TITLE:

Improvement on nutritional properties of Chorizo de Pamplona by replacement of pork backfat with soy oil.

AUTHORS:

Muguerza, E., Ansorena, D., & Astiasarán, I.[√]

Department of Food Science and Technology, University of Navarra, Faculty of Pharmacy, 31008-Pamplona, Spain.

[√]Corresponding author. Tel.: +34-48-425600 ext 6405; fax: +34-48-425649.

E-mail address: iastiasa@unav.es (I. Astiasarán).

ABSTRACT

Dry fermented sausages with a partial substitution of 15%, 20% and 25% of pork backfat by preemulsified soy oil were prepared. No differences were detected in the water, protein and fat content between control and modified sausages. Cholesterol amount scarcely decreased in the modified sausages (92.96mg/100g product in control sausages, 87.71mg/100g in sausages prepared with 25% of substitution). No increase in oxidation was detected through chemical or sensory analysis in modified sausages. Saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) in control products were 37.83 and 45.78g/100g of total fatty acid, respectively, decreasing in the modified formulations, to 32.81 and 42.09g/100 of total fatty acid in the 25% replacement products, respectively. Polyunsaturated fatty acids (PUFA) increased from 15.22 (control) to 23.96g/100g of total fatty acid (25% product) due to the significant increase in linoleic and α-linolenic acids when soy oil was added. In relation to texture profile analysis (TPA), hardness and springiness did not show significant differences among products. The instrumental measured colours were comparable with that of commercial products. Sensory evaluation of most of the modified sausages did not show significant differences with regard to the control.

Keywords: lipids, texture, colour and sensory evaluation.

INTRODUCTION

During the last years there has been a tendency to consume low-fat products, to try to reduce prevalence of obesity. However, despite this change in the dietary pattern, the incidence of obesity and correlated diseases is still growing. Nowadays, more emphasis is being made in the type of fat present on the diet than in the total fat intake.

Traditional meat products can be an important source of fat and particularly saturated fat together with dairy products. In dry fermented sausages, reduction of fat has been shown to be difficult because it is often cause of technological and sensory problems (Wirth, 1988), so research has been focussed on a partial substitution of the animal fat by other types of fat or also in the modification of the animal diets to improve the lipid profile of the raw matter (Enser et al., 2000; Bryhni et al., 2002). In general, saturated fatty acids (SFA) have been considered as a risk factor in relation with cardiovascular diseases (Grundy, 1986). On the other hand, epidemiological studies have demonstrated that monounsaturated fat (MUFA) intake was inversely associated with risk of coronary heart diseases (CHD), although the association was weaker than for polyunsaturated fat (PUFA) (Hu et al., 1997). Moreover, different studies suggest that PUFA may improve the serum lipid profile, may have beneficial effects on cardiovascular disease and diabetes, may improve insulin sensitivity and may have anti-arrhythmic effect (Abeywardena, McLennan & Charnock, 1991; Lovejoy & DiGirolamo, 1992; Lovejoy, 1999; Hu et al., 1999a; Simopoulos 1999; Von Shacky, 2000; De Caterina et al., 1996).

The substitution of pork backfat by olive oil, which is the most abundant monounsaturated vegetable oil, has been researched in dry fermented sausages. Bloukas, Paneras & Fournitzis (1997) obtained Greek fermented sausages with the same and even better processing and quality characteristics replacing a 20% of pork back fat by olive oil preemulsified with soy protein isolate. In chorizo de Pamplona, a type of

Spanish dry fermented sausage, up to 25% of pork backfat can be replaced by preemulsified olive oil (Muguerza, Gimeno, Ansorena, Bloukas & Astiasarán, 2001). These products showed an increase in MUFA and PUFA fractions and a reduction in the cholesterol content thus improving the nutritional characteristics of these products compared with traditional ones. Muguerza, Fista, Ansorena, Astiasarán & Bloukas (2002) obtained Greek fermented sausages with different fat levels and also with partial replacement of pork backfat with olive oil. They found that fat level affected ($p<0.05$) the weight losses, the chemical composition, the Gram negative bacterial count, the lightness, the texture and the appearance of the fermented sausages. Also, lightness and yellowness of sausages where affected ($p<0.05$) when a replacement of 20% of pork backfat by olive oil was tested. The appearance of fat-reduced sausages (with and without olive oil) was acceptable, whereas that of low-fat sausages was unacceptable.

Vegetable oils with a high content in PUFA such as corn, sunflower, cotton seed oil, partially hydrogenated vegetable fat, palm fat and soybean oil have been used to substitute the fat content in cooked sausages producing in some cases problems related to lipid oxidation process (Paneras & Bloukas, 1994; Papavergou, Ambrosidis & Psomas, 1995; Tan, Aminah, Mohd Suria Affandi, Atil & Babji, 2001). Linoleic acid (C18:2 *n*-6) and α-linolenic acid (C18:3 *n*-3) are essential fatty acids for humans because they can not be synthesized by human body and have to be provided with the diet. Linoleic acid is widely present in vegetable oils, especially corn, sunflower and soy. The mayor sources of α-linolenic acid in the diet are green leafy vegetables and soy beans and canola oils. Soy oil production is the most important in the world among the vegetable oils. The main producers are USA, Brazil and China. This oil is one of the most polyunsaturated vegetable oils.

The use of vegetable oils with high content in PUFA has not been studied in dry fermented sausages. The aim of this study was to analyze the possibilities of manufacturing chorizo de Pamplona with a partial replacement of pork backfat with pre-emulsified soy oil in order to improve the fatty acid profile to develop healthier products. Also the influence of soy oil addition on instrumental measures of texture and colour and on oxidation processes was evaluated.

MATERIAL AND METHODS

Sausage manufacture.

Chorizo de Pamplona, a type of traditional Spanish fermented sausage, were manufactured under the conditions described by Muguerza et al. (2001). Four treatments of these fermented sausages, about 5 kg each, were prepared. The control was produced using 75% pork meat and 25% pork backfat and the other three produced with a substitution of pork backfat with 15, 20, and 25 % pre-emulsified soy oil following the conditions of Hoogemkamp (1989 a,b).

Chemical analysis.

Moisture was determined according to the Association of Official Analytical Chemist method (AOAC, 2002a). Total fat was determined by an extraction technique with petroleum ether according to (AOAC 2002b). Protein was analyzed according to the Kjeldahl method (AOAC, 2002c). A factor of 6.25 was used for conversion of nitrogen to crude protein. Acidity content and peroxide value were respectively determined using method ISO 1740 (ISO, 1991) and AOAC (AOAC, 2002d). During the ripening process, also the following parameters were determined: Moisture, pH (measured using a Needle combined standard electrode in a pHmeter micro pH 2000; CRISON instrument S.A., Barcelona) and water activity (determined with a Novasina aw center at 25^{o}C).

The method of Folch, Lees & Stanley (1957) was used for the extraction of lipids. Fatty acid composition of soy oil used and dry fermented sausages elaborated was determined by gas chromatography according to Muguerza et al. (2001). Boron trifluoride/methanol was used for the preparation of fatty acid methyl esters (AOAC, 2002e).

Cholesterol content was analyzed by gas chromatography following conditions of Muguerza et al. (2001), with previous extraction according to Kovacs, Anderson & Ackman (1979).

The determination of hexanal was made with a simultaneous distillation-extraction method and further analysis in a HP 6890 GC System (Hewlett-Packard) coupled to 5973 Mass Selective Detector (Hewlett-Packard) using the conditions described by Ansorena, Zapelena, Astiasarán & Bello (1998). The identification was based on comparison of its retention time and its spectrum to those of a standard sample (Sigma).

TBA value was determined according to Tarladgis, Watts, Younathan & Dugan (1960) with modifications by Tarladgis, Pearson & Dugan (1964).

Instrumental measures.

Texture profile analysis (TPA) was performed as described by Bourne (1978) with a Universal TA-XT2i texture analyzer. Squared samples of 1x1x1 cm were compressed twice to 60% of their original height with a compression platen of 75 mm in diameter. Textural analyses were performed at ambient temperature. Force-distance deformation curves were recorded at a crosshead speed of 5 mm/s and recording speed was also 5 mm/s. Hardness (g), springiness (mm), cohesiveness, gumminess (g), and chewiness (g x mm) were evaluated. These parameters were obtained by using the available computer software. For colour measurement, samples were sliced and covered with a polyethylene film, with pressure to obtain a uniform, bubble-free surface. A UV/VIS Perkin-Elmer Lambda 5 spectrophotometer was used to obtain the reflectance spectra from 400 to 700 nm using an integrating sphere. Colour coordinates were obtained with the conditions established by Ansorena, De Peña, Astiasarán & Bello (1997) (CIE L* a* b* system, angle 10º, illuminant D65). L*, a* and b* parameters indicate lightness, redness and yellowness, respectively. Each sample was measured at four locations on the slice surface of the dry fermented sausages.

Sensory evaluation

Sensory evaluation was carried out to compare the sensory properties of the control and modified sausages. Quantitative descriptive analysis (QDA) was used. Four samples per batch were examined by 10 selected and trained panellists for colour intensity, juiciness, hardness, cohesiveness, rancid taste and general acceptability. A continuos scale between 1 and 9 was used for evaluation. Control sausages were always taken as the reference with a score of 5. A value of 1.0 corresponded to the lowest intensity for each parameter and a value of 9.0 to the highest.

Statistical analysis.

Four samples were analyzed from each type of dry fermented sausage. Each parameter was determined four times in each sample. Data shown in the tables are the means. Analysis of variance (ANOVA) and a Tuckey's b posteriori test were used to determine significant differences ($p \leq 0,05$) among the different types of sausages. Software used was SPSS version 9.0. (© 1998, SPSS inc. Chicago, Illinois).

RESULTS AND DISCUSSION

The content of fatty acids of soy oil used in the manufacture of the modified dry fermented sausages was 64.09g of PUFA/100g of total fatty acid (55.78g/100g of linoleic acid and 8.09g/100 g of α-linolenic acid), 21.21g of MUFA/100g of total fatty acid and 14.44g of SFA/100g of total fatty acid.

The quantities of pork backfat, soy oil, isolated soy protein and water added per gram of meat mixture in each treatment are given in table 1. The pork backfat content was reduced from 25% to 18.75% and the soy oil increased from 1.97 to 3.28 g/ 100 g of meat mixture. In the final products, water and protein content did not show significant differences among all samples, with values that ranged between 30.0-30.8g/100g product and 25.9-26.2 g/100g, respectively.

When trying different formulations from traditional ones, it is useful to know both the evolution of the technological process, through parameters such as acidification and desiccation, and also the safety of the new products. Figures 2, 3 and 4 show the changes in moisture, pH and water activity respectively during the ripening of the dry fermented sausages. No significant differences were observed in the moisture content among the four types of products analyzed from the 3rd week of drying. Changes in the values for pH and water activity during ripening guaranteed the safety of the modified products with small differences with regard to control sausages. Table 2 shows parameters related to fat and oxidation processes at the end of the ripening period. Fat content ranged between 31.2 and 34.4g/100g product without significant differences among products. Cholesterol amounts decreased progressively as the percentage of oil used was increased, but the differences from the control were not statistically significant. Muguerza et al. (2001) found a 13% reduction in cholesterol in products with a 25% of replacement of pork backfat by olive oil. Taking into account the results obtained for water, fat and consequently, protein (although this parameter was not analyzed), it can be established that from a quantitative nutritional point of view these treatments did not present nutritional advantages.

One of the problems to consider when adding an oil rich in PUFAs to the modified formulations is the high susceptibility of these fatty acids to oxidation. That could possibly be the cause of the problems detected in frankfurters made with soy oil (Paneras et al., 1994). Those products increased 6-7 times and 10 times their linoleic acid and α-linolenic acid amounts, respectively, but they showed a darker red colour and had the lowest scores for flavour and overall acceptability.

In our work, four parameters related to oxidation were analysed. Acidity index at the end of ripening reached values between 10.86 and 10.23 mg KOH/g fat without significant differences between treatments. Acidity index is a measure of the free fatty acids produced during the lipolysis, which is one of the processes that takes place during fat alteration. Lipolysis induces the oxidation process, which affects, among other compounds, fatty acids and cholesterol. The primary components of the oxidation process are peroxides; unstable compounds which disappear resulting in other oxidized products. The analysis of peroxide values (table 2) showed that none of the analyzed samples had detectable amounts of peroxides. Other oxidation parameters, TBA values and hexanal content, decreased when soy oil was added (table 2). The higher the soy oil added, the higher the decrease of values was found. The only explanation for this fact is an efficient antioxidant activity of the vitamin E present in the added oil (16 mg of vitamin E per 100g). No rancid taste was detected in the sensory evaluation of any of the products (Fig 5). This behaviour was also observed in dry fermented sausages elaborated with olive oil, in which, although the percentages of MUFA and PUFA increased, no increment in the oxidation intensity was observed (Muguerza et al., 2001).

Table 3 shows the fatty acid profile in the lipid fraction of every elaborated product. The total amount of saturated fatty acids decreased from 37.83g/100g of total fatty acid in control products to 32.81g/100g of total fatty acid in products with 25% of soy oil replacement. In metabolic studies, it has been shown that different classes of saturated fatty acids have different effects on plasma lipid and lipoprotein levels. Among the cholesterol-raising saturated fatty acids**,** myristic acid appears to be more potent than lauric acid or palmitic acid, although data are not entirely consistent (Kirs-Etherton & Yu, 1997; Temme, Mensink & Hornstra, 1996). In our study, the decrease in the SFA's fraction was caused especially by palmitic acid which is abundant in pork backfat. Myristic acid also decreased significantly in relation to control. Stearic acid, which did not show significant differences with regard to control, had been usually not included in the saturated fraction because it does not raise plasma cholesterol levels. However, recent studies have demonstrated that it reduces HDL levels, raises Lp(a) and Factor VII and impairs fibrinolysis suggesting, in agreement with epidemiological studies, that it is not justified to remove stearic acid from the saturated fraction (Hu, Manson & Willet, 2001). Arachidic acid was the only one who showed a significant increase with regard to control, however, it is present in a very small amount. According to this, the modification in the profile of the saturated fraction only had a beneficial effect considering the decrease in the total sum of SFA.

A significant but small decrease has been detected in oleic and palmitoleic acids leading to a slight decrease in the total MUFA fraction (45.78g/100g of total fatty acid in control products to 42.09g/100g of total fatty acid in 25%). This fraction increased in a significant way when olive oil was used in this type of products (Muguerza et al., 2001). The sum of PUFA's was higher in modified sausages (23.96g/100g of total fatty acid) than in control (15.22g/100g of total fatty acid) as a consequence of the significant increment of linoleic and α-linolenic acids. Soy oil is the richest vegetable oil in α-linolenic acid (8.09g/100g of total fatty acid) and its main predominant fatty acid is linoleic acid (55.78g/100g of total fatty acid).

The relevance of a high polyunsaturated/saturated ratio was shown in the epidemiological Nurses´ Health Study, in which it was proved that this ratio was strongly associated with a lower risk of CHD, making the suitable adjustments for age, smoking, other non-dietary variables, intakes of monounsaturated fat, trans fat, protein and total energy (Hu et al., 1999b). In our study, PUFA/SFA ratios showed a progressive increase from control to product with 25% of substitution, giving raise to a nutritional benefit. The value observed in products with 25% substitution was 0.73, which is higher than (0.61) found when olive oil was used (Muguerza et al., 2001). In relation with *n*-6/*n*-3 ratio, small differences were found between control (11.47) and modified products (11.76, 10.39 and 10.98) as a consequence of the significant increase of both linoleic (*n*-6) and α-linolenic (*n*-3) acids.

The sum of *trans* fatty acids ranged between 0.95 and 1.25g/100g of total fatty acid and none of them except palmitelaidic acid showed significant differences among the different products. The small amount of *trans* in dry fermented sausages is an interesting fact from the health aspect. Recently, researches have stated up that the net effect of *trans* fatty acid on the ratio of LDL cholesterol to HDL cholesterol is approximately double than that of saturated fatty acids (Ascherio, Katan, Zock, Stampfer, Willett, 1999).

Table 4 shows the results of instrumental texture and colour parameters for every analyzed product. Modifications of the formulation did not lead to changes in hardness and springiness, whereas a slight increase in cohesiveness, gumminess and chewiness was detected for products with 20% of substitution. Partial substitution of pork back fat with olive oil gave different results. Greek sausages were softer than the control if the addition of the oil was in a liquid form, whereas no differences in texture were detected if the addition was made as a preemulsion with soy protein (Bloukas et al.,1997; Muguerza et al., 2002). However, Muguerza et al. (2001) found lower values for hardness in chorizo de Pamplona, elaborated with preemulsified olive oil. In our work, sensory analysis of texture only showed a slightly lower value for hardness in the 20% substitution sausage without significant influence in the evaluation for the general acceptability of the product (Fig. 6).

Lightness (L*), redness (a*) and yellowness (b*) were not significantly affected by the soy oil addition. Values obtained for L* ranged between 49.95 and 52.81, all of them within the normal range for this type of sausages (46.87-54.29) (Gimeno, Ansorena, Astiasarán & Bello, 2000). Values for Hue (arctg b*/a*) were between 29.58 and 34.21, also within the range calculated for this type of sausages using data for a* and b* parameters in other studies (Ansorena et al., 1997; Gimeno et al., 2000). A higher value for colour intensity was described in the sensory analysis for the 20% substitution sausage (Fig 5). These products showed the lowest L* value but without statistical significance.

In summary, from the technological point of view, acceptable sausages were obtained by substitution of 15, 20 and 25% of the pork backfat by preemulsified soy oil. A reduction of the SFA’s fraction was achieved for all levels of substitution, together with an increase in linoleic and α-linolenic acids. Despite the increase in the PUFA’s fraction, no oxidation problems were detected at the end of the ripening process. The modified products were similar to the control in sensory properties.

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Table 1. Amounts (g/100g mixture) of pork backfat and soy emulsion used in the formulations of the different manufactured products: traditional formulation (control) and products manufactured with 15, 20 and 25% of substitution with soy oil.

	Control	Modified products with different percentages of substitution		
		15%	20%	25%
Pork backfat	25	21.25	20	18.75
Emulsion				
- Soy oil	—	1.97	2.63	3.28
- Isolated soy protein	—	0.20	0.26	0.33
- Water	—	1.58	2.10	2.63
Total added fat	25	23.22	22.63	22.03
- As animal fat (*)	100	91.5	88.4	85.0
- As soy oil (*)	—	8.5	11.6	15

(*) Expressed as percentage over the total added fat.

Table 2. Water, protein, fat, cholesterol and hexanal, TBA value, peroxide index of dry fermented sausages manufactured with traditional formulation (control) and with 15, 20 and 25% of substitution with soy oil.

	Control	15%	20%	25%
Fat (%)	33.9[a] (3.75; 11.06)	34.4[a] (1.85; 5.39)	31.2[a] (0.59; 1.89)	32.9[a] (0.82; 2.49)
Cholesterol **(mg/100g product)**	92.96[a] (6.10; 6.56)	90.87[a] (2.66; 2.93)	88.51[a] (8.42; 9.52)	87.71[a] (2.65; 3.02)
Acidity index **(mg KOH/g fat)**	10.85[a] (0.78; 7.19)	10.43[a] (0.74; 7.09)	10.86[a] (0.64; 5.89)	10.23[a] (0.44; 4.30)
Peroxide index **(meq O_2/kg fat)**	n.d	n.d	n.d	n.d
TBA value **(mg malonaldehyde/ kg dry matter)**	0.56[c] (0.05; 8.93)	0.39[b] (0.04; 10.25)	0.38[b] (0.02; 5.26)	0.29[a] (0.03; 10.34)
Hexanal **(ng dodecane /g dry matter)**	116[c] (33; 28.2)	73[b] (13; 17.8)	35.5[a] (4; 10.8)	27.25[a] (11; 40.4)

Values in the same row bearing different letters are significantly different (p≤ 0.05). Values in parenthesis are (standard deviation, SD and coefficient of variation, CV).n.d.: non detected

Fig 2. Moisture (%) during the ripening in control and modified products

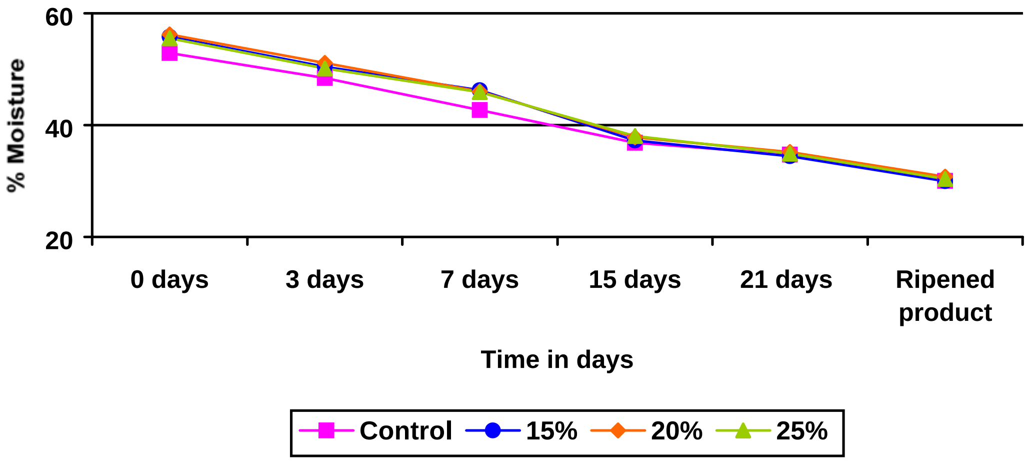

Fig 3. pH during the ripening in control and modified products

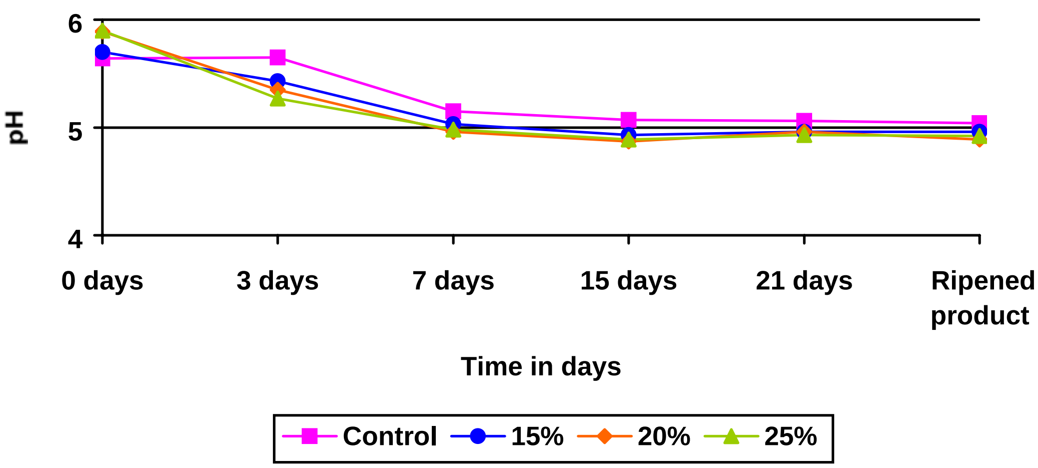

Fig 4. Aw during the ripening in control and modified products

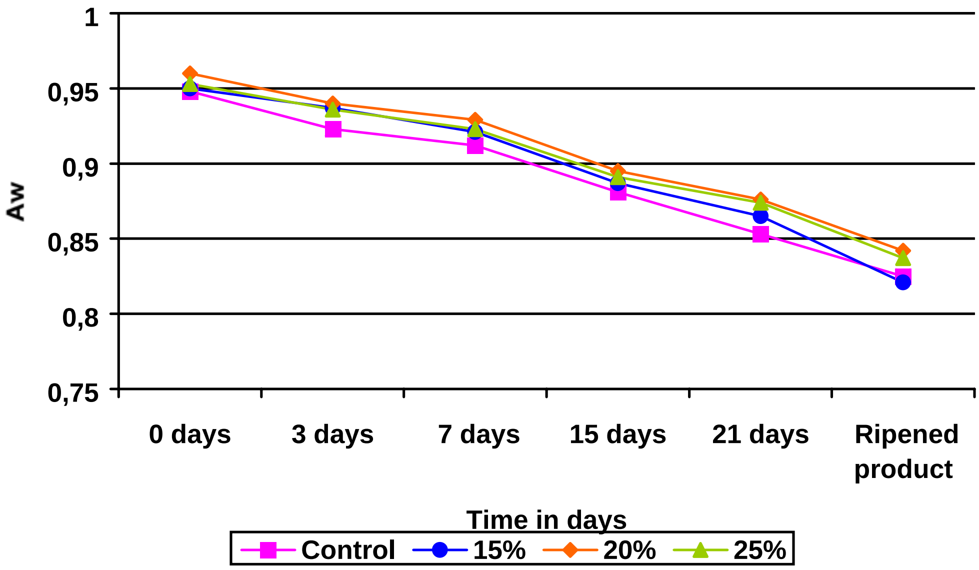

Table 3. Fatty acid content (g per 100 g of total fatty acid) in dry fermented sausages manufactured with traditional formulation (control) and with 15, 20 and 25% of substitution with soy oil.

	Control	15%	20%	25%
Lauric 12:0	0.12^{a} (0.00; 2.95)	0.97^{c} (0.02; 6.17)	0.98^{c} (0.08; 8.91)	0.64^{b} (0.08; 12.18)
Myristic 14:0	1.40^{c} (0.07; 0.49)	1.22^{b} (0.05; 4.10)	1.09^{a} (0.06; 5.50)	1.02^{a} (0.01; 0.98)
Palmitic 16:0	23.71^{d} (0.28; 1.18)	22.19^{c} (0.23; 1.04)	19.78^{b} (0.19; 0.96)	18.80^{a} (0.40; 2.13)
Stearic 18:0	12.08^{a} (0.10; 0.84)	11.70^{a} (0.14; 1.20)	11.93^{a} (0.11; 0.92)	11.71^{a} (0.21; 1.79)
Arachidic 20:0	0.21^{a} (0.03; 14.82)	0.23^{ab} (0.03; 12.48)	0.24^{ab} (0.02; 8.33)	0.27^{b} (0.01; 3.70)
Behenic 22:0	0.31^{a} (0.12; 37.06)	0.24^{a} (0.09; 37.5)	0.35^{a} (0.05; 14.28)	0.37^{a} (0.09; 24.32)
Σ SFA	37.83	36.55	34.37	32.81
Palmitoleic 16:1	2.53^{c} (0.04; 1.63)	2.31^{b} (0.05; 2.16)	1.83^{a} (0.07; 3.82)	1.73^{a} (0.03; 1.70)
Oleic 18:1	42.85^{b} (0.22; 0.52)	41.16^{a} (0.21; 0.51)	41.14^{a} (0.17; 0.41)	40.12^{a} (0.89; 2.22)
Erucic 22:1	0.40^{a} (0.16; 41.28)	0.40^{a} (0.20; 50.49)	0.23^{a} (0.04; 17.39)	0.24^{a} (0.03; 12.5)
Σ MUFA	45.78	43.87	43.20	42.09
Linoleic 18:2 n-6	13.93^{a} (0.14; 1.02)	16.94^{b} (0.04; 0.23)	19.18^{c} (0.27; 1.41)	21.82^{d} (0.50; 2.29)
α-linolenic 18:3 n-3	1.05^{a} (0.17; 16.32)	1.36^{b} (0.14; 10.29)	1.74^{c} (0.08; 4.60)	1.82^{c} (0.05; 2.75)
Arachidonic 20:4 n-6	0.07^{a} (0.06; 88.44)	0.07^{a} (0.06; 85.71)	0.15^{a} (0.02; 13.33)	0.14^{a} (0.05; 32.98)
EPA 20:5 n-3	0.07^{a} (0.02; 23.70)	0.13^{a} (0.07; 53.85)	0.05^{a} (0.01; 20)	0.07^{a} (0.02; 28.57)
DHA 22:6 n-3	0.10^{a} (0.02; 20.82)	0.09^{a} (0.00; 3.96)	0.07^{a} (0.01; 14.28)	0.11^{a} (0.01; 6.08)
Σ n-3	1.22	1.58	1.86	2.00
Σ n-6	14	17.01	19.33	21.96
Σ PUFA	15.22	18.59	21.19	23.96
PUFA/SFA	0.40	0.51	0.62	0.73
n-6 /n-3	11.47	11.76	10.39	10.98
Palmitelaidic *trans* 16:1	0.44^{b} (0.03; 6.82)	0.39^{a} (0.01; 3.63)	0.42^{b} (0.01; 3.50)	0.41^{b} (0.005; 1.22)
Elaidic *trans* 18:1	0.16^{a} (0.04; 26.28)	0.18^{a} (0.08; 48.06)	0.35^{a} (0.24; 68.57)	0.23^{a} (0.14; 60.87)
Linolelaidic *trans* 18:2	0.08^{a} (0.03; 36.53)	0.08^{a} (0.02; 31.33)	0.07^{a} (0.03; 42.86)	0.06^{a} (0.02; 33.33)
Brassidic *trans* 22:1	0.49^{a} (0.51; 103.83)	0.30^{a} (0.20; 60.66)	0.41^{a} (0.02; 4.64)	0.43^{a} (0.03; 6.98)
Σ Trans	1.17	0.95	1.25	1.13

SFA: saturated fatty acid; **MUFA**: monounsaturated fatty acid; **PUFA**: polyunsaturated fatty acid. **EPA**: Eicosapentaenoic; **DHA**: Docosahexaenoic. Values in the same row bearing different letters are significantly different ($p \leq 0.05$).Values in the parenthesis are (standard deviation, SD and coefficient of variation, CV).

Table 4. Mean values for texture and colour measures in dry fermented sausages manufactured with traditional formulation (control) and with 15, 20 and 25% of substitution with soy oil: texture(TPA texture profile analysis) and colour (CIE L*a*b* system).

	Control	15%	20%	25%
Hardness, g	1432.00[a] (117.63; 8.21)	1558.00[a] (158.88; 10.20)	1602.56[a] (238.92; 14.31)	1599.41[a] (59.22; 3.70)
Springiness, mm	0.58[a] (0.18; 31.46)	0.65[a] (0.05; 8.30)	0.69[a] (0.10; 14.72)	0.69[a] (0.05; 17.80)
Cohesiveness	0.62[a] (0.03; 4.63)	0.61[a] (0.03; 4.84)	0.69[b] (0.59; 8.51)	0.61[a] (0.02;3.78)
Gumminess, g	892.20[a] (86.02; 9.64)	953.30[a] (103.09; 10.81)	1100.18[b] (172.33; 15.56)	980.47[ab] (62.74; 6.34)
Chewinness, g x mm	578.95[a] (76.24; 13.17)	620.48[a] (69.63; 11.22)	765.66[b] (211.04; 27.92)	680.06[ab] (52.47; 7.71)
Lightness (L*)	52.81[a] (4.48; 8.48)	51.91[a] (1.73; 3.33)	49.95[a] (4.16; 8.33)	51.57[a] (2.66; 5.17)
Redness (a*)	15.57[a] (2.58; 16.55)	17.29[a] (2.08; 12.04)	17.94[a] (2.89; 16.11)	17.98[a] (2.32; 12.90)
Yellowness (b*)	8.79[a] (8.79; 31.68)	11.79[a] (3.95; 33.52)	11.43[a] (1.42; 12.40)	11.07[a] (2.07; 18.73)
Hue (arctg b*/a*)	29.58	34.21	32.51	31.38

Values in the same row bearing different letters are significantly different ($p \leq 0.05$). Values in the parenthesis are (standard deviation, SD and coefficient of variation, CV).

Figure 6. Sensory evaluation: results of QDA carried out in dry fermented sausages manufactured with traditional formulation (control) and with 15, 20 and 25% of substitution with soy oil.