Nutritional and sensory properties of dry fermented sausages enriched with ω-3 PUFAs

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ABSTRACT

Enrichment of dry fermented sausages with ω-3 fatty acids trough a partial substitution of pork backfat by deodorised fish oil resulted in improved nutritional properties with regard to conventional sausages, without affecting sensorial properties and oxidation status. The developed products supplied 0.64g EPA/100g and 0.46g DHA/100g product, and showed PUFA+MUFA/SFA ratio of 1.76 and ω-6/ω-3 ratio of 2.97. No signs of oxidation were found in any type of sausages, control and modified. None of the dienals and trienals reported as secondary lipid oxidation products and typical from fish oil were detected in the modified sausages. Instrumental colour differences were detected without relevance in the sensorial analysis. Sensory evaluation panel did not find differences in general acceptability. The modified dry fermented sausages can be considered a technological viable functional food.

Key words: deodorised fish oil, ω-3 fatty acids, EPA, DHA, functional dry fermented sausages.

INTRODUCTION

Fish meal, fish oils and microalgal oil are relevant sources of very-long chain polyunsaturated fatty acids (PUFA) of the ω-3 family such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Their positive health effects are well recognised: they show antithrombogenic, antiinflamatory and hypotriglyceridemic properties, inhibit the formation of atherosclerotic plaques and prevent arrhythmias, contributing to prevent or ameliorate autoinmune disorders, crohn disease, breast, colon and prostate cancers, rheumatoid arthritis and particularly prevent cardiovascular diseases (Connor, 2000).

The first dietary recommendations for ω-3 PUFA established different intakes of DHA+EPA ranging from 0.8 to 1.2g/day (British Nutrition Foundation, 1992**)** and more recently, an international group of experts on the role of these fatty acids in health established adequate intakes (AI) for DHA+EPA on 0.65g/day, where each fatty acid should account at least for 0.22g (Simopoulos, Leaf & Salem, 1999). Even higher amounts (2-4g) for people needing triglyceride lowering have been postulated (Kris-Etherton, Harris & Appel, 2002).

Also, the nutritional authorities have recommended the consumption of foods rich in ω-3 polyunsaturated fatty acids with the objective of reducing the dietary ω-6/ω-3 PUFA ratio. Nowadays this ratio is about 15-20:1 in the Western diet instead of the recommended range, 1-4:1 (Simopoulos, 2002), due to the extremely low daily dietary intake of ω-3 fatty acids in some population.

Different types of enriched ω-3 fatty acids foodstuffs are being developed nowadays by the food industry. Concerning meat and meat products different possibilities to increase the content of ω-3 PUFA have been assayed. The inclusion of oils rich in ω-3 fatty acids in the diet of pig (Leskanich, Matthews, Warkup, Noble & Hazzledine, 1997;

Enser, Richardson, Wood, Gill & Sheard, 2000; Bryhni, Kjos, Ofstad & Hunt, 2002), beef (Scollan, Choi, Kurt, Fisher, Enser, & Wood, 2001) and ostrich (Hoffman, Joubert, Brand & Manley, 2005) in order to modify the lipid composition of the meat has been tested. Another possibility is to enrich the meat products by adding a source of ω-3 PUFA as an ingredient of the formulation. In a previous work, a pilot experience was carried out adding small amounts of fish oil concentrates to the traditional formulation of dry fermented sausages (Muguerza, Ansorena & Astiasarán, 2004). In that work a potential increase of oxidation process in the lipid fraction during the curing process of very rich ω-3 PUFA products was pointed out.

Substituting pork backfat by fish oil is another approach to obtain dry fermented sausages enriched with ω-3 PUFA. Pork backfat is traditionally used in the formulation of dry fermented sausages, due to its relevant contribution to the properties of the final product, including its appearance, being difficult to substitute it in a great percentage. In previous works in which some vegetable oils have been used as potential substitutes it was stated up that from the technological point of view up to 25% of fat substitution is possible (Muguerza, Gimeno, Ansorena, Bloukas & Astiasarán, 2001; Muguerza, Ansorena & Astiasarán, 2003).

The aim of this paper was to study the nutritional and sensory properties of an enriched ω-3 PUFA dry fermented sausages made by a partial substitution of the traditionally used pork backfat by emulsified deodorised fish oil and to compare it with the traditional products. The intensity of the oxidation process was specially investigated.

MATERIALS AND METHODS

Sausage formulation and processing.

Two batches of dry fermented sausages (Chorizo de Pamplona), about 9 Kg each, were prepared according to the procedure described by Muguerza, Gimeno, Ansorena, Bloukas and Astiasarán (2001). The control batch was elaborated using 75% lean pork meat and 25% pork backfat. In the modified batch, a substitution of 25% of pork backfat by an emulsion containing deodorised fish oil obtained from a mixture of different fish (LYSI, Reykjavik, Island) was carried out. The emulsion was prepared mixing for two minutes eight parts of hot water with one part of isolated soy protein and then with ten parts of fish oil for other three minutes (Hoogenkamp, 1989a,b). Analysis of the profile of fatty acids of the fish oil was carried out. The following ingredients per kilogram of meat mixture were added to both formulations: NaCl 26g, red pepper 30g, dextrin 15g, lactose 10g, powdered milk 12g, dextrose 5g, sodium ascorbate 0.5g, sodium caseinate 10g , garlic 3g , polyphosphates 2g, curing agents (a mixture of NaCl, preservatives E-250, E-252 and antioxidant E-331) 3g, ponceau 4R (E-124) 0.15g. The starter culture was a mixture of *Lactobacillus plantarum* L115 (50%) and *Staphylococcus carnosus* M72 (50%). The amount added was 10^6-10^7 cfu/kg of mixture. 100mg/kg of butylhydroxytoluene (BHT) and 100mg/kg of butylhydroxyanisole (BHA) were added as antioxidants in the experimental batch.

The sausages were fermented in a drying chamber (STA model W 80XDHG-VEH Noain, Spain) at 22-23ºC and 90-100% relative humidity (RH) for 24h, 19.5-20.5ºC and 80-90% RH for 24h, 16.5-17.5ºC and 80-90% RH for 24h. Then the sausages were dried for 7 days at 14-15ºC and 74-86% RH, until the end of ripening.

Chemical analysis.

Moisture was determined according to the Association of Official Analytical Chemists method (AOAC, 2002a). Total fat was determined by an extraction with petroleum ether according to AOAC, (2002b). The method of Folch, Lees and Stanley (1957) was used for the extraction of lipids. Fatty acids were determined in the lipid extract by gas chromatography. Boron trifluoride/methanol was used for the preparation of fatty acid methyl esters (AOAC, 2002c). A Perkin-Elmer Clarus 500 gas chromatograph (PE, Shelton, CT, USA) fitted with a capillary column SP^{TM}-2560 (100m x 0.25mm x 0.2μm) and flame ionization detection was used. The temperature of the injection port was 250ºC and of the detector was 260ºC. The oven temperature was programmed at 175ºC during 10min and increased to 200ºC at a rate of 10ºC/min, then increased to 220ºC at a rate of 4ºC/min, which was kept for 15min. The carrier gas was hydrogen, and the pressure was 20.5psi. Split flow was 120cm/s. The identification of the fatty acid methyl esters was done by comparison of the retention times of the peaks in the sample with those of standard pure compounds (Sigma, St. Louis, MO, USA) and by spiking the sample with each standard individually. The quantification of individual fatty acids was based on the internal standard method, using heptadecanoic acid methyl ester (Sigma, St. Louis, MO, USA). Peroxide value was determined using the official method of AOAC (AOAC, 2002d). TBA value was determined according to Tarladgis, Watts, Younathan and Dugan (1960) with modifications by Tarladgis, Pearson and Dugan (1964). Results are shown in mg malonaldehyde/kg sample (ppm).

Cholesterol content was analyzed by gas chromatography with previous extraction with hexaneaccording to Kovacs, Anderson and Ackman (1979). A Perkin-Elmer Autosystem XL gas chromatograph equipped with an HP1 column (30m x 0.25mm x 0.1μm) was used. The oven temperature was 265ºC. The temperature of both the

injection port and detector was 285ºC. Cholesterol was identified by comparing its retention time with that of a standard (Signa, ST. Louis, MO, USA) and quantification was done using by pure cholestane as an internal standard (Sigma, St. Louis, MO, USA). A Perkin-Elmer Turbochrom programme was used for quantification.

Volatile compounds

A Likens-Nickerson extraction using dicloromethane was carried out according to the method described by Ansorena, Zapelena, Astiasarán and Bello (1998).

Instrumental measures.

For colour measurement, samples were homogenated and homogenated and introduced in a plate of 1cm height. They were 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 700nm using an integrating sphere. Colour coordinates were obtained with the conditions established by Ansorena, De Peña, Astiasarán, and Bello**, (**1997). (CIE L* a* b* system, angle 10º, illuminant D65). L*, a* and b* parameters indicate lightness, redness and yellowness, respectively. Chroma and Hue were calculated. Each sample was measured at four locations on the 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 general acceptability, typical sausage odour, colour intensity, juiciness and fishy taste. A continuos scale among 0 and 5 was used for evaluation. A value of 0 corresponded to the lowest intensity for each parameters and a value of 5 to the highest. Data shown corresponded

to the mean value obtained for each type of product taking into account scores given by all panellists.

Data analysis.

Two samples were analysed from each type of dry fermented sausage. Each parameter was determined four times in each sample. Means and standard deviations are shown in the tables.

t-student test was used to determine significant differences ($p<0.05$) between the different types of sausages. The statistics package chosen for analysis was SPSS version 11.0 (SPSS inc. Chicago, Illinois, USA).

DISCUSSION

The effect of a partial substitution of pork backfat by an emulsion containing deodorised fish oil in the elaboration of dry fermented sausages was studied in this paper. Table 1 shows the differences in the fatty acid profile of the these two lipidic ingredients, pork backfat and fish oil. No significant differences were found for total amount of saturated fatty acids (SFA), whereas very high differences were found for monounsaturated fatty acids (MUFA) and PUFA. The deodorised fish oil extract showed a 36.36% of PUFA, where the long-chain ω-3 fatty acids accounted for 16.92g EPA/100g fatty acids and 13.44g DHA/100g fatty acids (table 1), making this extract an excellent source of ω-3 fatty acids to be incorporated into sausages formulation. However, it showed a relatively high cholesterol content, reaching 542mg/100g of product, which is much higher than that showed by pork backfat (Table1).

The significant differences in the type of fat used in the formulation gave rise to products with significant differences in the lipid composition and, in consequence, in the nutritional value. Total fat content of traditional and functional products was similar, being 27.28% and 27.7% respectively. The high cholesterol amount of the fish oil gave rise to a significantly higher cholesterol content in products made with fish oil than in the traditional ones (134 and 102mg/100g product, respectively). This difference could be considered as a negative aspect for modified products, although nowadays the intake of cholesterol is considered of lower importance than the intake of an adequate fatty acid profile (Zyriax & Windler, 2000).

The fatty acid profiles of both types of dry fermented sausages, control and modified, are shown in table 2. Statistical significant differences were found between the two types of sausages, although in most cases they were quantitatively very low. The greatest differences were found for the ω-3 fatty acids. 0.64g EPA/100g product+0.46g

DHA /100g product were obtained in modified sausage, whereas in control sausages the results were 0.1gEPA+0.2gDHA. When 10.7g of a concentrated fish oil extract (omega-3 700, Solgar Vitamins Ltd, Newcastle, UK) per kg of raw mixture was formerly used by our research group in the elaboration of dry fermented sausages, the contents of DHA and EPA were 0.33 and 0.26 g/100g product, respectively (Muguerza et al., 2004). Jenn-Hong, Yuan-Hui & Chun-Chin (2002) developing chicken frankfurters from chickens fed with supplement fish oil obtained products with 0.43g/100g product of EPA+DHA.

Regarding to the AI stablished for EPA and DHA, an average portion of the developed dry fermented sausage, which can be estimated in 50g, would supply the 85% of AI for DHA and EPA, reaching the minimum of 0.22g recommended for each one of them.

Concerning other PUFA, α-linolenic acid, ω-3 essential fatty acid, was only slightly higher in the developed products than in the traditional ones. Linoleic acid, PUFA ω-6, was slightly higher in control sausage (4.20g/100g product) than in modified sausage (4.02g/100g product). Definitively, the PUFA fraction was significantly higher in the modified product due to the higher supply of long chain ω-3 fatty acids in the fish oil.

In relation to the SFA fraction, the profile was quite similar between both products as a consequence of the similar profile shown by the two types of fats used. Concerning the MUFA fraction, the difference detected between pork backfat and fish oil for oleic acid was reflected in the final product values, with a higher value for control sausage than for modified ones (11.05 and 10.37g/100g product, respectively).

With these fatty acid profiles, modified products showed better ratios than control products from the nutritional point of view. Both MUFA+PUFA/SFA and PUFA/SFA were higher in modified products than in control ones, which is considered beneficial in relation to blood lipid regulation. Furthermore, ω-6/ω-3 ratio was 2.97 in modified

products instead of 13.86 found for control ones, that also means a nutritional benefit, as it perfectly fits within current recommendation for this ratio.

The undoubtedly positive health benefits associated to the lipid composition achieved in the developed products might involve a higher risk for the stability of the product. This hypothesis, which was confirmed in previous works, was taken into account in the experimental design of the present experiment, leading to the inclusion of a mixture of the antioxidants BHA+BHT in the formulation of the modified products. Lipid oxidation was followed through the analysis of TBA, peroxides and some volatile compounds related to lipid oxidation. Despite the presence of a higher PUFA content in modified sausages, TBA and peroxides showed significantly greater values in control sausages than in the experimental ones. Control sausages showed 0.27mg malonaldehyde/kg sample and 1.36meqO_2/kg, fat whereas fish oil containing products showed 0.17mg malonaldehyde/kg and <1meqO_2/kg fat. However, in any case differences were quantitatively relevant and it could be concluded that values revealed no signs of oxidation.

The analysis of volatile compounds related to lipid oxidation (Table 3). confirmed these results. Typical n-aldehydes used as lipid oxidation markers, such as n-hexanal, n-heptanal and n-nonanal showed significant higher values for control sausages than for the experimental products. It has been postulated that the 2,4,7-decatrienal isomers contribute with fishy off-flavours in highly autooxidazed oils containing ω-3 PUFA (Meijboom & Stroink, 1972), and also in low oxidised fish oil containing milk emulsions (Venkateshwarlu, Let, Meyer, & Jacobsen, 2004). Also (E,E)-2,4-heptadienal and (E,Z)-2,6-nonadienal are important markers of ω-3 PUFA degradation and are characterised by their rancid and cucumber or green odour. These volatile compounds were particularly searched in fish oil containing sausages, however they were not

detected in any of the analysed products. As a consequence of use of fish oil, the 2,6,10,14-tetramethylpentadecane (pristane) was present in the modified sausages as found by Elmore et al. (2005) in the volatile profile of lamb fed fish oil. This isoprenoid alkane, which has been reported to contribute a green, sweet aroma to crayfish, can be originated from lipid autooxidation process through alkyl radicals or from descomposition of carotenoids (Spurvey, Pan, & Shahidi, 1998) and also it is possible that appeared in fish oil due to a contamination in the diet (Alvarez Piñeiro, Lage Yusty, Carril González-Barros and Simal Lozano, 1996). Taking into account these results it can be stated up that the oxidation process in meat products enriched with ω-3 PUFA can be avoided in an efficient way with the use of BHA+BHT.

Substitution of pork backfat by the fish oil emulsion decreased significantly the L* value, as it could have been expected, as pork backfat contributes to the final product with its white colour and it is present in a higher amount in control sausages. This fact was also found by Éstevez, Ventanas and Cava, (2005) when formulating different fat containing patés detecting higher values for higher-fat products. Parameter a*, that has been used to monitor lipid oxidation stability, although showed statistical differences between both sausages, they were not quantitatively relevant. Higher b* values in fish oil containing sausages led to a more saturated red colour (higher Chroma) and 2 degrees difference for the Hue angle. Nevertheless, as it will be reflected later on in this paper, non of the instrumental colour differences detected were relevant in the sensorial analysis.

One of the limiting factor for introducing fish oil or derivatives into foodstuffs is the fishy taste that negatively affects sensorial characteristics. Park, Rhee, Keeton, & Rhee, (1989) prepared frankfurters with 5% fish oil, detecting an undesirable flavour and aroma derived from fish oil in the products. Also Muguerza et al. (2004) concluded that

sausages with a concentrated fish oil extract rich in ω-3 fatty acids were not-viable from the sensorial point of view due to off odours. Several experiments in which fish oil was incorporated in different amounts into the animals diet resulted in unacceptable off-flavours and odours in meat (Øverland, Taugbøl, Haug, & Sundstøl, 1996; Sheard, Enser, Wood, Nute, Gill & Richardson, 2000), obtaining higher scores for fishy flavour in the sensory evaluation (Elmore et al., 2005). In our case, a sensory evaluation by means of a quantitative descriptive analysis was carried out in both types of products, control and modified. Juiciness was slightly better evaluated in modified products, probably due to the physical properties and palatability of the protein-oil emulsion used for substituting pork backfat. This substitution did not have an effect on the colour intensity of sausages, without differences in this parameter according to panellists observations. However, flavour related parameters were slightly different between the two products. Some of the panellists detected a low intensity fishy taste in the modified sausage and also a less intense typical sausage odour in the modified product was obtained in comparison to the control one. However, these differences did not negatively affect the evaluation of the general acceptability of the product, as panellists gave similar scores for both products.

In summary, according to the results of the present research it can be stated up that it is possible to develop functional dry fermented sausages with nutritional benefits related to a significant supply of PUFA ω-3 without a significant loss of their sensory quality.

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Figure 1. Sensory evaluation: results of quantitative descriptive analysis (QDA) carried out in control and modified dry fermented sausages.

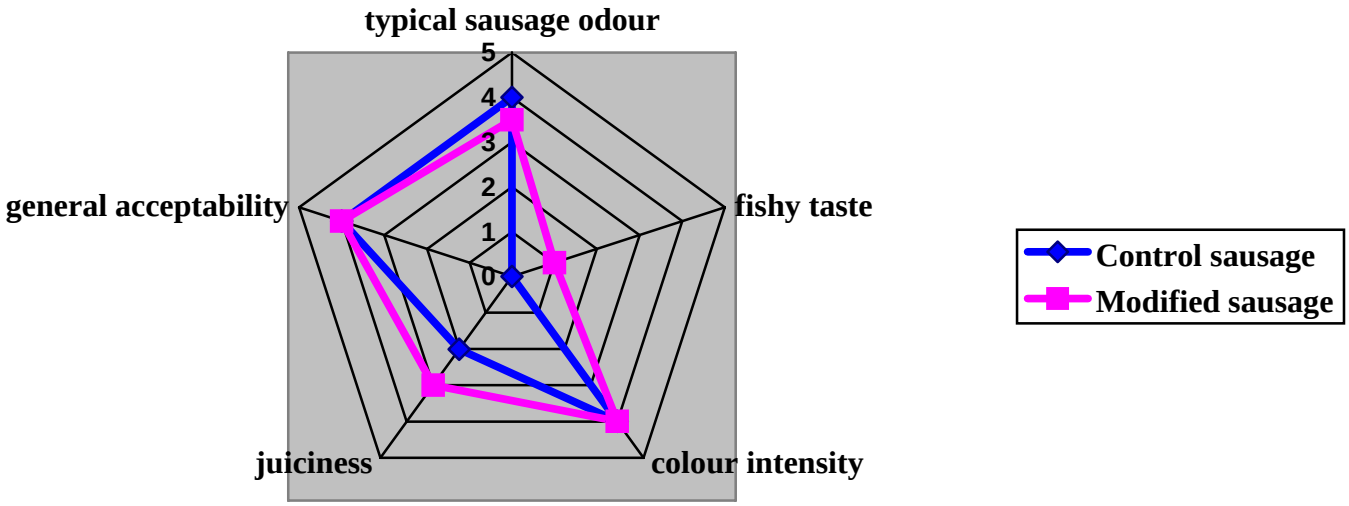

Table 1. Fatty acid profile (g/100g of fatty acids) and cholesterol content (mg/100g of product) of the pork backfat and deodorised fish oil and used in the elaboration of dry fermented sausages.

	Pork backfat	**Fish oil**	**LS**
Lauric C12:0	0.10; 0.00	0.16; 0.01	**
Myristic C14:0	1.28; 0.01	7.04; 0.35	***
Palmitic C16:0	21.95; 0.22	17.33; 0.59	***
Stearic C18:0	9.33; 0.14	3.50; 0.07	***
Arachidic C20:0	0.08; 0.01	0.20; 0.01	***
Behenic C:22:0	0.00; 0.00	0.05; 0.00	***
∑SFA	***32.74; 0.37***	***28.29; 1.03***	***ns***
Palmitoleic C16:1	2.50; 0.03	7.96; 0.40	***
Oleic C18:1(ω-9)	41.71; 0.35	8.69; 0.29	***
Vaccenic C18:1(ω-9)	2.99; 0.02	3.11; 0.11	ns
Erucic C22:1	0.00; 0.00	0.05; 0.00	***
∑MUFA	***47.20; 0.39***	***20.41; 0.79***	*****
Linoleic C18:2(ω-6)	17.85; 0.17	1.26; 0.05	***
α-Linolenic C18:3(ω-3)	1.18; 0.01	1.16; 0.07	ns
γ-Linolenic C18:3(ω-6)	0.03; 0.03	0.22; 0.02	***
Arachidonic C20:4(ω-6)	0.24; 0.01	1.14; 0.10	***
Eicosapentaenoic C22:5(ω-3)	0.03; 0.00	16.92; 2.03	***
Docosahexaenoic C22:6(ω-3)	0.12; 0.01	13.44; 0.58	***
∑PUFA	***19.45; 0.20***	***36.36; 2.85***	******
t-Palmitoleic C16:1t	0.43; 0.01	0.57; 0.18	ns
Elaidic C18:1t	0.08; 0.01	1.17; 0.11	***
t-Linoleic C18:2t	0.00; 0.00	0.06; 0.02	**
Brassidic C22:1t	0.10; 0.00	1.84; 0.02	***
∑TRANS	***0.61; 0.01***	***3.64;0.29***	******
Cholesterol	***70; 0.05***	***542; 8.82***	*****

LS. Level of significance ns; Not significant (P>0.05), *P<0.05, **P<0.01, ***P<0.001.

Table 2. Total fatty acids (g/100g of product) and content in cholesterol (mg/100g of product) of control and modified sausages after 30 days of ripening.

	Control sausage	**Modified sausage**	**LS**
Lauric C12:0	0.02; 0.00	0.03; 0.00	***
Myristic C14.0	0.31; 0.01	0.56; 0.01	***
Palmitic C16:0	6.23; 0.12	6.26; 0.06	ns
t-Palmitoleic C16:1t	0.10; 0.00	0.11; 0.00	ns
Palmitoleic C16:1	0.49; 0.04	0.79; 0.01	***
Stearic C18:0	3.49; 0.04	3.11; 0.02	***
Elaidic C18:1t	0.02; 0.00	0.02; 0.00	ns
Oleic C18:1(ω-9)	11.05; 0.20	10.37; 0.14	**
Vaccenic C18:1(ω-11)	0.74; 0.01	0.81; 0.01	***
t-Linoleic C18:2t	0.00; 0.00	0.01; 0.00	***
Linoleic C18:2(ω-6)	4.20; 0.10	4.02; 0.05	*
Arachidic C20:0	0.02; 0.00	0.03; 0.00	**
γ-Linolenic C18:3(ω-6)	0.01; 0.00	0.02; 0.00	***
α-Linolenic C18:3(ω-3)	0.29; 0.01	0.31; 0.00	**
Behenic C22:0	0.00; 0.00	0.00; 0.00	-
Brassidic C22:1t	0.00; 0.00	0.00; 0.00	-
Erucic C22:1	0.03; 0.00	0.01; 0.00	***
Arachidonic C20:4(ω-6)	0.13; 0.00	0.18; 0.00	***
Eicosapentaenoic C20:5(ω-3)	0.01; 0.00	0.64; 0.02	***
Docosahexaenoic C22:6(ω-3)	0.01; 0.00	0.46; 0.03	***
∑SFA	**10.08; 0.17**	**9.99; 0.10**	**ns**
∑MUFA	**12.30; 0.21**	**11.98; 0.16**	*****
∑PUFA	**4.65; 0.10**	**5.62; 0.00**	*******
∑TRANS	**0.12; 0.00**	**0.13; 0.00**	*****
PUFA/SFA	**0.46; 0.00**	**0.56; 0.00**	*******
MUFA+PUFA/SFA	**1.68; 0.00**	**1.76; 0.00**	*******
ω-6/ω-3	**13.86; 0.03**	**2.97; 0.13**	*******
Cholesterol	102; 4.22	134; 3.03	***

LS. Level of significance ns; Not significant (P>0.05), *P<0.05, **P<0.01, ***P<0.001.

Table 3. Selection of volatile compounds obtained by Likens-Nickerson extraction and further mass spectrometry quantification of control and modified sausages after 30 days of ripening.

RID[a]	Compounds	Control sausage	Modified sausage	LS
A	Hexanal	1273; 44.00	275; 30.10	***
A	Heptanal	331; 29.40	15; 1.50	***
B	t-2-heptenal	0.00; 0.00	0.00; 0.00	-
B	2-pentyl amilofurane	237; 19.60	41; 2.60	***
C	t,t-2,4-heptadienal	0.00; 0.00	0.00; 0.00	-
B	2-octenal	33; 6.40	0.00; 0.00	***
B	Nonanal	1867; 77.20	162; 15.20	***
C	c,t-2,6-nonadienal	0.00;0.00	0.00;0.00	-
C	t,t-2,4-nonadienal	0.00; 0.00	0.00; 0.00	-
B	t,t-2,4-decadienal	58; 5.00	0.00; 0.00	***
B	2,4-decadienal	311; 29.20	0.00; 0.00	***
C	c,c,t-2,4,7-decatrienal	0.00; 0.00	0.00; 0.00	-
C	c,t,t-2,4,7-decatrienal	0.00; 0.00	0.00; 0.00	-
B	Tetradecanal	496; 54.75	557; 30.14	ns
B	2-pentadecanone	108; 12.68	55; 2.75	***
B	Heptadecane	0.00; 0.00	1125; 43.34	***
B	Pristane	0.00; 0.00	504; 23.89	***
B	Hexadecanal	4768; 535	3449;133.83	**

RID[a], reliability of identification, indicated by the following symbols: A, mass spectrum and retention time identical with those of pure standars; B, mass spectrum and Kovats index in agreement with the correponding literture data; C, extracted ion chromatograms of the characteristic ions were studied. Results expressed in nanograms of dodecane per gram of dry mater.
LS. Level of significance ns; Not significant (P>0.05), *P<0.05, **P<0.01, ***P<0.001.

Table 4. Mean values for colour (CIE L*, a*, b* system) measures in control and modified sausages after 30 days of ripening.

	Control sausage	Modified sausage	LS
lCIE	51.18; 0.74	48.60; 0.60	*
aCIE	18.15; 0.02	18.27 0.04;	*
bCIE	12.73; 0.37	14.02; 0.30	*
Chroma	22.17; 0.28	23.03; 0.21	*
Hue angle	35.04; 0.91	37.50; 0.43	*

LS. Level of significance *P<0.05