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Effect of the Inclusion of Olive Cake in the Diet on the Physicochemical Characteristics of Dry-Cured Loin and Dry-Cured "Cachaço" of Bísaro Pig

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Abstract: The purpose of the present study was to characterize the dry-cured loin and dry-cured "cachaço" of Bísaro pork and evaluate the effect of the inclusion of olive cake in the animals' diet on the cured products. For this purpose, forty loins and forty "cachaços" were used, followed by a process of cold curing with controlled ventilation, without adding nitrites or synthetic additives. The dry-cured loin and "cachaço" chemical compositions were significantly different in moisture, total fat, protein, chlorides, ash, and *haem* pigments. The "cachaço" showed a much higher value of total fat and a lower protein value. Its chloride content was lower and was related to the lower ash percentage. Neither product differed significantly in the water activity and collagen content. The proportions of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids were significantly different between these products. The dry-cured "cachaço" showed higher values of SFA and PUFA, and the dry-cured loin had higher MUFA content. No significant effect of different olive cakes on diet was observed in the chemical compositions. Both products are of high quality and with good nutritional and physicochemical characteristics, and the introduction of olive cake in the diet did not affect any of the quality parameters analyzed.

Keywords: Bísaro breed; olive industry coproduct; dry-cured meat; chemical composition; fatty acids

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1. Introduction

According to FAO, there are two native pig breeds in Portugal: Bísaro and Alentejano [1]. Almost extinct in the 1980s, the Bísaro pig is a breed belonging to the Celtic line, raised mainly in Northern Portugal. Contrary to the status of the Celta pig, the Bísaro pig is no longer in danger of extinction today [1]. Nowadays, consumers are increasingly demanding high-quality products, manufactured in a traditional way; specific rare breeds such as Bísaro can be an essential aid in their valorization and differentiation in relation to similar products from other commercial breeds and their crossbreeds.

One of the most popular goods consumed worldwide is dry-cured loin, made from one of the most valuable joints of the pork carcass—the lumbar and thoracic parts of the *Longissimus thoracis et lumborum* (LTL) muscle. Another important product with similar characteristics is the dry-cured neck ("cachaço")—a product made from the proximal part of *Longissimus thoracis et lumborum* (LTL) muscle which runs from the column's cervical part noticeable beneath the scapula until the fifth thoracic vertebra. The production process for the loin is the same as the "cachaço"; only the size and location of the piece varies (vertebral from the end of the joint of the "cachaço" to the last lumbar vertebra).

The final product's dry-cured quality is based on the raw material quality and the processing conditions [2]. The curing process is a set of conditions where a temperature increase and a relative humidity decrease are applied gradually over a period of time, usually between 50 and 60 days, leading to a final product with typical characteristics that characterize this process. Paprika and garlic are two spices with a very important role in these products since they add flavor and act as antioxidant agents [2]. During the curing process of these products, and according to several authors, there is a progressive increase in the phenomena of proteolysis [3–5] and lipolysis [6,7]. Free fatty acids and free amino acids are also responsible for the release of odorous compounds, which provide aroma. Additionally, these molecules are subjected to various conversion and degradation processes, among which oxidative processes stand out [8,9] because they release a large number of secondary compounds responsible for the characteristic odor and flavor of these types of products [10]. In addition, the curing process is responsible for the most significant biochemical changes that will determine the quality of the final product [6,11].

It is well known that the largest production cost of the livestock industry is animal feed. In this regard, countless examples of the use of coproducts from agro-food industries as dietary supplements can be found in the literature, which undoubtedly has a positive impact on cost reduction and coproduct valorization. The olive industry constitutes a large sector in the Iberian Peninsula, both economically and culturally. However, high amounts of wastes (olive wastewater) and coproducts (olive pomace) are generated during olive processing [12,13]. It is estimated that coproducts represent approximately 20% of the total weight of the pomace after olive oil extraction, and 70–80% of the initial weight of the olive [14]. Thus, taking into account the enormous potential represented by the coproduct of this industry, a unique opportunity is presented to value said product while reducing the production costs of pig farming and putting a differentiated product on the market. Nevertheless, it is important to highlight that the pig, being a monogastric animal, incorporates certain components directly from the diet, which can affect the chemical composition of the meat, and therefore, the quality of the meat products obtained from them. For this reason, it is necessary to verify and monitor the effect of the diet on the chemical composition of the meat.

However, to the best of our knowledge, the characteristics of the aforementioned meat products in the Bísaro breed are unknown, despite the increasing demand for these products by Bísaro meat consumers. In addition, it is interesting to study the effect of the use of a coproduct such as olive cake in the diet during the pig fattening period on the final cured products, once the effect on the physicochemical characteristics of raw Bísaro meat was already described by Leite et al. [15]. Thus, the objectives of this study were: (i) to characterize dry-cured loin and "cachaço" products to provide information to the meat industry and consumers; (ii) to analyze the effect of the inclusion of different olive cakes in the diet of Bísaro pigs on the physicochemical characteristics and fatty acid profiles of the loin and "cachaço" products.

2. Materials and Methods

2.1. Composition of Experimental Diets

To carry out this study, animals of the Bísaro breed (*Sus scrofa*) with an approximate weight of 100 kg were used. These animals were divided into five groups (of eight animals each), with one of them being the control (basic diet) and the other four groups with different olive cakes (in combination with the basic diet). The different types of the olive bagasse differ in the way that they were extracted (centrifuged, pressed, or extracted).

The animals came from a farm (Bísaro Salsicharia Tradicional®) and were raised in an extensive production system. In total, 40 animals of the Bísaro breed were used. The feed was applied to all groups simultaneously and under the same conditions (feed level was "ad libitum" with an average consumption of 3 kg per day). An analysis of the diets was performed at the Meat Technology Center of Galicia, Ourense, Spain. Different types of olive oil cakes were used from different extraction units that receive olives from all over Northeastern Portugal. The experimental feed trial was administered to all groups for a period of three months. The chemical composition and the fatty acid profile of the diet applied to the animals was made according to Leite et al. [15]. This experiment was carried out at the University of Trás-os-Montes e Alto Douro, Vila Real, Portugal.

2.2. Slaughter Procedure

The Bísaro pigs were slaughtered at the Municipal Slaughterhouse of Bragança. For this study 40 animals were used (slaughter was carried out as described by Álvarez-Rodríguez and Teixeira [16]). The animals were slaughtered following the legislation, respecting compliance and animal welfare protocols [17].

2.3. Dry-Cured Bísaro Loin and "Cachaço"

The curing process was carried out at the company Bísaro—Salsicharia Tradicional, Lda, and forty loins and forty "cachaços" were used, corresponding to the 40 animals slaughtered. Per decreasing order, the following ingredients were added: 1.5% of salt, 0.5% of paprika, 0.5% of garlic, and 0.1% of oregano. The curing time of both joints (loin and "cachaço") was 60 days. After extracting the muscles from the animal carcasses, the pieces (loin and "cachaço") were refrigerated in a chamber between 2 and 5 °C. The excess of superficial fat was eliminated from each piece. After cleaning, pieces were selected to start the curing process. The next step was the salting and seasoning phase. At this stage, the pieces were placed in a rotating drum for approximately 30 min. Before starting this rotating process, all the ingredients (salt, paprika, garlic, and oregano) were added. When the mixing was complete, the joints were removed to a container and placed in a refrigeration chamber between 2 and 4 °C with a relative humidity of approximately 90%. This mixture remained in a refrigeration chamber for 4 days for the ingredients to penetrate the pieces. The next phase involved stuffing the pieces into collagen casings. The last step was the drying—curing phase, in which the most important biochemical changes take place. The temperature and relative humidity change as the curing time progresses, increasing the temperature and decreasing the relative humidity. In the first 15 days, the cuts were submitted to a temperature between 4 and 8 °C with a relative humidity between 80 and 90%. After this period, the product was submitted to a temperature between 8 and 12 °C and relative humidity between 70 and 80% for another 15 days. Finally, for the last 20 days the product was submitted to a temperature between 12 and 18 °C and a relative humidity between 60 and 70%.

Figure 1 shows the flow chart fabrication and general formulations of this products.

2.4. Chemical Composition and Physicochemical Analysis

The chemical compositions of the dry-cured loin and "cachaço" were analyzed using established protocols. The determination of moisture was performed according to the Portuguese Standard NP 1614 [18]. We added 5 mL of ethanol (96% v/v) to 3 g of sample. Next, the samples were dried in a drying oven (Raypa DO-150, Barcelona, Spain) for 24 h at 103 ± 2 °C. Ashes were assessed according to the Portuguese Standard [19]. We added 1 mL of magnesium acetate (15% w/v) in crucibles to 3 g of sample. Following this, the samples were subjected to 550 °C ± 25 °C for 5 h in a muffle furnace (Vulcan BOX Furnace Model 3-550, Yucaipa, CA, USA). Protein determination was carried out following the Portuguese Standard [20] using the Kjeldahl Sampler System (K370, Flawil, Switzerland) and Digest System (K-437, Flawil, Switzerland). In 25 mL of sulfuric acid (97%), two catalyst tablets and 2 g of sample were placed in mineralization tubes. After mineralization completion, the distillation procedure was carried out. Finally, the distillate was titrated with hydrochloric acid solution and the required volume was recorded. Water activity was assessed according to AOAC [21] using a HigroPalm Rotronic 8303 probe (Bassersdorf, Switzerland). The hydroxyproline determination of the collagen content and concentration was performed according to the Portuguese Standard NP 1987 [22]. Total chloride content was analyzed according to the recommended methodology in the Portuguese Standard NP 1845 [23]. The total pigment content [24] was obtained using the reflectance on the exposed surface by spectroscopy using a Spectronic Unicam 20 Geneys, expressed as mg myoglobin/g fresh muscle.

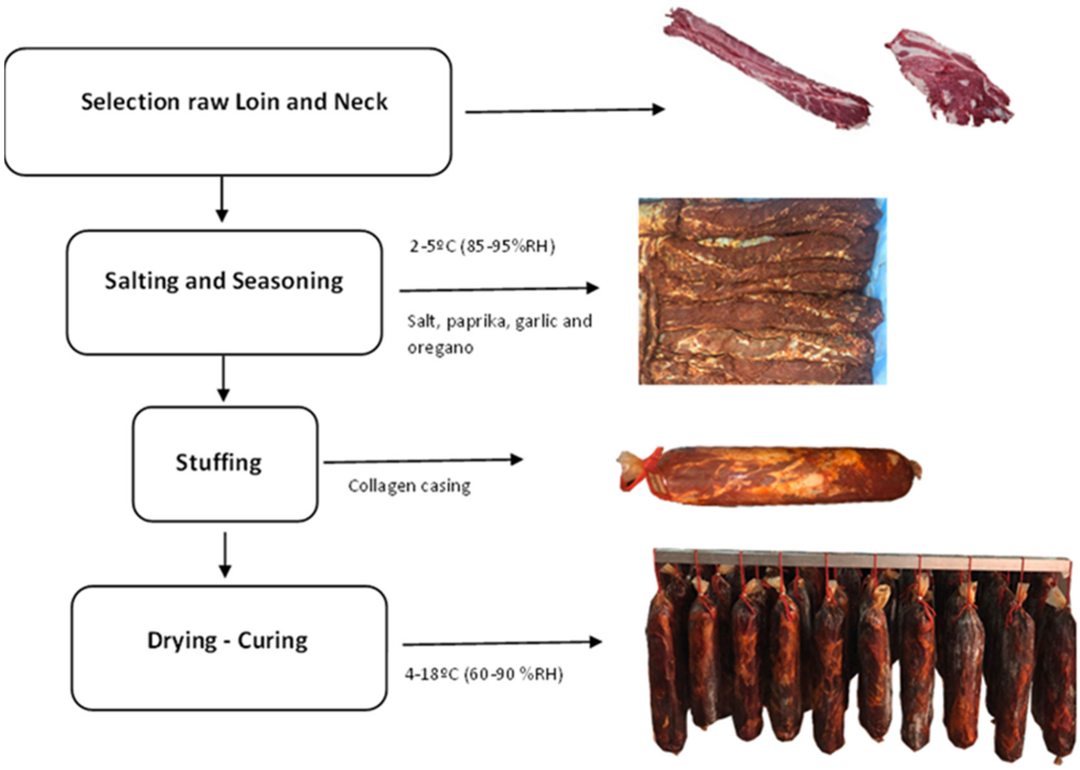

Figure 1. Flow chart of the fabrication of dry-cured loin and "cachaço" of the Bísaro pig (%RH: relative humidity).

2.5. Fatty Acid Analysis

Fatty acids in the loin and "cachaço" samples were analyzed in the Carcass and Meat Quality Laboratory of ESA–IPB. The total lipids were extracted from 25 g of meat sample according to the Folch procedure [25]. The fatty acid profile was determined using 50 mg of fat. The fatty acids were transesterified according to the method described by Domínguez et al. [26]; after adding 4 mL of a sodium methoxide solution and vortexing it for five minutes at a time for 15 min at room temperature, 5 mL of H_2SO_4 solution (in methanol at 50%) was added. Then, we added 2 mL of distilled water and vortexed once more. The organic phase (with the methyl esters of fatty acids) was extracted with 2.35 mL of hexane. The fatty acid methyl esters separation and quantification were performed using a gas chromatograph (GC-Shimadzu 2010Plus; Shimadzu corporation, Kyoto, Japan) equipped with a flame ionization detector and an automatic sample injector AOC-20i and using a Supelco SP TM-2560 fused silica capillary column (100 m length, 0.25 mm i.d., 0.2 µm film thickness). The fatty acid contents were calculated using chromatogram peak areas and were expressed as g per 100 g of total fatty acid methyl esters. In addition, the percentage of saturated fatty acids (ΣSFA), monounsaturated fatty acids (ΣMUFA), polyunsaturated fatty acids (ΣPUFA), the ratio PUFA n-6/n-3, and Σtrans were calculated according to Vieira et al. [27]. To measure the lipid quality, the index of atherogenicity (IA) and the index of thrombogenicity (IT) were calculated according to Ulbricht and Southgate [28] formulas:

$$IA = \frac{C12:0 + 4 \times C14:0 + C16:0}{\sum MUFA + \sum PUFA}$$

$$IT = \frac{C14:0 + C16:0 + C18:0}{0.5 \times \sum MUFA + 0.5 \times \sum PUFA\ n-6 + 3 \times \sum PUFA\ n-3 + \frac{PUFA\ n-3}{PUFA\ n-6}}$$

2.6. Statistical Analysis

The statistical program JMP® Pro 16.0.0 by 2021 SAS Institute Inc. © was used to analyze the data. The mean values and standard error of the mean for the experimental results were presented. Using the same program, analysis of variance one-way ANOVA for the dry-cured loin and "cachaço" was carried out. The statistical differences were defined as $p < 0.05$.

3. Results

3.1. Chemical Composition and Physicochemical Characteristics

The results of the chemical compositions of the dry-cured loin and "cachaço" of the Bísaro breed and the effect of each of the diet treatments employed in this research are listed Table 1. No significant differences were observed between the different treatments ($p > 0.05$) or for the interaction between types of product X diet treatment of all physicochemical parameters studied. However, there were significant differences between loin and "cachaço" for moisture, ash, total fat, *haem* pigments, chlorides, and protein content. As expected, the curing process caused water activity to decrease, and the values ranged from 0.831–0.886; however, no significant differences were found between the two products analyzed ($p > 0.05$). According to Pateiro et al. [6] the water activity values for the dry-cured loin of the Celta pig are close to those obtained in this work (0.841). Similar values were reported in the dry-cured loin of the Korean pig (0.830) [29] and the dry-cured neck of the Polish White Large breed pig (0.838) [30]. Compared with other species, such as the foal, similar values of water activity were also reported for the cured loins of this species (0.838) [31]. Moisture is one of the technological parameters that indicates the maturation of the product and how it can affect the shelf life. As expected, the manufacturing process caused a moisture content drop, and the loin showed significantly higher ($p < 0.001$) values than "cachaço, 35.41–38.59% and 25.65–29.83%, respectively. The decrease in moisture content, and by extension in water activity, is due to the progressive and continuous release of water during the drying–ripening phases of these meat products. This observation supports the finding of Andres et al. [7], who observed that the moisture level of cured meat products is inversely proportional to ripening time. The difference among products is likely explained in part by the total fat content of the two products, which was more than two times higher in the "cachaço" than in the loin, on average 45.16% against 21.26%. Therefore, it is expected that if the fat content is much higher, the content of both moisture and protein (as we will see below) will be lower in percentage terms. The moisture content in the final product of dry-cured loin was similar to the moisture content levels described by other authors in the same products [6,31,32]. Close values were observed in a traditional Italian product very similar to "cachaço" designated as "Coppa" (28.94–30.38%) by Di Rosa et al. [33]. As previously mentioned, the total fat content was significantly different ($p < 0.001$) between the loin and "cachaço", 19.02–22.12% and 41.22–48.58%, respectively. In a dry-cured loin of native Korean pork, Seong et al. [29] found values of total fat of 5.88% much lower than those observed by us. In addition, Pateiro [6] reported lower values of 11% for total fat in dry-cured loins of the Celta breed than those observed by us for loin. However, the high-fat content of "cachaço" was also found by Di Rosa et al. [33] for the dry-cured "Coppa" of the Nero Siciliano pig (37.85% and 42.45%). In relation to protein content, the cured loin showed a higher content than "cachaço", 33.83–36.49% and 24.43–26.83%, respectively. These differences in protein content between the two products were justified by the differences in fat content already reported; it is interesting to emphasize that these are two products manufactured using the same muscle, the *Longissimus Thoracis* et *lumborum*, but from different sections with different chemical compositions. This and the other qualitative characteristics of these products are the results of the complexity of the meat matrix. Therefore, not only the location or the type of muscle will have a huge influence on the chemical composition, but within the same muscle, a different section of it can also play an important role in its composition. Thus, taking into account that fat is one of the quality attributes of meat products, it is expected that both products have different characteristics and that fat exerts an influence on the dehydration and curing process of said products, differentiating both of them. This variability is evidenced in other studies, such as for dry-cured foal loin with 29.59% protein [31], 41.67% for dry-cured products of the native Korean pig [29], and 47.81% for dry-cured loin of the Celta pig [6]. Similar values of protein content of "cachaço" were found in "Coppa" (23.64% and 25.25%) [33]. In any case, it is to be expected that there are multiple differences between products from different studies, since the processing conditions, the times and temperatures/relative humidity used in the drying–ripening phase, and even the breeds or diets of the animals will largely determine both the chemical composition of the final product and the reactions that will take place during processing.

Table 1. Chemical composition of Longissimus thoracis et lumborum (LTL) muscle from the Bísaro pig breed (loin and neck joints). Effect of treatment with olive cake, product, and interaction between product and treatment.

	Physicochemical Composition (g/100 g)							
	Water Activity	Moisture (%)	Total Fat (%)	Protein (%)	Chloride (%)	Ash (%)	Collagen (%)	Haem Pigments
Dry-cured loin								
T1	0.833	37.95	19.02	35.63	3.95	5.59	2.38	2.10
T2	0.866	35.41	23.34	35.96	3.74	4.72	1.59	1.78
T3	0.886	38.33	20.33	36.49	3.60	5.43	1.89	2.03
T4	0.867	38.59	21.47	35.78	4.26	5.82	1.71	1.90
T5	0.867	36.56	22.12	33.83	4.13	5.49	2.84	1.72
Dry-cured "cachaço"								
T1	0.856	29.83	41.22	26.05	3.59	5.20	2.03	4.19
T2	0.864	26.93	47.38	25.67	3.24	4.66	2.09	4.13
T3	0.865	27.09	48.58	24.43	2.97	4.25	2.02	4.26
T4	0.856	28.90	43.55	25.76	3.18	4.60	1.54	4.06
T5	0.831	25.65	45.07	26.83	3.95	5.49	1.58	3.82
SEM	0.02	2.97	3.07	1.64	0.36	0.42	0.39	0.25
Significance								
Treatment	ns	ns	ns	ns	ns	ns	ns	ns
Product	ns	***	***	***	*	*	ns	***
Product × treatment	ns	ns	ns	ns	ns	ns	ns	ns

ns—not significant; * $p < 0.05$; *** $p < 0.001$. SEM—Standard Error of the Mean. Haem pigments in mg myoglobin/g fresh muscle. T1—Basic diet and commercial feed; T2—Basic diet + 10% crude olive cake; T3—Basic diet + 10% olive cake in two phases; T4—Basic diet + 10% exhausted olive cake; T5—Basic diet + 10% exhausted olive cake + 1% olive oil.

An essential element in the curing process is salt, producing a typical taste and providing microbiological stability to the product [34]. In addition, salt controls the enzymatic reactions, including proteolysis and lipolysis phenomena, and modulates the lipid oxidation process (sodium chloride is a potent pro-oxidant), which determines the volatile production and release during the curing process [10]. The knowledge of salt content in a product is of utmost importance to consumers due to the relationship between salt consumption and human heart disease [35]. The different treatments had no influence on the final amount of salt in the cured products, but significant differences were observed regarding the type of cured product. The cured loin had a mean value of 3.94% salt while the "cachaço" had a lower value (3.39%). In any case, despite these differences, it can be seen that the values obtained for both products are very similar. The salt values obtained for both products are below those presented by other authors for the dry-cured loin of the Celta breed [6], dry-cured foal loin [31], and dry-cured "Coppa" [33,36]. The differences obtained in the different products will be determined by the processing conditions, as well as the type and mode of application of the salt during the salting phase of the product.

As a result of the different salt content between products, the ash content is also significantly different ($p < 0.05$). In the dry-cured loin, the ash values ranged between 4.72% and 5.82% while for the dry-cured "cachaço" the average values obtained were lower (4.25–5.49%). Higher ash values were observed in a product designated as "Capollo di Martina Franca" [37], which is the same as "cachaço". Higher values were obtained in the dry-cured foal loin by other authors [31] compared with the cured products of the Bísaro breed studied.

According to the data obtained from the fresh loin of the Bísaro pig, with the same diet treatments [15], the increases in protein, ash, and fat levels with the curing process could be attributed to the decreased moisture content and, consequently, to an increase in the dry matter of this type of product.

Significant differences ($p < 0.001$) were found in the *haem* pigments. The myoglobin content ranged from 1.72–2.84 mg/g and 3.82–4.26 mg/g in dry-cured loin and dry-cured "cachaço", respectively. Similar values were found to those obtained from the dry-cured "cachaço" and from the dry-cured ham of the Iberian pig (3.52–4.89 mg/g) [38].

No significant differences ($p > 0.05$) were found between treatments or between the two types of products for collagen content, ranging from 1.59–2.84% and 1.54–2.09% in the dry-cured loin and dry-cured "cachaço", respectively.

3.2. Fatty Acids Composition

Table 2 shows the fatty acid composition of the dry-cured loin and dry-cured "cachaço". In both cases, the most abundant fatty acids were palmitic acid (C16:0) as saturated fatty acids (SFA), oleic acid (C18:1n-9) as monounsaturated fatty acids (MUFA), and linoleic acid (C18:2n-6) as polyunsaturated fatty acids (PUFA). Significant differences ($p < 0.05$) were found in C18:2n-6 for the treatments. For both treatments, T2 and T5, higher values of linoleic acid were obtained, and the same trend was observed for both products. In relation to elaidic acid (9t-C18:1), a monounsaturated *trans* fatty acid with negative effects related to the increase in LDL cholesterol and a strong relationship with cardiovascular disease [39], significant differences ($p < 0.05$) were found between treatments, with the T4 treatment standing out for both products, with a lower value. However, the content of elaidic acid in all treatments, varying from 0.14 to 0.19 in cured loin and from 0.12 to 0.19 in "cachaço", were within the safety values recommended by joint WHO/FAO expert consultation of less than 1% of total energy intake [40]. Concerning the product, significant differences were obtained for the following fatty acids and indices: C14:0; C16:1n-7; C18:0; C18:2n-6; C20:1n-9; C20:2n-6; C20:4n-6: SFA, MUFA, PUFA; n-6/n-3, and the IT index. Within the SFA, the predominant fatty acid was palmitic (C16:0) which represented 63–64% and 61–62% of total intramuscular SFA in dry-cured loin and dry-cured "cachaço", respectively. These results agree with other authors on dry-cured ham of the Celta pig [41], dry-cured loin of the Celta pig [42] and dry-cured loin of the Iberian pig [43]. Lower values were observed in the "Capocollo di Martina Franca" dry-cured product (57–58%) [37]. The total SFA content of both dry-cured products was not influenced by the inclusion of olive cake in the animals' diet. However, significant differences ($p < 0.01$) were observed for SFA among the dry-cured products. The dry-cured "cachaço" had significantly higher values (43.05–44.02%) than the dry-cured loin (41.95–42.91%). Other authors have reported similar values for dry-cured loin of the Iberian pig [43]. In addition, similar values were obtained in Croatian and Montenegrin traditional dry-cured products [44] and "Capocollo di Martina Franca" dry-cured product [37]. Despite these differences, it is noteworthy that the difference that exists is around 2%, which shows that there is little influence of the product on the SFA profile. On the other hand, MUFA was the highest fatty acid group identified in all treatments and products, and the major fatty acid (C18:1n-9) showed no significant differences between treatments or between products. Values between 46.19% and 47.55% were obtained in the dry-cured loin and 45.74 and 46.56% in the dry-cured "cachaço".

Compared with the products studied in this work, Cavas et al. [45] reported many high concentrations of oleic acid in Iberian ham (53.2%), dry-cured "Coppa" of Nero Siciliano (48.01–48.98%) [33], and dry-cured loin of the Iberian pig (48.8–52.7%) [43]. From the results, and in comparison with the bibliography, it is evident that, contrary to expectations, the oleic concentration of the products from the Bísaro pigs fed with a coproduct of the olive cake does not show higher content of this MUFA. This can be explained, as it is well known that both saturated and unsaturated fatty acids are synthesized from other energy sources (mainly carbohydrates) by enzymatic processes in pigs. In fact, the content of C16:0, C18:0, C16:1n-7, and C18:1n-9 fatty acids are directly and intimately related to de novo synthesis processes, so the effect of diet on these acids fatty acids is usually less important than incorporation via enzymatic processes. In contrast to our results, lower values were obtained by other authors for the dry-cured loin of the native Korean pig (40.22%) [29], "Capollo di Martina Franca" dry-cured product (38.4–40.19%) [31], and the dry-cured ham of the Celta pig (39.86–44.99%) [41]. Similar values were found by other authors [42] in the dry-cured loin of the Celta pig (47%). However, significant differences ($p < 0.001$) were obtained between the two types of dry-cured products for the sum of MUFA. The dry-cured loin had a higher mean value of MUFA compared with the dry-cured "cachaço" (48.97% and 50.57%), respectively.

The values for the PUFA content ranged from 6.65–7.58% and 7.20–8.00% in dry-cured loin and dry-cured "cachaço", respectively. There were significant differences between the products ($p < 0.05$), but these differences were not evident between the different treatments ($p > 0.05$). The dry-cured "cachaço" presented a higher PUFA value compared with the dry-cured loin. The average PUFA values obtained in this study were higher than those observed in the dry-cured loin of Iberian pork [43], Iberian × Duroc genotypes [46], and the native Korean pig [29]. The lower values were found in the dry-cured loin of Alentejano [47]. Concerning the dry-cured "cachaço", higher values for total PUFA were found in similar products, such as "Capollo di Martina Franca" dry-cured product (11%) [37]. Moreover, in results contrary to the expectations, products from the Bísaro pigs fed with diets enriched in linoleic acid do not show higher content of this polyunsaturated fatty acid. This can be explained by the fact that the amount and structure of dietary fatty acids, the synthesis of fatty acids, the rate at which they are converted into other fatty acids and metabolites, and the ratio of oxidation to energy consumption all affect the concentration of PUFA [48]. Olive cake, which is rich in MUFA, reduces the amount of PUFA content in red blood cell membranes [48,49]. Therefore, the fatty acid profile found in the processed products in the present study is in agreement with the characteristic fatty acid composition in swine. Although breed, diet, production systems, geographic location, and others are factors that affect the fatty acid composition in these types of dry-cured products, the lipid profile always follows the same trend. Several authors report similar values within dry-cured products of other breeds, such as the dry-cured loin of the Iberian pig [43,46,50], and the dry-cured loin of the Celta pig [6]. The possible deviations, apart from being due to the breed, are also due to the animals' diet. The diet can have an influence on the final composition of fatty acids in the case of monogastric animals that do not have the ability to synthesize polyunsaturated fatty acids [51]. This explains the low oleic acid values in the dry-cured loin and "cachaço" considering the diet is rich in C18:2n-6.

Table 2. Fatty acids profile (g/100 g) of dry-cured loin and dry-cured "cachaço" of the Bísaro pig breed. Effect of treatment with olive cake, product, and interaction between product and treatment.

Fatty Acids	Dry-Cured Loin					Dry-Cured "Cachaço"						Significance		
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	SEM	Treatment	Product	Product × Treatment
C14:0	1.23	1.25	1.26	1.26	1.23	1.15	1.09	1.17	1.14	1.11	0.04	ns	***	ns
C16:0	27.00	27.30	26.83	27.32	26.75	27.31	27.00	26.90	27.29	26.59	0.33	ns	ns	ns
C16:1n-7	2.62	2.67	2.70	2.92	2.56	1.77	2.09	2.19	2.22	2.04	0.15	ns	***	ns
C17:0	0.19	0.21	0.18	0.20	0.20	0.21	0.22	0.21	0.22	0.20	0.01	ns	ns	ns
C17:1n-7	0.19	0.18	0.18	0.18	0.17	0.18	0.18	0.19	0.19	0.18	0.01	ns	ns	ns
C18:0	13.82	13.76	13.24	13.25	13.59	14.86	14.87	14.33	14.63	14.82	0.43	ns	***	ns
9t-C18:1	0.19 a	0.15 ab	0.16 a	0.14 b	0.16 ab	0.18 a	0.16 ab	0.19 a	0.12 b	0.16 ab	0.02	*	ns	ns
C18:1n-9	46.58	46.19	47.55	46.72	46.60	46.17	45.83	46.56	45.75	45.74	0.58	ns	ns	ns
C18:2n-6	5.89 b	6.16 ab	5.76 b	5.79 b	6.62 a	6.58 b	6.92 ab	6.53 b	6.86 b	7.31 a	0.27	*	***	ns
C20:0	0.21	0.18	0.18	0.16	0.18	0.19	0.19	0.19	0.19	0.19	0.01	ns	ns	ns
C20:1n-9	0.79	0.77	0.74	0.75	0.66	0.40	0.49	0.52	0.39	0.65	0.07	ns	*	ns
C18:3n-3	0.26	0.26	0.24	0.24	0.29	0.23	0.24	0.26	0.24	0.27	0.02	ns	ns	ns
C20:2n-6	0.21	0.22	0.21	0.23	0.27	0.27	0.26	0.28	0.26	0.29	0.02	ns	**	ns
C20:4n-6	0.31	0.27	0.27	0.29	0.24	0.02	0.02	0.08	0.02	0.03	0.03	ns	***	ns
ΣSFA	42.73	42.91	41.95	42.48	42.20	44.02	43.64	43.05	43.76	43.17	0.64	ns	**	ns
ΣMUFA	50.44	50.01	51.40	50.78	50.22	48.77	48.81	49.71	48.75	48.83	0.63	ns	***	ns
ΣPUFA	6.83	7.07	6.65	6.74	7.58	7.20	7.54	7.24	7.48	8.00	0.33	ns	*	ns
PUFA/SFA	0.16 a	0.16	0.16	0.16	0.18	0.16	0.17	0.17	0.17	0.18	0.01	ns	ns	ns
PUFAn-6/n-3	20.87	21.15	22.64	22.73	20.63	25.68	26.23	24.18	25.79	25.43	1.62	ns	***	ns
IA index	0.56	0.57	0.55	0.57	0.55	0.57	0.56	0.55	0.57	0.55	0.01	ns	ns	ns
IT index	1.43	1.44	1.39	1.42	1.40	1.51	1.49	1.45	1.49	1.46	0.04	ns	*	ns
h/H	1.88	1.86	1.92	1.86	1.93	1.87	1.89	1.91	1.86	1.93	0.04	ns	ns	ns

ns—not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. SEM—Standard Error of the Mean. Mean values with different lowercase letters (a,b) are significantly different ($p < 0.05$). Mean values without letters have no significant differences ($p > 0.05$). Haem pigments in mg myoglobin/g fresh muscle. h/H—Hypocholesterolemic/hypercholesterolemic index. T1—Basic diet and commercial feed; T2—Basic diet + 10% crude olive cake; T3—Basic diet + 10% olive cake in two phases; T4—Basic diet + 10% exhausted olive cake; T5—Basic diet + 10% exhausted olive cake + 1% olive oil.

Thus, in conclusion, the variations that may exist depending on the diet will be determined by the relationship between the different fatty acids in the diet, the importance of de novo synthesis processes versus the direct incorporation of dietary fatty acids, or the duration of treatment. This last aspect refers to the fact that for changes in the diet to be reflected in the composition of the meat, they must be prolonged and constant. Therefore, the results obtained could also be partially explained due to the fact that the period of administration of the different diets is not sufficient for these changes to be reflected in the quality of the meat (chemical composition) or of the fat (fatty acid profile). Similarly, despite being the same muscle, it is known that the total fat content is a faithful reflection of the importance of de novo synthesis processes, since the greater the fat, the greater the deposition of fatty acids derived from this enzymatic process. This would help explain the small variations that exist in fatty acids between the two products studied in this study.

PUFA/SFA and PUFA n-6/n-3 ratios were calculated to assess fat quality. In relation to the PUFA/SFA ratio, this study presented values between 0.16 and 0.18 for both products, below the recommended minimum amount for healthy foods and diets [52]. For the PUFA/SFA ratio, no significant differences were obtained between the different treatments and between muscles ($p > 0.05$). Values obtained for similar products showed that the PUFA/SFA ratio of the Bísaro pig was within the values reported in the dry-cured loin of Iberian pig [43] (between 0.12 and 0.16), while in "Capollo di Martina Franca" [37] and "Coppa" of Nero Siciliano products [33], the authors reported higher values (0.25–0.29, respectively). For a product to be considered healthy, it is not enough to have a high proportion of PUFA. It is also necessary that the n-6/n-3 ratio be balanced [41–43]. In our study, the PUFA n-6/n-3 ratio values ranged from 20.63–22.73 in dry-cured loin and 24.18–26.23 in dry-cured "cachaço". Similar values were found in "Coppa" of Nero Siciliano [33]. The results obtained indicate that the treatments had no significant effect on this ratio, with the differences observed being due to the type of muscle. Although the value of this ratio for dry-cured "cachaço" is much higher, the value of this ratio in both products exceeds the internationally recommended values (<4) for a healthy and balanced diet [53,54], with the optimal value being 1 [55–57]. Based on the work of other authors on fresh Bísaro pork loin [15], we can observe that the fatty acid profile was not negatively affected by the processing process and consequent curing of the product. Even the ratio of n-6/n-3 PUFA improved relative to the fresh product. As with the fresh loin [15], the dry-cured loin and "cachaço" products were not influenced by the different feed treatments. As with other dry-cured products of the Bísaro breed [58], the curing process did no induce considerable changes in the fatty acid profile and its index and ratios, which leads us to conclude that dry-cured products do not contribute more to the potential development of cardiovascular comorbidities compared with raw meat.

The index of atherogenicity (IA) and the index of thrombogenicity (IT) characterize, respectively, the atherogenic and thrombogenic potentials of fatty acids [28]. For the IA, there were no significant differences ($p > 0.05$) between the two types of products and no influence at the level of the different treatments. For the IT, there were significant differences at the muscle level; at the treatment level, this difference was not observed. Higher values of IT were observed in the dry-cured "cachaço" (1.45–1.51). Better nutritional quality is indicated by lower AI and IT index, which may decrease the risk of coronary heart disease. However, no organization has yet provided recommended values for this index [59]. The functional effects of fatty acids on cholesterol metabolism are the basis for the h/H ratio, and Cava et al. [60] found that the higher the h/H ratio, the more nutritionally adequate the oil or fat in the food. The h/H ratio found by us varied between 1.86 and 1.93 for dry-cured loin and "cachaço", and no significant differences ($p > 0.05$) were recorded between treatments and muscle.

4. Conclusions

A study of the main characteristics of dry-cured loin and dry-cured "cachaço" of the Bísaro pig were investigated. This study was an incentive to make a comparison between traditional Trás-os-Montes Bísaro meat products in terms of chemical composition and fatty acid profile and the study of the use of olive industry coproducts in the animals' diet. The results obtained can strengthen efforts to increase the level of recognition of this breed and its cured products in the country itself, which could significantly contribute to the valorization and dissemination of traditionally cured products of the Bísaro breed in the international market. Considering the inclusion of 10%, the olive cake can be used as another ingredient in the diet of Bísaro animals, valuing a coproduct of the olive industry (mainly in the region of Trás-os-Montes) and reducing the environmental impact of olive-mill wastewaters of the extractive industries.

This study provided knowledge about the differences between the loin and "cachaço", two products manufactured with the same muscle (LTL) but from different parts, the dorsal and proximal sections, respectively. The loin showed a higher protein and lower fat content than the "cachaço". The saturated and polyunsaturated fat were lower in loin than in "cachaço", but the monounsaturated fat was higher. This information would be interesting to consumers which search for a more differentiated product and according to the different acceptability of lipidic quality. The inclusion of olive cake in the animals' diet had no significant effect on the analyzed parameters, but there were no negative effects either. Therefore, and based on this work, the products obtained are of high quality and with good nutritional and physicochemical characteristics. However, future studies on microbiological, and sensorial quality should be carried out.

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