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Handmade fish meal as a partial replacement of soybean meal in diets for feedlot lambs: Effects on growth performance, dietary energy and meat quality

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ABSTRACT

With the aim to evaluate a handmade fishmeal (HFM) as a partial replacement of soybean meal (SBM) in finishing diets, 36 intact male Dorper × Pelibuey lambs (41.43±7.38 kg of initial weight) were used in a completely randomized block design to test the following treatments: 1) Cracked corn-based diet containing 12% SBM, 2) inclusion of 3.5% of HFM partially replacing SBM, and 3) inclusion of 7% of HFM partially replacing SBM. Urea and limestone were utilized to balance diets in CP and calcium content. The feeding trial lasted 30 days. Replacement of SBM with HFM did not modify the effects on average daily gain (ADG) and dry matter intake (DMI), but there were numerical differences in ADG; HFM inclusion linearly improved gain-to-feed ratio; dietary net energy (NE) and observed-to-expected diet NE. Hot carcass weight and dressing percentage were not affected by HFM. Except a linear increase on C22:6, the effect of SBM replacement on fatty acid profile in meat was not significant. The meat *p*H registered at 24 h post-mortem linearly increased with HFM inclusion, but meat colour and sensorial values were unaffected. It was concluded that inclusion of up to 7% of HFM in diet as partial replacement of soybean meal did not negatively affect DMI and ADG, but can increase feed efficiency and dietary energy utilization. The effects of HFM on carcass and meat quality were inappreciable. Due to variations in handmade processing, it is important to verify its chemical composition before HFM can be incorporated into diets.

Keywords: Byproducts, Dietary energy, Feedlot lambs, Handmade fishmeal, Meat quality

Catch fishes discarded in fishing farms represents a major pollution problem. Globally, it is estimated that between 7 and 10 million tons of commercial fisheries catches are discarded annually (Europe Commission 2019). One of the strategies to reduce the impact of fisheries waste is to convert it into fish meal with the aim to offer it as a feed ingredient to animal production. In some regions of developing countries, the processing plants to treat fish wastes are scarce. A solution for this kind of residue is handmade processing. Valdés-García *et al*. (2016) demonstrated that 3.5% of handmade fish meal (HFM) can replace 7.2% of soybean meal (SBM) in diets for lactating ewes without adverse effects on milk yield. However, HFM increased milk protein content and live weight of suckling lambs at 21-d of age. This research indicate that HFM could be a low-cost alternative to high-protein ingredients as soybean meal (SBM) which is an expensive feed ingredient. Compared to SBM, fish meal has a greater content of rumen undegradable protein (NRC 2007) rich in lysine and methionine, and has higher content of essential fatty acids (Ma *et al*. 2019). These characteristics are conducive to optimum productive performance in the fattening phase because lysine and methionine are limiting amino acids to lamb's growth during finishing, when they are not present in adequate concentrations (Estrada-Angulo *et al*. 2018). On the other hand, ruminal undegradable protein (RUP) can increase the metabolizable protein that reaches the intestine, positively affecting the dietary energy utilization efficiency during finishing phase (Zinn and Owens 1993, Tomlinson *et al*. 1997). Because of type of diet and the fish metabolism itself, compared to other protein sources (i.e. meat animal meal and the vegetable sources), HFM have greater concentration of long-chain fatty acids (LCFA) such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) since it contains an average of 8% oil, of which 25 to 30% are composed of these LCFA (Cho and Kim 2011).

Even though the consumption of supplemental DHA and EPA from marine origin has been shown to benefit the growth performance and feed efficiency in finishing lambs

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(Pewan *et al*. 2022), it is also true that high supplemental level inclusion of DHA and EPA in diet could increase their deposition in adipose tissue or muscle which would negatively influence the nutritional and sensory values of meat (Webb and O'Neill 2008). Nevertheless, to the best of our knowledge, there is no information regarding the effects of HFM inclusion in growth performance and meat quality of finishing lambs. It was hypothesized that partially replacing SBM by HFM at moderate levels (up to 7% in diet) in finishing diets can enhance rate of gain and energy efficiency without detrimental effects on dry matter intake, carcass dressing percentage, and meat quality of finishing lambs. For this reason, the aim of this experiment was to evaluate the effects of replacing SBM by HFM on growth performance, dietary energetics and meat quality of lambs finishing feeding with a corn-based diets.

MATERIALS AND METHODS

This experiment was conducted at the Autonomous University of Sinaloa, Feedlot Lamb Research Unit, located in the Culiacán City, México (24°46' 13" N and 107°21' 14" W). Culiacán city is about 55 m above sea level, and has a tropical climate. All animal management procedures were conducted within the guidelines of Federal-locally-approved techniques for animal use and care (NOM 1995).

Handmade fishmeal processing: Catch fishes discarded were obtained from a coastal region of the Pacific Ocean located at 484 km of distance from experimental facilities. The fisheries (mainly *Selene peruvian*, catfish, *Mugil cephalus*, Anguilla) residue was mainly composed (different proportions) of whole small fishes, tail, heads, visceral parts and backbones. Handmade processing was performed as described previously by Valdés-Garcia *et al*. (2016): the fish was cooked at 90°C for 25 min in order to eliminate pathogenic germs, separate the fat and obtain a more homogeneous paste. The paste was pressed in cylindrical tanks with perforations. Once the product contained <20% moisture by pressing, it was sundried at<10% moisture by using a metal panel covered by cloth. Once the product was dried then it was grounded using a hammer mill (Maquinova, MMB10, Iztacalco, Mexico) with screen diameter of 1 cm. Then, the handmade fish meal was packed and transported to the research facilities.

Animals, experimental design, treatments and sampling: Thirty-six intact male Dorper × Pelibuey lambs (205±16 d age; 41.4±7.38 kg of initial weight) were used to evaluate the effects of replacing SBM by HFM on growth performance, dietary energetics and meat quality of lambs finishing feeding with a corn-based diets. Upon arrival, lambs were treated for parasites (7.5 mg/kg LW; Closantel Panavet 15%, Panamericana Veterinaria de México City, México). Three weeks before initiation of the experiment, lambs were fed with the diet that did not contain HFM used during the experimental period (Table 1). Upon the initiation of the study, lambs were individually weighed before the morning meal and were blocked by weight into three weight grouping and assigned within weight grouping to 18 pens (two lambs/pen and 6 replicas per treatment).

Table 1. Experimental diets offered to the lambs

Item	Handmade fish meal inclusion level, %		
	0	3.5	7.0
Ingredient (% DM basis)			
Sudangrass hay	13.50	13.50	13.50
Cracked corn grain	63.50	63.25	63.00
Soybean meal	12.00	9.00	6.00
Handmade fishmeal	0.00	3.50	7.00
Urea	0.50	0.25	0.00
Cane molasses	7.50	7.80	8.00
Mineral supplement[1]	2.50	2.50	2.50
Limestone	0.50	0.20	0.00
Chemical composition (%)[2]			
Dry matter	87.92	87.80	87.98
Crude protein	14.37	14.38	14.40
Ether extract	3.01	3.63	4.26
Neutral detergent fiber	17.55	17.15	16.74
Rumen undegradable protein[3]	39.15	44.28	49.40
Diet energy (Mcal/kg)[4]			
Maintenance	1.93	1.95	1.97
Gain	1.30	1.32	1.34

Mcal, megacalorie. [1]Mineral supplement contained: Calcium, 20%; phosphorus, 0.55%; magnesium, 0.58%; potassium, 0.65%; NaCl, 15%; vitamin A, 1100 IU/kg; vitamin E, 11 UI/kg. [2]Dietary composition was determined by analyzing subsamples collected and composited throughout the experiment. Accuracy was ensured by adequate replication with acceptance of mean values that were within 5% of each other. [3]Calculated from NRC (2007). [4]Calculated from tabular net energy (NE) values for individual feed ingredients published by NRC (2007).

Pens had area of 6 m^2 with overhead shade, automatic waterers and 1 m fence-line feed bunks. Lambs were subjected to the treatments: 1) Cracked corn-based diet with 12% SBM, 2) inclusion of 3.5% of HFM partially replacing SBM, and 3) inclusion of 7% of HFM partially replacing SBM. Urea and limestone were utilized to balance diets in CP and calcium content. Soybean meal used was obtained from a commercial distributor (Primos & Cousins Products, Culiacán, Sinaloa, México). Guarantee analysis was: minimum 46% CP and maximum 7% crude fiber, 6% ash, and 12% moisture. Ingredients and chemical composition of the basal diet are shown in Table 1. Lambs were provided fresh feed twice daily at 0800 and 1400 h in an approximately proportion of 30:70 of total feed daily offered, feeding was adjusted daily, allowing for a feed residual ~50 g/kg. Residual feed was collected between 0740 and 0750 h each morning and weighed. The adjustments to either increase or decrease daily feed delivery were provided in the afternoon feeding. Lambs were weighed just prior to the morning feeding on days 1 and 30 (final day) of the experimental period. Live weights (LW) on days 1 was converted to shrunk body weight (SBW) by multiplying LW by 0.96 to adjust for the gastrointestinal fill (Cannas *et al*. 2004) All lambs were fasted for 18 h before recording the final LW.

Laboratory analysis and calculations: Feed samples were collected from each prepared batch. Feed refusal was collected daily and composited weekly for DM analysis (oven drying at 105°C until no further weight loss; method 930.15, AOAC 2000). Feed samples were subjected to the following analyses: DM (oven drying at 105°C, method 930.15), crude protein (CP, N× 6.25, method 984.13), ash (method 942.05), and ether extract (EE, method 991.36) according to AOAC (2000). Neutral detergent fiber (NDF) was determined by corrected for NDF-ash, incorporating heat stable α-amylase (Van Soest *et al*. 1991). Fatty acids in HFM and in *Longissimus muscle* (LM) were extracted and determined according to the method described by Luo *et al*. (2019). Estimates of ADG and dietary net energy were based on initial SBW and final (d 30) fasted BW. Average daily gain was computed by subtracting initial SBW from final SBW and dividing the result by the number of days on feed. Feed efficiency was computed as ADG/ DMI. Based on estimated diet, NE concentration and measures of growth performance, one approach for evaluation of the efficiency of dietary energy utilization in growth-performance trials was the ratio of observed-to-expected dietary NE, performed following the methodology, coefficients, and equation described by Castro-Pérez *et al*. (2022).

Carcass and meat quality: All lambs were harvested in the same day. After humanitarian sacrifice, lambs were skinned, and the gastrointestinal organs were separated and carcasses (with kidneys and internal fat included) were weighed to determine dressing percentage. After carcasses (with kidneys and internal fat included) chilled in a cooler at -2 to 1°C for 24 h, carcass *p*H was registered at 24 h postmortem following the methodology described by Honikel (1998). Two LM steaks (10 cm thick) from each carcass were removed between the 12^{th} and 13^{th} rib interface, preserved immediately on dry ice and shipped to the Meat Quality Laboratory, steaks were frozen at −20°C vacuum packaged, and stored for subsequent meat quality trait analysis, variables measured included color determined following the procedure reported by Luo *et al*. (2019). The sensory characteristics of LM samples were evaluated by 70 untrained consumer panelists following the procedures described by Costa *et al*. (2018).

Statistical analyses: Performance and carcass data were analyzed as a randomized complete block design, considering the pen as the experimental unit. All the data were tested for normality using the Shapiro-Wilk test. MIXED procedure of SAS (2004) was used to analyze the variables. Meat quality was analyzed as a randomized complete block design with subsampling, with pen as the experimental unit and animal as the observational unit. Because sensory test data did not show a normal distribution of residuals, a nonparametric Friedman test was used. Treatment effects were tested for linear, quadratic, and cubic components of the HFM level. Polynomials were considered significant when the P-value was ≤0.05.

RESULTS AND DISCUSSIONS

Owing to the difference in chemical composition between SBM and HFM, replacing SBM by HFM linearly increased the ether extract content (EE) and estimated rumen undegradable protein (RUP, Table 1). As was planned, dietary protein and energy value of diets were very similar between treatments. The chemical composition and fatty acid profile of HFM is shown in Table 2. Compared to commercial fish meal (NRC 2007), HFM contained lesser CP and NDF, but higher concentration of EE and ash. Compared to HFM used in the present experiment, a similar proportion of CP and ash, but lower EE for HFM was reported previously (Valdés-García *et al.* 2016). Fatty acid profile was in accordance with those reported for Ocean Pacific fish (Huynh and Kitts 2009); although, values for C16:0 was lower and C22:6 n3 was higher than those reported for Gümüş and Erdogan (2010) to commercial fishmeal. The most abundant unsaturated fatty acids were oleic (C18:1, cis-9), palmitoleic (C16:1) and docosahexaenoic [C20:3 (n-6)]. As expected, total saturated fatty acids concentration was lower than total unsaturated fatty acids. The difference observed in the fatty acid profile in fishmeal can be attributed to type of fish (species) used and by environmental factors when it captured, as well as by variations during meal manufacturing process (Petricorena 2014, Hilmarsdottir *et al*. 2020). Therefore, composition of handmade fish meal can greatly vary. The greater content of ether extract in HFM obtained here could be due to either a greater quantity of viscera and due to insufficient pressing during its preparation Thus, it is important to verify its chemical composition before that HFM be incorporated into diets.

Treatments effects on growth performance and dietary energy are shown in Table 3. Replace SBM with HFM did not modify ADG and DMI, but due of numerically

Table 2. Chemical composition and fatty acid profile[1] of handmade fishmeal (HFM)

Item	HFM[2]	Fish meal NRC (2007)	Difference, %
Dry matter	93.99	92.30	+1.8%
Crude protein	57.73	66.24	-12.84
Ether extract	19.53	11.90	+31.43
NDF	8.3	13.60	-38.97
Ash	24.10	20.02	+20.38

[1]HFM fatty acid profile: C14:0, 6.37%; C14:1, 0.12%; C16:0, 15.25%, C81:0, 7.0%, C81:1 (trans-9), 0.54%; C18:1 (cis-9), 15.17%; C18:2, 0.82%; C20:0, 0.73%; C18:3 (n-6), 0.32%; C20:1, 1.29%; C18:3 (n-3), 0.10%; C21:0, 0.35%; C20:2, 0.14%; C22:0, 0.38%; C20:3(n-6), 0.85%; C20:3 (n-3), 0.20%; C22:1, 0.88%; C20:4, 0.19%; C23:0, 3.04%; C24:0, 0.36%, C24:1, 1.23%, C22:6 (n-3), 24.71%; saturated fatty acids, 33.47%; unsaturated fatty acids, 66.53%; SFA/UFA, 0.503. [2]HFM composition was determined by analyzing subsamples collected and composited from elaborated batch. Accuracy was ensured by adequate replication (3×) with acceptance of mean values that were within 5% of each other.

Table 3. Effect of treatments on growth-performance and dietary energy of finishing lambs

Item	Handmade fish meal inclusion level (%)			SEM	Contrast *P*-value	
	0	3.5	7.0		L	Q
Days on test	30	30	30			
Pens	6	6	6			
Weight (kg)						
Initial	41.44	41.70	41.42	0.317	0.98	0.73
Final	47.82	48.61	48.73	0.541	0.16	0.80
Daily gain (g)	0.212	0.230	0.244	0.021	0.32	0.93
Dry matter intake (kg)	1.274	1.268	1.261	0.072	0.91	0.98
Gain to feed ratio	0.167	0.182	0.194	0.006	0.02	0.91
Diet net energy (Mcal/kg)						
Maintenance	1.95	2.06	2.13	0.027	<0.01	0.44
Gain	1.30	1.39	1.46	0.024	<0.01	0.44
Observed-to-expected diet NE						
Maintenance	0.99	1.04	1.07	0.014	<0.01	0.52
Gain	0.99	1.05	1.08	0.017	<0.01	0.77
Hot carcass weight (kg)	27.31	28.08	27.97	0.678	0.57	0.77
Dressing percentage	57.10	57.77	57.40	0.683	0.89	0.57

SEM, Standard error of the mean; L, linear; Q, quadratic; NE, net energy.

difference on ADG, HFM inclusion linearly improved (P<0.01) gain-to feed ratio, dietary NE and observed-to-expected diet NE. There are no current reports in which fishmeal has been evaluated in diets for feedlot lambs. But earlier reports indicate that DMI responses of diets containing commercial fishmeal are inconsistent. In this sense, Tan and Bryant (1991) observed that increase of concentrate intake was positively associated with level (from 3 to 7%) of fish meal. However, others reports did not observed effects on DMI when conventional fishmeal was included up to 10% (Pond 1984, Hussein and Jordan 1991, Atti *et al*. 2007). Even when the basis of this inconsistencies is not fully understood, differences on forage-to-concentrate ratio, CP level, and RUP (Walz *et al*. 1998, Estrada-Angulo *et al*. 2018) have been defined as the main factors that can affect DMI when fishmeal is

Table 4. Influence of replacing soybean meal with handmade fishmeal on long chain fatty acid profile in muscle

Item	Handmade fish meal inclusion level (%)			SEM	Contrast *P*-value	
	0	3.5	7.0		L	Q
C12:0	0.0818	0.0758	0.0638	0.0059	0.04	0.69
C14:0	2.0495	1.9928	1.9293	0.1083	0.45	0.98
C14:1	0.1758	0.1807	0.1806	0.0107	0.75	0.84
C16:0	25.2471	25.4931	25.0335	0.5280	0.78	0.59
C16:1	1.9916	2.3357	2.1325	0.1218	0.43	0.09
C18:0	14.8438	12.2887	13.4434	0.8815	0.28	0.10
C18:1	46.167	47.080	47.418	0.7554	0.26	0.76
C18:2	3.9945	4.6406	4.1027	0.3846	0.85	0.23
C20:0	0.0949	0.08053	0.1048	0.0096	0.48	0.12
C18:3	0.3181	0.3422	0.2886	0.0519	0.69	0.55
C20:1	0.1469	0.1427	0.1657	0.0112	0.25	0.33
C21:0	0.0499	0.0533	0.0550	0.0025	0.17	0.79
C20:2	0.1805	0.2141	0.1844	0.0171	0.82	0.15
C20:3	1.8079	2.1171	1.5722	0.1583	0.31	0.07
C23:0	0.3054	0.4581	0.3301	0.0697	0.80	0.12
C24:1	0.0486	0.0517	0.0534	0.0033	0.32	0.87
C22:6	0.1130	0.1534	0.1814	0.0204	0.03	0.80
SFA	44.5676	41.3941	42.1227	2.0405	0.42	0.21
MUFA	48.9614	50.9626	51.3687	4.1343	0.55	0.74
PUFA	6.4710	7.63431	6.5089	0.6237	0.91	0.16

SEM, Standard error of the mean; L, linear; Q, quadratic; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

included in diets. In line with results reported here, absence of effects on DMI was noted in lactating ewes when 3% of similar product of HFM was included in diet (Valdés-García *et al*. 2016). In the experiment of Valdés-García *et al*. (2016), diets contained a similar CP (~13.6%) and RUP (53 vs 56%). Similarly, in the present experiment diets were isoproteic (~14.4% CP), but RUP increased from 39 to 49% by the HFM inclusion. Therefore, other factors (i.e. diet composition, organoleptic characteristics of fishmeal, among others) must be existing that can affect the DMI when fishmeal, handmade or commercial, is included into diets. Previous reports indicate that inclusion of fishmeal did not affect ADG and gain efficiency in finishing feedlot cattle (Comerford *et al*. 1992, Lehmkuhler and Kerley 2007) and lambs (Hussein and Jordan 1991, Atti *et al*. 2007). Likewise, in the present experiment ADG was not influenced by HFM inclusion, but by numerically difference on DMI, gain efficiency was linearly increased as HFM was included in diets. Increases in gain efficiency in lambs have been observed when fishmeal (RUP ~65%) replace a rumen high-degradable protein ingredient such as SBM (RUP~32%) (Can *et al*. 2005). It has been reported that ratio of rumen non-degradable/ degradable protein can affect the dietary energy utilization of feed as well. Accordance, improvements on dietary energy utilization when high rumen undegradable protein ingredients are included in finishing diets have been reported in cattle (Zinn and Owens 1993, Tomlinson *et al*. 1997). As is previously exposed (Castro-Pérez *et al*. 2022), the estimation of dietary NE based on measures of growth-performance provides important insight into potential ingredients (or other factors) effects on the efficiency of dietary energy utilization independently of DMI and rate of gain.

Based on observed diet NE concentration, one approach for evaluation of the efficiency of energy utilization in growth-performance trials is the ratio of observed (based on growth performance)-to-expected dietary NE (based on energy tabular values from NRC Tables). In such a way, that the interpretation of energy utilization efficiency is as follows: An observed-to-expected dietary NE ratio of 1.00 indicates that performance is consistent with dietary NE values based on tables of feedstuff standards (NRC 2007) and observed DMI. A ratio that is greater than 1.00 is indicative of greater efficiency of dietary energy utilization. Whereas, a ratio that is lower than 1.00 indicates lower than expected efficiency of energy utilization. Under these energetic approach, HFM increased 4.8% and 7.4% of observed-to-expected dietary NE at 3.5 and 7% supplementation level, respectively. Similarly, Zinn and Shen (1998) evaluated the effect of 4.5% inclusion of either fishmeal or soybean meal in isoproteic (11.5% CP) finishing steam-flaked corn-based diets (2.14 Mcal EN_m/kg diet) for feedlot cattle. Cattle that were fed with fishmeal showed an improvement of 3.3% on dietary energy. As expected, due to similarity in rate of gain among treatments, carcass weight and dressing percentage were not affected by HFM inclusion (Table 3).

Effects of treatments on meat fatty acids profile, and meat quality are presented in Tables 4 and 5. Except of a tendency (P=0.10) of linear decrease of C18:0 and linear increase (P=0.04) on C22:6, the effect of SBM replacement on fatty acids profile in meat was not significant. All proportions of fatty acids, and saturated/ unsaturated ratio were into the range reported for lambs feeding a high concentrate diet (Dervishi *et al*. 2019). In agreement with Berthelot and Gruffat (2018), and in line with the HFM richness in C18:3 n-3, as increased HFM in diet, *L. muscle* showed a higher proportion of C22:6 n-3. This has a positive effect on consumers because DHA plays a role in mediating the expression of at least 100 genes in the areas of neural development, function, and metabolism (Vanden Heuvel 2012). The meat *p*H registered at 24-h did not differ (P>0.05) between treatments (Table 5) which is within the normal range across from 5.3 to 5.7 registered at 24 h after slaughter in lamb meat (Estrada-León *et al*. 2022). This is important because some characteristics such as colour, juiciness, and tenderness depend on meat *p*H (Pérez and Ponce 2013). Similarly, the meat colour scale (CIE L* a* b) was not modified (P>0.05) by the inclusion levels of HFM in diets (Table 5). Moreover, the values measured in the present experiment are similar to those observed for meat from wool and hair sheep feeding without inclusion of fishmeal in diets (Camacho *et al*. 2016).

Table 5. Influence of replacing soybean meal with handmade fishmeal on meat *p*H, colour, and sensorial values

Item	Handmade fish meal inclusion level (%)			SEM	Contrast *P*-value	
	0	3.5	7.0		L	Q
*p*H- 24 h	5.67	5.58	5.58	0.032	0.05	0.29
Colour						
L*	41.69	40.24	39.77	1.032	0.20	0.71
a*	20.71	20.72	20.62	0.364	0.85	0.80
b*	4.73	4.26	4.84	0.402	0.84	0.45
Sensorial values						
Appearance	5.85	5.85	5.82	1.04	0.97	0.88
Odour	5.83	5.69	5.85	1.24	0.92	0.74
Tenderness	5.62	5.44	5.48	1.45	0.72	1.69
Flavour	5.45	4.99	5.17	1.54	0.29	0.38

SEM, Standard error of the mean; L, linear; Q, quadratic.

Inclusion HFM up to 7% in diet did not affect appearance, odour, flavour, or tenderness of meat. The absence of fish-associated flavours and odours in sheep meat when diets are supplemented with low-to-moderate (i.e. <10%) fishmeal levels (Atti *et al*. 2007, Dewi *et al*. 2021) can be explained because of the hydrolysis and biohydrogenation of the lipids in the rumen (Kitessa *et al*. 2001). In non-ruminants, lipids reach the intestinal with very little or no changes of their original form in which it was ingested, while in ruminants, rumen microorganisms rapidly modify the lipids of the diet saturating through biohydrogenation the long-chain unsaturated fatty acids limiting the tissue synthesis of EPA and DHA same which have effects on meat odour and flavour (Jiang *et al*. 2011).

It can be concluded that inclusion up to 7% in the diet of HFM, as partial replacement of soybean meal, did not negatively affect DMI and ADG, but due to its content of rumen protein by-products and essential fatty acids, can increase feed efficiency and dietary energy utilization. The effects of HFM on carcass, and meat quality were inappreciable. Due to its high variability by handmade processing it is important to verify its chemical composition before HFM be incorporated into diets as replacement of SBM.

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