated in the states of Sinaloa, Sonora, Baja California, and Baja California Sur (CONAPESCA, 2021; FAO, 2022). Despite this, there is a lack of standards defining the parameters for the quality control of fishmeal, with NOM-242-SSA1-2009 being the only official document establishing a limit of 100 mg/kg of histamine (SSA, 2009). Consequently, product quality in the national market tends to be heterogeneous between factories due to the non-standardisation of production processes (Hernández-Cerón, 2020).

The present study aimed to evaluate the proximal chemical quality of fishmeal collected in 6 different processing plants distributed in the Northwest region of Mexico to establish a baseline on its parameters that will allow an eventual qualitative standardization.

MATERIALS AND METHODS

The present study was conducted at the Proximal Chemical Analysis laboratory of the Centro de Investigaciones Biológicas del Noroeste, S. C. (CIBNOR), La Paz, Baja California Sur (24° 08' 10.03" LN and 110° 25' 35.31" LO), and at the Food Science and Technology Laboratory of the Universidad Autónoma de Baja California Sur (UABCS), campus La Paz (24° 6'-3.14"-LN, 110° 18'-54.44" LO).

A completely randomized experimental design was used with one factor under study (fishmeal). Table 1 shows the six treatments considered, each with three replicates per variable.

Table 1. Species, producing company, and origin of fishmeal.

Treatment	Company and location	Fish species
Fishmeal 1	Bahía Magdalena Harinera S.A de C.V., Puerto San Carlos, B.C.S.	California pilchard (*Sardinops sagax*)
Fishmeal 2	Maz Industrial S.A. de C.V., Mazatlán, Sin.	California pilchard (*Sardinops sagax*)
Fishmeal 3	Proteínas Marinas y Agropecuarias S.A. de C.V., Guadalajara, Jal.	Skipjack tuna (*Katsuwonus pelamis*)
Fishmeal 4	Proteínas Marinas y Agropecuarias S.A. de C.V., Guadalajara, Jal.	California pilchard (*Sardinops sagax*)
Fishmeal 5	Sardinera del Real S. de R.L. de C.V., Puerto San Carlos, B.C.S.	California pilchard (*Sardinops sagax*)
Fishmeal 6	Sardinera del Real S. de R.L. de C.V., Puerto San Carlos, B.C.S.	Pacific thread herring (*Opisthonema libertate*)

The proximate chemical composition was analysed according to AOAC (2005) methods: constant weight for moisture; charring in the furnace for ash; Soxhlet method for ether extract (EE, crude fat); acid and alkaline hydrolysis for crude fiber (CF); Kjeldahl method for crude protein (CP); and subtraction for free nitrogen extract (FNE). An analytical balance (Mettler Toledo®, CDMX, Mexico) was used for all gravimetry.

Statistical analyses were performed with Statistica® v. 10.0 for Windows (StatSoft®, 2011). Data were checked for normality (Kolmogorov-Smirnov, $p>0.20$) and homoscedasticity (Levene, $p=0.05$). Analysis of variance (ANOVA) and multiple comparisons of means were performed. For all variables, means were considered significantly different when $p\leq0.05$.

RESULTS AND DISCUSSION

In general, the quality parameters of the fishmeals analyzed in the present study showed similar values to those previously reported in the literature (Cabello *et al.*, 2013; Quijije *et al.* 2019). However, the variations observed in their proximate chemical composition make it necessary to classify them according to the results of the analyses.

Fishmeals' moisture was statistically different between all treatments, except for fishmeals 1 and 5 ($F=928.2$, $p<0.000$). Figure 1 shows that fishmeal 4 obtained the highest parameter value (7.61±0.10%), which is within the range suggested by De Koning (2002) of 5 to 10% to avoid the development of microorganisms. Except for fishmeal 6 (4.18%±0.03), all of them complied with the standard. The low percentage of the latter suggests overheating during drying (Hilmarsdottir *et al.*, 2020). Also, its nutritional quality is compromised as this generates a reaction between lysine and histamine that produces gizzerosine, an irritant toxin in the digestive tract of crustaceans, fish, and chickens (Cruz-Suarez *et al.*, 1999; Takakuwa *et al.*, 2021).

Ash percentages ranged from 13 to 25% (see Figure 2), with fishmeal 1 having the lowest value (13.06±0.03%) and fishmeal 2 the highest (24.87±0.09%). Statistically, all treatments showed significant differences ($F=7153.3$, $p<0.000$). This is consistent

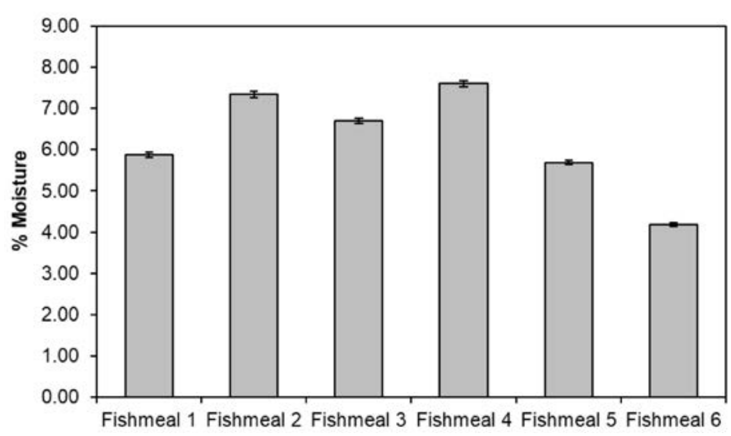

Figure 1. Mean percentages of the moisture content in fishmeal ($p<0.001$). Vertical bars show ± standard error.

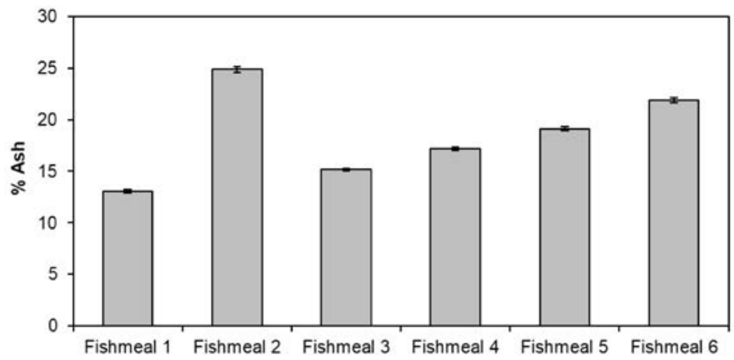

Figure 2. Mean percentages of ash content in fishmeal ($p<0.001$). Vertical bars show ± standard error.

with previous studies, as fishmeals usually contain between 10 to 25% ash since the bones of the raw material are not discarded entirely (Rossi and Davis, 2014; Quijije *et al.*, 2019). In the case of fishmeal 2, it exceeds the maximum of 20% ash recommended by New and Wijkström (2002), thus its nutritional quality is diminished as excess ash reduces digestibility. In contrast, in fishmeal 3, the low value of the parameter may be a result of its raw material, skipjack tuna, which, due to its size, is minced before being introduced into the wet pressing machine, allowing a greater bone removal (Kim *et al.* 2019).

The EE values ranged from 4 to 9.5% as shown in Figure 3, and showed statistical differences between all treatments, apart from fishmeals 2 and 4 ($F=8235.2$, $p\leq 0.000$). This is consistent with previous reports mentioning that fishmeal normally contains between 6 to 10% fat (Mih and Lacherai, 2020). Fishmeal 1 obtained the highest EE value (9.41±0.05%), which exceeds the maximum optimum of 8% recommended by FAO (1986), and therefore falls into category B (medium quality). This is usual for sardine meals, which in many cases contain up to 20% lipids (Chaula *et al.*, 2019; Mih and Lacherai, 2020). In contrast, the low EE level observed in meal 6 (4.14±0.02%) indicates overheating that combusted its fats (Hilmarsdottir *et al.*, 2020; Takakuwa *et al.*, 2021). Likewise, fishmeal 3

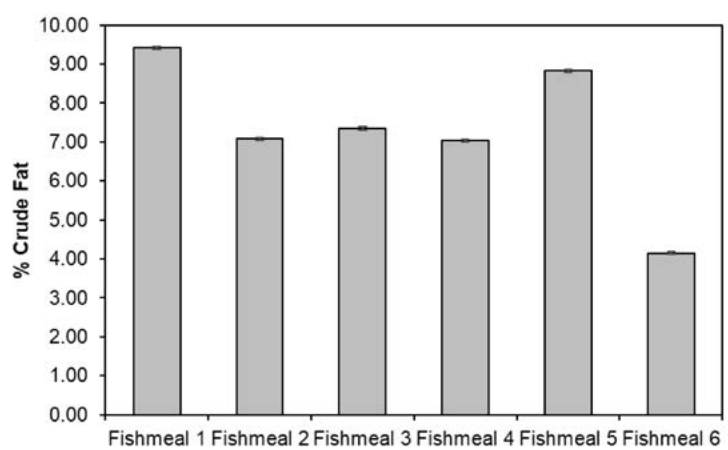

Figure 3. Mean percentages of EE in fishmeal ($p<0.001$). Vertical bars show ± standard error.

presents an EE (7.34±0.03%) consistent with previous studies on tuna meals (Hernández *et al.*, 2014; Souza *et al.*, 2017).

The CF content presented values below 0.20% in all the fishmeals (Figure 4). Significant differences were also found ($F=61.00$, $p \leq 0.0001$): fishmeals 2, 3, and 5 were the same, as well as fishmeals 4, and 6. Only fishmeal 1 was different from all the others. These products regularly have low FC in the form of celluloses and non-digestible carbohydrates (Villarreal-Cavazos *et al.*, 2019; Rawski *et al.*, 2020). Therefore, good fishmeal should not contain more than 1% FC as a high percentage can lead to digestibility problems (Morales *et al.*, 1999; Arriaga-Hernández *et al.*, 2021).

The CP levels of the tested flours ranged from 53 to 62%, with statistical differences between three groups ($F=11.90$, $p \leq 0.00025$). Fishmeals 1, 2, and 6 were equal (see Figure 5); meal 4 showed no differences between them and fishmeal 5. Fishmeal 5

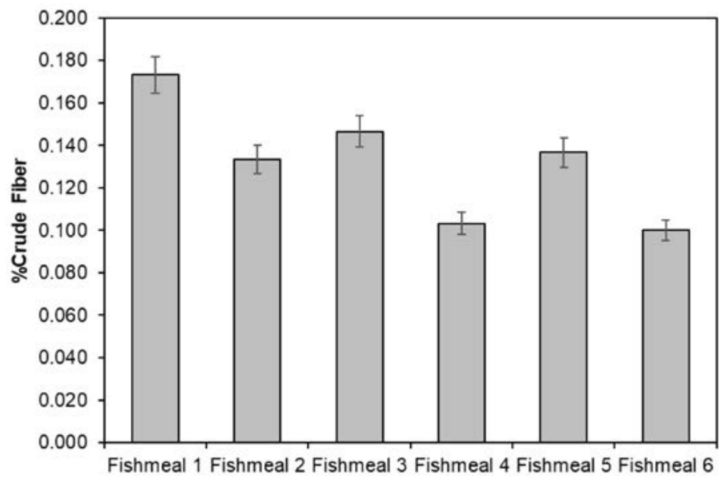

Figure 4. Percentage averages of CF in fishmeal ($p<0.001$). Vertical bars show ± standard error.

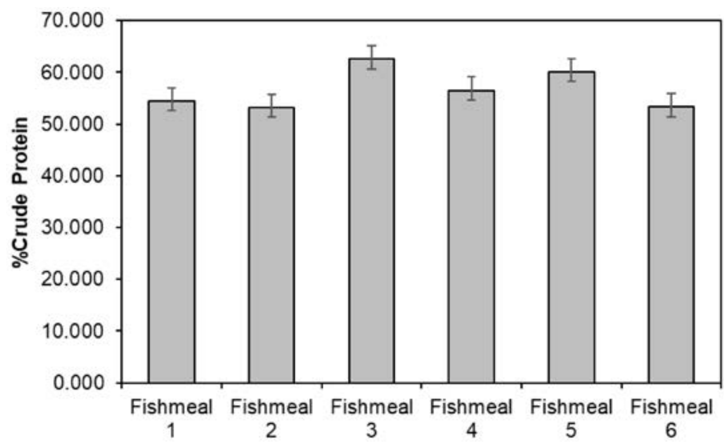

Figure 5. Percentage mean CP in fishmeal. Different letters differ statistically ($p<0.001$). Vertical bars show ± standard error.

(60.05±0.80) was equal to meal 3, which obtained the highest value (62.55%±1.26). In contrast, fishmeal 2 showed the lowest CP content (53.15±1.17%). Regularly, the protein level of fishmeal ranges from 50 to 72% depending on the species processed and the production process, which is consistent with these results (Arriaga-Hernández *et al.*, 2016; FAO, 2022). Fishmeal 3 can be classified as category A (superior quality), which is common for tuna meals (Souza *et al.*, 2017; Kim *et al.*, 2019; Li *et al.*, 2023). Likewise, fishmeal 5 is in category A, although its protein content is relatively low considering that the best Monterey sardine meals have up to 70% CP (Hernández *et al.*, 2014; Arriaga-Hernández *et al.*, 2021). All other fishmeals are considered category B as they do not reach 60% CP, which may be a consequence of protein denaturation during manufacture (meal 6), high inclusion of bones (fishmeal 2), or poor nutritional status of the fish at the time of capture (De Koning, 2002; Cabello *et al.*, 2013; Chaula *et al.*, 2019).

The FNE presented percentages between 6 and 17% (Figure 6), with differences between treatments ($F=16.53$, $p \leq 0.00005$). Fishmeal 1 obtained the highest value of

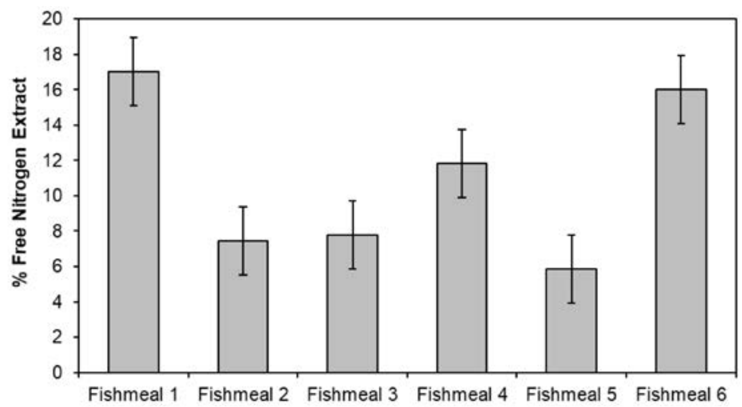

Figure 6. Mean percentages of the FNE in fishmeal. Different letters differ statistically ($p<0.001$).

the parameter (17.03%±2.74%), being equal to fishmeals 4, and 6 (11.55±2.92% and 16.39±1.96%). Fishmeal 5 showed the lowest percentage (6.18±0.08%) and had no significant differences with fishmeal 2, and 5. Fishmeal 4 was statistically equal for both groups. Generally, the FNE percentage of fishmeal's ranges from 3 to 12%, which is consistent with part of the results (Hernández *et al.*, 2014). However, higher than 10% is discouraged for the formulation of feeds for carnivorous fish and crustaceans as they do not metabolise carbohydrates efficiently (Ween *et al.*, 2017; Yen-Ortega *et al.*, 2021). Consequently, fishmeals 2, 3, and 5 would provide the optimal carbohydrate intake without detracting from other parameters (CP or EE), while fishmeals 1, 4, and 6 would have a lower nutritional quality.

CONCLUSIONS

Fishmeal produced on the northwest coast of Mexico has considerable variation in its proximate chemical composition due to the lack of standardised fabrication processes and quality control norms. In particular, the differences observed between the California pilchard meals confirm the information. Likewise, fishmeals 3, and 5 are the most recommendable for inclusion in aquaculture diets as they comply with the recommended quality intervals, while the use of fishmeal 6 is not recommended due to its possible overheating. A focused evaluation of tuna-derived meals is also recommended to assess their variability between production plants.

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