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Preparation of Biological Fish Silage and its Effect on the Performance and Meat Quality Characteristics of Quails *(Coturnix coturnix japonica)*

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ABSTRACT

The aim of the present study was to produce fish silage by lactic acid fermentation and evaluate its use in feeding of quails (Coturnix coturnix japonica)*. An oven-dried mixture of fish silage and soybean meal (1:1 w/w) was used to prepare the diets with different levels of inclusion (0, 10, 20 and 30%) and evaluate its effect on the performance and meat quality of 160 quails. The inclusion level did not affect the growth and feed conversion ratio. The carcass yield (70.3%) and sensory quality of breast meat were not significantly different among the treatments ($p>0.05$). However, the concentration of unsaturated fatty acids such as oleic (C18:1n9C), linoleic (C18:2n6C), linolenic (C18:3n3), arachidonic (C20:4n6), cis eicosapentaenoic (C20:5n3) and cis docosahexaenoic (C22:6n3) increased in quail breast meat with the inclusion of fish silage:soybean mixture in the diet ($p<0.05$). Fish silage and its use in quail diets could offer a good alternative for fish waste utilization as feedstuff component for the improvement of fatty acid composition in its breast meat.*

Key words: fish wastes, biological silage, quails feeding, meat quality

INTRODUCTION

Fish processing for human consumption yields around 40% of edible meat, while the remnant 60% composed of bones, skin, head, viscera, meat scraps and scales, is fishery by-products (Gildberg 1993). Commonly, the fishery by-products are discarded as waste all over the world that causes serious environmental problems and economic losses (Kjos et al. 2000; Barroga et al. 2001). It is estimated that fish waste production is between 17.9 and 39.5 million tons per year, representing an important loss of valuable nutrients. Fish waste can be transformed into fish-meal. However, its production process is considered expensive. The high prices of fish-meal and its periodic scarcity have encouraged researchers to look for alternative protein feedstuffs (Fagbenro and Jauncey 1998). Fish silage has been considered an alternative process to improve the use of fish waste, or fishery by-products providing with a high quality protein source for animal feeding (Zinudheen et al. 2008). Fish silage can be produced either by the addition of acids to fish, or fish waste (chemical silage), or

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by adding a carbon source along with lactobacilli species for lactic acid fermentation (biological silage) (Ramirez-Ramirez et al. 2008).

During the fermentation, lactic acid bacteria (LAB) transform sugars into lactic acid with the concomitant decrease in the pH of the mixture (around 4.5). The low pH along with bacteriocin molecules produced by certain LAB prevents the growth of harmful organisms (Shirai et al. 2001). Biological fish silage production offers a great potential for the conversion of an underutilized protein to a valuable hydrolyzed product (Fagbenro and Jauncey 1998; Plascencia et al. 2002; Shirai and Ramírez-Ramírez 2011). Vidotti et al. (2002) reported that the proteins from biological silage were more digestible than those obtained by the chemical silage due to the autolytic process catalyzed by the enzymes present in the fish waste that degraded the proteins into short peptides and free amino acids. The process is accelerated by proteases and lactic acid secreted from LAB (Yin et al. 2005). Lactic fermentation provides fat stability in fish silage, improving its acceptability in the animal feed (Enes-Dapkevicius et al. 2007).

Biological fish silage is considered a valuable source of LAB, which act as probiotics in silage-fed animals bringing health benefits (Yin et al. 2005; García et al. 2007). Fish silage has adequate levels of essential amino acids (Vidotti et al. 2003; Ramírez-Ramírez 2009), which can be used as a high nutritional value protein source for the feeding of different animal species such as broilers (Espe et al. 1992; Kjos et al. 2000; Santana-Delgado et al. 2008; Al-Marzooqi et al. 2010), pigs (Kjos et al. 1999), laying hens (Kjos et al. 2001), lambs (Barroga et al. 2001), fish (Fagbenro and Jauncey 1998; Vidotti et al. 2002; Borghesi et al. 2008) and laying quails (Zinudheen et al. 2008). It has been reported that the use of diets with fish oil and fish silage may increase the content of polyunsaturated (PUFA) and long-chain omega-3 (C20:1, C22:1, C22:5 and C22:6) fatty acids in pig and broiler meat (Kjos et al. 1999, 2000). This may be beneficial for human nutrition, since the consumption of long-chain omega-3 fatty acid may strength immune and nervous systems, as well as prevention of the cardiovascular diseases and some types of cancer (Carroll 1986; Shirai and Ramírez-Ramírez 2011). To the best of our knowledge, there are no reports on the use of fish silage in quails feeding for meat production. Therefore, the objective of this study was to produce biological fish silage and evaluate its inclusion in quails feeding to assess the impact on the growth performance, carcass yield, sensory quality and fatty acid content in meat.

MATERIALS AND METHODS

Fish silage production

Fresh fish by-products mixture (MixW), which contained heads, viscera, skin, bones and meat scraps of the following species: *Bagre panamensis*, salema butterfish (*Peprilus snyderi)*, Mexican barracuda *(Sphyraena ensis)*, derbio (*Trachynotus ovatus)*, meagre (*Argyrosomus regius)* and common two-banded seabream (*Diplodus vulgaris)* were obtained from the fishery plants located in San Blas Port, Nayarit (Mexico). Fish by-products were minced through a 5-mm sieve using a meat mincer (TORREY 32, Mexico). Sugar cane molasses supplied by the sugar mill “El Molino S.A. de C.V.”, Tepic Nayarit, was used as carbon source. Sugar cane molasses contained (%) water 25.1, ashes 10.4 and soluble carbohydrates 55.7. *Lactobacillus* sp. B2 was used as starter, which was cultivated in MRS (Man Rogosa and Sharpe) broth at 30°C during 24 h until a concentration of $1X10^9$ cfu/mL was reached. Sugar cane molasses were added to MixW (18.0% wet basis) and inoculated with *Lactobacillus* sp. B2 (5.0% wet basis). The fermentation was carried out at pilot scale using the methodology described by Ramirez-Ramírez (2008).

Analyses of fish silage

The pH of fish silage was measured using a potentiometer UB10, UltraBasic (Denver Instrument, USA). Fish silage samples were diluted in distilled water (1:10) and the lactic acid concentration (%) was determined by titration with 0.1N NaOH until a final pH of 7.5. Fermentation was carried out for four days (the fish silage reached a pH value of 4.4 and a lactic acid content of 4.45%). Proximal composition of MixW and silage samples was determined using standard methods (AOAC 2000) while amino acids composition was performed according to the method reported by Vázquez-Ortiz et al. (1995). Microbial analysis of fish silage was determined by colony enumeration of mesophiles, coliforms, lactic acid bacteria, yeast and fungi (Shirai et al. 2001; Ramírez-Ramírez 2009).

In order to estimate the proteins digestion at stomach and small intestine level, the method *in vitro* reported by Calsamiglia and Stern (1995) was used with slight modifications. Briefly, a fish silage sample of 15 mg of nitrogen in 10 mL of a 0.1N HCl solution (pH 1.9) containing 1.0 g/L of pepsin (Sigma P-7012, Sigma) was incubated at 38°C. After 1 h, the pH was neutralized using 0.5 mL of 1N NaOH, then 13.5 mL of 0.5M phosphate buffer (pH 7.8) containing pancreatin (0.3%) (Sigma P-7545, Sigma) was added. The samples were incubated (38°C) under constant shaking for 24 h. After this, 3.0 mL of 6.1N trichloroacetic acid solution (TCA) was added to precipitate undigested proteins and kept for 15 min. Samples were centrifuged at 10,000×g at 4°C for 15 min (Beckman J2-M1Centrifuge, Beckman Coulter, USA). Total soluble nitrogen was determined by Kjeldahl method (AOAC 2000) and digestible protein in pepsin-pancreatin was calculated with the following expression:

$$\text{digestible protein } (\%) = \frac{\text{Soluble nitrogen in TCA}}{\text{Total nitrogen of the sample}} \times 100$$

Experimental diets

The semi-liquid fish silage obtained was mixed with soybean meal in a 1:1 ratio and the resulting mixture was oven-dried at 45°C for 48 h. Dried mixture was used in the experimental diets formulation (flour form) for the growth performance of quails using inclusion levels of 0, 10, 20 and 30% (Table 1). Control diet (number 1) consisted predominantly of soybean meal as supplemental protein source. Protein content in all experimental diets was adjusted in order to satisfy the requirements of quails (NRC 1994). Chemical composition of experimental diets was determined using official methods (AOAC 2000).

Table 1 - Composition of experimental diets used in feeding of quails (*Coturnix coturnix japonica*).

Ingredient (g/100g)	Diets			
	1 (Control)	**2**	**3**	**4**
Maize	52.5	52.5	52.5	52.5
Fish silage- soybean meal (50:50)	0	10.0	20.0	30.0
Soybean meal (44% of PC)	40.4	30.4	20.4	10.4
Orthophosphate	1.5	1.5	1.5	1.5
Soybean oil	2.8	2.8	2.8	2.8
Calcium (38%)	1.0	1.0	1.0	1.0
Refined salt	0.3	0.3	0.3	0.3
Novasil plus	0.25	0.25	0.25	0.25
Sodium bicarbonate	0.18	0.18	0.18	0.18
Metionine	0.11	0.11	0.11	0.11
Px-v10-cod*	1.0	1.0	1.0	1.0

* = Pre mix of vitamins and minerals for growth performance of quails.

Bird management

The biological evaluation of the diets was performed in a commercial farm under closed housing system, using 160 quails (*Coturnix coturnix japonica*) unsexed for meat production, 21 days old and 78.06 ± 3.96 g average weight. Four cages (78 cm long, 55 cm wide and 35 cm high) were used. Each cage was divided with wire cloth into four compartments and 10 quails were randomly assigned in each compartment. Four replications per treatment (experimental diets) were carried out. Experimental diets were randomly distributed and each group of 10 quails received 700 g of food daily. Experiment was performed during April and May. Animals were exposed to natural lighting, 55% relative humidity and a average temperature of 28°C. Birds remained under hygienic conditions and were provided with water *ad libitum*.

Measurements

The weight of the quails was registered in the morning at the beginning of the experiment before feeding and then every week for 35 days to record the weight gain. Food offered and refused was recorded daily to determinate the feed intake. Based on the feed intake and weight gain, weekly feed conversion ratio was calculated.

Evaluation of carcass yield and sensory quality of meat

After the growth performance trial, five quails from each of the experimental treatments were chosen randomly. Body weights of quails were recorded and slaughtered in a slaughterhouse attached to farm production to evaluate the carcass and meat quality characteristics. The slaughter was made by cervical dislocation, followed by exsanguination. Carcasses weight was recorded and the yield (%) was calculated as part of final live body weight of quails. Then the carcasses were wrapped in plastic bags and immediately frozen (-20°C). A month after the freezing, the sensory evaluation of meat was carried out. The carcasses were thawed in a microwave oven and then were cooked keeping the carcasses in closed plastic bags, and introduced into hot water (80°C/45 minutes). Breast meat of cooked quails carcasses was separated and sensory evaluation was conducted by a trained panel of 14 panelists who answered a questionnaire with a scale of 1 to 9, where 1 was the lowest and 9 the highest intensity for color, odor, off-odor, flavor, off-flavor, tenderness, juiciness and total quality.

Fatty acid content in meat of quails

Lipids were extracted from quail breast meat using chloroform/methanol (2:1 v/v) solvent and in a 1:20 proportion according to Folch et al. (1957). Fatty acid composition was determined as described by Park and Goins (1994). Briefly, 30 mg lipids were dissolved into 0.1 mL methylene cloride and 1.0 mL NaOH 0.5N in methanol. After nitrogen flushing and screw-capping, the test tubes were heated in water bath at 90ºC for 10 min. After cooling at room temperature, 1.0 mL of 14% boron trifluoride in methanol was added and heated again 90ºC for 10 min after nitrogen flushing. The tubes were removed and cooled to room temperature (25°C). The fatty acid methyl esters (FAMES) were extracted with 0.5 mL of hexane by vigorous agitation and FAMES composition was analyzed by GC using a Hewlett Packard 6890 gas chromatograph with flame ionization detector (FID) and an analytical column Supelco 2560 (100 m X 0.25 mm X 0.2 µm). The oven temperature was programmed from 100 to 190ºC at 15ºC/min and then to 220ºC during 45 min. The carrier gas was He, injection mode split and inlet temperature detector at 220 and 260ºC, respectively.

Statistical analysis

Data obtained from the performance trial (feed intake, weight gain and feed conversion ratio), carcass yield, sensory quality attributes and fatty acid composition of meat were statistically analyzed by one-way ANOVA for a completely randomized design. The Tukey-Kramer test for the means comparison was used at a significance level (p=0.05). The analyses were conducted with the NCSS 2007 program (NCSS Inc., USA).

RESULTS AND DISCUSSION

Fish silage composition and protein digestibility

Fish waste and fish silage contained 52.4 and 39.9% of protein and 24.5 and 14.5% of lipids, respectively, (Table 2). Ash content was similar in the fish waste and fish silage. However, the content of nitrogen-free extract (carbohydrates) was higher in the fish silage due to added molasses (Table 2).

Table 2 - Proximate composition (%)*, acidity and protein digestibility *in vitro* of fish waste and fish silage.

Component	Fish waste	Fish silage
Moisture	70.3 ± 0.4	65.5 ± 0.3
Crude protein (Nx6.25)	52.4 ± 0.9	39.9 ± 0.7
Ether extract	24.5 ± 0.6	14.5 ± 0.4
Ash	19.0 ± 0.5	18.0 ± 0.6
Nitrogen free extract	3.6 ± 0.2	26.9 ± 0.6
pH	6.49 ± 0.03	4.4 ± 0.02
Lactic acid (%)	0.34 ± 0.003	4.45 ± 0.01
Protein digestibility (%)	69.00 ± 1.51	81.61 ± 0.9

* = Mean ± SD values, (n=3), expressed in dry basis.

The decrease in pH and high lactic acid production prevented the growth of harmful microorganisms, which allowed the preservation of fish silage. The product showed grayish brown color, pleasant sweet aroma and faint fish odor, this latter caused by the residual molasses, or aromatic compounds released by proteolytic activity, thus improving the sensorial properties (Bulut et al. 2005). The protein hydrolysis occurring during the fermentation increased the digestibility of fish silage (69 to 81.6%), therefore fish silage was more convenient in diets formulation. This could be due to the release of peptides and free amino acids resulting from protein hydrolysis, which could have potential chemo-attractants as well as nutritious stimulants in carnivorous and in other animal species (Lian et al. 2005).

Amino acid content

In this study, fish silage had similar concentrations of histidine, threonine, methionine, valine and isoleucine to those of fish meal with the exception of glycine and tyrosine content (Table 3). White et al. (1999) reported a lower content of histidine, threonine, methionine, glycine, alanine and tyrosine in fermented silage of silver hake than that obtained in this study. In contrast, Don et al. (1993) reported higher amino acid content in fermented silage of salmon viscera compared to the present results, except for glycine and tyrosine. Most of the amino acids content was close to half of that reported for fermented silage from tilapia wastes (Vidotti et al. 2003). However, the same authors reported two-fold more aspartic and glutamic acids and lower tyrosine than fish silage obtained in this study.

Zinudheen et al. (2008) reported higher values in amino acid score of biological fish silage from surimi processing waste and Santana-Delgado et al. (2008) in chemical silage of whole Spanish mackerel.

Table 3 - Aminoacid content (g/100g protein) * in fish silage and fish meal.

Amino acid	Fish silage	Fish meal
Aspartic acid	3.1	5.8
Glutamic acid	4.4	8.7
Serine	1.7	2.9
Histidine	1.8	1.3
Glycine	7.7	5.2
Threonine	2.4	2.8
Arginine	1.9	5.7
Alanine	5.2	4.4
Tirosine	4.3	2.0
Metionine	2.0	1.7
Valine	2.5	2.9
Phenilalanine	1.7	2.5
Isoleucine	2.4	2.6
Leucine	3.2	4.5
Lysine	2.2	3.9

* = Mean values (n=3).

Proximate composition of experimental diets

The proximate chemical composition of experimental diets is presented in Table 4. The average dry matter content was 89.1 and 88.7% for the control and diets with fish silage, respectively. Crude protein content was similar in all the experimental diets, which were adequate to meet the requirements of quails (Gorrachategui 1996). Lipids and minerals content were higher in the diets with fish silage, which could be due to the high content of these nutrients in the unfermented fish waste (Table 2). Crude fiber content of the experimental diets was low and met the minimum requirement for growing the quail (Gorrachategui 1996).

Table 4 - Proximate analysis* of experimental diets used in feeding trial of quails (*Coturnix coturnix japonica*).

Component (g/100 g)	Diet			
	1 (Control)	2	3	4
Moisture	10.9 ± 0.6	11.5 ± 0.9	11.3 ± 0.6	11.2 ± 0.3
Crude protein (Nx6.25)	21.1 ± 0.2	20.3 ± 0.5	21.0 ± 0.9	20.4 ± 0.7
Ether extract	3.8 ± 0.4	7.3 ± 0.6	7.7 ± 0.6	9.6 ± 1.1
Crude fiber	3.3 ± 0.2	2.8 ± 0.3	2.6 ± 0.2	2.1 ± 0.3
Ash	9.8 ± 0.1	11.4 ± 0.1	12.3 ± 0.9	13.0 ± 0.6
Nitrogen free extract	51.1 ± 1.0	46.8 ± 1.1	45.0 ± 1.6	43.7 ± 1.0

* = Mean ± SD values, (n=3), expressed in wet basis.

Growth and feed conversion ratio

The level of fish silage in the diet did not affect the growth rate of quails (p>0.05). However, after 21 days, the inclusion of 20 and 30% of fish silage:soybean mixture in the diets improved the weight gain of quails (Fig. 1). This was very likely due to the similar amino acid content of fish silage compared to fish meal (Ramírez-Ramírez 2009).

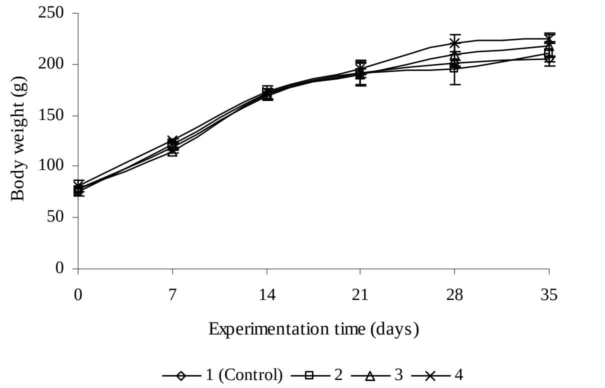

Figure 1 - Growth response of quails fed with diets containing different levels (1=0%, 2=10%, 3=20% and 4=30%) of fish silage:soybean mixture.

Another reason could be the content of soluble protein in the diet, which could be rapidly absorbed, resulting an early start of protein synthesis (Espe et al. 1992). In this sense, the high protein digestibility of silage used might have influenced the growth of quails.

The results obtained showed a trend similar to those reported by Santana-Delgado et al. (2008), who found no significant difference on weight gain among the treatments in broilers feed with increasing amounts of fish silage (p>0.05). However, it has been reported that a better growth development is obtained when part of the protein of the diet was replaced with fish silage in feed broilers (Espe et al. 1992; Al-Marzooqi et al. 2010).

In this study, the weekly feed conversion ratio was different for each of the diets during the 35 days of the experiment (Table 5). Although there was no significant difference between the treatments during each week (p>0.05), feed conversion ratio was better at 14 days (Table 5). However, at day 21 and 28, feed conversion values were acceptable and consistent with the recommendations for this line of quails (Gorrachategui 1996).

These results showed a similar pattern to those reported by Espe et al. (1992), who did not find significant difference in feed intake, weight gain and feed efficiency by including fish silage up to 30% in broilers feed. The results obtained at day 7 using 10% of dried fish silage:soybean mixture were in concordance with those reported by Denli et al. (2004) who included black seed oil in the feed of quails (*Coturnix coturnix japonica).* Feed conversion values after 35 days of the experiment showed low efficiency of feed for all the treatments, so commercially it would not be advisable to fatten up the quails until that time (Table 5).

Table 5 - Feed conversion ratio (g feed/g gain)[a,b] of quails fed with diets containing different levels of fish silage:soybean mixture.

Diet*	**Time (days)**				
	7	14	21	28	35
1	3.10 ± 0.24	2.92 ± 0.22	3.67 ± 0.31	4.63 ± 0.38	5.76 ± 0.50
2	2.62 ± 0.26	2.65 ± 0.17	3.38 ± 0.37	4.37 ± 0.32	5.48 ± 0.45
3	3.16 ± 0.19	2.72 ± 0.20	3.62 ± 0.41	4.23 ± 0.47	5.24 ± 0.55
4	2.85 ± 0.44	2.89 ± 0.36	3.55 ± 0.31	4.11 ± 0.28	4.99 ± 0.51

[a] Mean ± SD values.
[b] n = 4; data from four replicates of 10 birds each.
[*] = (1 = control = 0%, 2 = 10%, 3 = 20%, 4 = 30%) of fish silage:soybean mixture, respectively.

Carcass yield and sensory quality of meat

The level of fish silage in the feed did not affect hot carcass yield, giving an average value of the four treatments of 70.30 ± 1.66% (p>0.05). The results agreed with those reported by Denli et al. (2004) for the same line of quails. Concerning sensory quality, quail breast meat attributes were not affected significantly by the addition of fish silage in the diet (p>0.05), thus, the meat was successfully accepted by the panelists (Table 6). To the best of our knowledge, this is the first report on the use of fish silage in the diet of quails and its effect on the sensory quality of meat. Contrary to this study, it has been reported that the addition (30%) of fish silage:corn (8:1.5 ratio) mixture in the diets fed to the birds caused an off flavour in birds breast, which was described as "fishy" by the sensory panel (Al-Marzooqy et al. 2010). Krogdahl (1985) reported that fish silage oil in feed (1.5%) adversely affected the sensory quality of chicken meat (leg and breast) and caused rejection by the judges.

Table 6 - Effect of diets with different levels of fish silage:soybean mixture on the sensory quality of quails breast meat.

Diet*	**Sensory quality attribute**[a]							
	Color	Odor	Off-Odor	Flavor	Off-Flavor	Tenderness	Juiciness	Total quality
1	7.50	7.79	1.00	7.21	1.28	7.21	6.57	7.50
2	6.93	8.0	0.93	7.28	1.07	7.71	7.00	7.50
3	7.35	7.43	0.93	7.43	0.93	7.71	7.00	7.64
4	6.93	7.07	0.86	6.78	1.00	7.93	7.00	7.5

[a] Mean values of panelists answers (n = 14).
[*] = (1 = control = 0%, 2 = 10%, 3 = 20%, 4 = 30%) of fish silage:soybean mixture, respectively.
Scale of 1 to 9, where 1 was the lowest and 9 the highest intensity for each sensory quality attribute.

Lopez-Ferrer et al. (1999) reported that the addition of fish oil in chicken food (8.2%) produced an unacceptable taste of the meat. Kjos et al. (2000) added fish silage (5%) and fish oil (1.7 to 2.5%) in broiler chickens feed, which caused odor and taste of fish in the leg meat. The same authors reported lower values of odor, flavor, juiciness and tenderness intensity of chicken meat than those obtained in this study for quail meat. It has been also reported that the addition of fish-meal together with fish silage in the broiler diet (4.0% each) produced strong fish odor and flavor in the meat (Mielnik et al. 2002). In this regard, present findings could be very valuable because the addition of dried fish silage:soybean mixture up to 30% in the feed did not alter the sensory quality of quail meat.

Fatty acid composition

The fatty acid composition of quail breast meat is shown in Table 7. Results showed that fish silage had a significant effect on concentration of fatty acids. The content of saturated fatty acid as myristic (C14), pentadecanoic (C15), palmitic (C16) and stearic (C18) was increased with increasing dried fish silage:soybean mixture from 10 to 30% ($p<0.05$). The level of fish silage had no effect on the concentrations of heptadecanoic acid (C17) and unsaturated like cis-10 heptadecenoico (17:1), elaidic (C18:1n9t), vaccenic (C18:1n7), gamma-linolenic (C18:3n6), cis-11-eicosenoic (C20:1), cis-11,14-eicosadienóico (C20:2), cis-8,11,14-eicosatrienoic (C20:3n6) and adrenic (C22:4n6) ($p>0.05$). However, the concentration of oleic (C18:1n9C), linoleic (C18:2n6C), linolenic (C18:3n3), arachidonic (C20:4n6), cis eicosapentaenoic (C20:5n3) and cis docosahexaenoic (C22:6n3) fatty acid increased with fish silage:soybean mixture in the diet ($p<0.05$). Similar results were reported in broilers (Lopez-Ferrer et al. 1999; Kjos et al. 2000).

The results obtained of the present study showed that the inclusion of fish silage in quails diet increased the unsaturated fatty acids in the meat. This finding appeared very important since diet intake with omega-3 PUFAs has been reported to reduce the levels of triglyceride, increase high-density lipoprotein cholesterol, increase glucose-induced insulin secretion and reduce the incidence of cardiovascular diseases among other beneficial effects (Rudkowska 2009; Shirai and Ramírez-Ramírez 2011).

Table 7 - Effect of diets with different levels of fish silage:soybean mixture on the fatty acid composition of quails breast meat (g/100 g wet sample)*.

Fatty acid	1 (Control)	2	3	4
C12:0	0.025 a	0.040 a	0.030 a	0.027 a
C14:0	0.080 b	0.080 b	0.115 a	0.135 a
C14:1	0.027 a	0.017 a	0.032 a	0.030 a
C15:0	0.053 c	0.062 c	0.082 b	0.110 a
C16:0	2.211 c	2.122 c	3.040 a	2.625 b
C16:1	0.860 a	0.695 c	0.817 b	0.587 d
C17:0	0.033 a	0.030 a	0.042 a	0.052 a
C17:1	0.058 a	0.052 a	0.052 a	0.055 a
C18:0	0.960 c	0.812 d	1.120 b	1.452 a
C18:1n9	0.058 a	0.037 a	0.065 a	0.050 a
C18:1n9	4.88 b	4.957 b	5.032 a	4.370 c
C18:1n7	0.028 a	0.022 a	0.027 a	0.025 a
C18:2n6	2.831 d	3.397 a	2.912 c	3.215 b
C18:3n6	0.013 a	0.015 a	0.015 a	0.012 a
C20:1	0.039 a	0.042 a	0.037 a	0.055 a
C18:3n3	0.184 c	0.240 a	0.200 b	0.172 d
C20:2	0.024 a	0.017 a	0.022 a	0.025 a
C20:3n6	0.021 a	0.020 a	0.020 a	0.022 a
C20:4n6	0.472 c	0.475 c	0.550 b	0.610 a
C20:5n3	0.021 c	0.020 c	0.037 b	0.045 a
C22:4n6	0.016 a	0.020 a	0.020 a	0.020 a
C22:6n3	0.175 d	0.187 c	0.250 b	0.322 a

* = Mean values (n=3).

a-d: Different letters in a row indicate significant differences among treatments ($p<0.05$).

CONCLUSION

Fish silage obtained by the use of LAB fermentation represents an alternative process for the use of fish waste. The inclusion of fish silage in quail diets neither adversely affected the productive parameters, nor the sensory quality of the meat, nor carcass yield. The content of polyunsaturated fatty acid in quail's meat could be increased with the inclusion of fish silage in the diet. The biological fish silage production is an attractive biotechnological process to utilize fish waste and reduce environmental problems.

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