Effect of reducing and replacing pork fat on the physicochemical, instrumental and sensory characteristics throughout storage time of small caliber non-acid fermented sausages with reduced sodium content

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ABSTRACT

The effect of pork fat reduction (from 44% to 20% final fat content) and its partial substitution by sunflower oil (3% addition) on the physicochemical, instrumental and sensory properties throughout storage time of small caliber non-acid fermented sausages (*fuet* type) with reduced sodium content (with partial substitution of NaCl by KCl and K-lactate) and without direct addition of nitrate and nitrite (natural nitrate source used instead), was studied. Results showed that sausages with reduced fat (10% initial fat content) and with acceptable sensory characteristics can be obtained by adding to the shoulder lean (8% fat content) during the grinding, either 3.3% backfat (3% fat content) or 3% sunflower oil, both previously finely comminuted with lean. Furthermore, sunflower oil showed to be suitable for partial pork backfat substitution in very lean fermented sausages, conferring desirable sensory properties similar to those of sausages with standard fat content. The sensory quality of the sausages was maintained after three-month cold storage in modified atmosphere.

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1. Introduction

Fermented sausages are meat products with high animal fat and sodium chloride (NaCl) contents, with fat values of 30–50% in *salami* (Jiménez-Colmenero, 2000) and 42% in small caliber non-acid fermented sausage *fuet* type (Spanish Food Composition Database [BEDCA], 2007), and with NaCl levels of 3.4–5.2% in *salami* (Dellaglio, Casiraghi, & Pompei, 1996) and around 3.7% in *fuet* (Zurera-Cosano, Otero-Carballeira, Carrasco-Jiménez, Pérez-Rodríguez, & Valero-Díaz, 2011). In most Western countries, intake of both saturated fat and sodium is higher than recommended (European Food Safety Agency [EFSA], 2005; World Health Organization [WHO], 2003), posing a threat to public health, especially because of their relationship with adverse cardiovascular effects including coronary heart disease, stroke and hypertension (EFSA, 2010; Kannel, 1996; Law, 1997). According to the recommendations of the World Health Organization (WHO, 2003), the daily fat intake should be less than 30% of the total calories, and the intake of saturated fatty acids and cholesterol should be reduced. Likewise, the mean daily sodium intakes are in excess of dietary needs (about 1.5 g sodium/day in adults) (EFSA, 2005). These recommendations have contributed to an increasing interest on healthier diets among consumers and to the development of reduced fat meat products by the meat industry. Nevertheless, it is difficult to reduce fat and NaCl levels in fermented sausages because they are essential ingredients. In sausage manufacture, fat affects important technological functions like water release during drying (Wirth, 1988), and sensory properties such as flavor and texture (Mendoza, García, Casas, & Selgas, 2001). Accordingly, fat reduction can adversely affect the acceptability of meat products (Giese, 1996). Different vegetable oils, i.e. olive, soybean, and linseed oils, have been used as fat substitutes in fermented sausages such as *salami*, *chorizo de Pamplona*, and *cervelat* (Dutch style fermented sausage) obtaining acceptable products (Ansorena & Astiasarán, 2004; Del Nobile et al., 2009; Muguerza, Ansorena, & Astiasarán, 2003; Muguerza, Gimeno, Ansorena, Bloukas, & Astiasarán, 2001; Pelser, Linssen, Legger, & Houber, 2007; Severini, De Pilli, & Baiano, 2003; Valencia, Ansorena, & Astiasarán, 2006). In a previous study (Mora-Gallego et al., 2013) sunflower oil (5%) was used as fat substitute in reduced fat non-acid fermented sausages with standard NaCl content showing good instrumental texture and sensory properties. Concerning NaCl, it is an essential ingredient that contributes to improve the water holding capacity, color, fat binding properties, flavor and shelf-life of processed meat products (Ruusunen & Puolanne, 2005). The preservative effect of NaCl is mainly due to its ability to lower water activity (Marsh, 1983; Sofos, 1994; Wirth, 1989). The reduction of sodium in meat products is possible from both technological and sensory viewpoints (Askar, El-Samahy, & Tawfik, 1994; Gelabert, Gou, Guerrero, & Arnau, 2003; Gou, Guerrero, Gelabert, & Arnau, 1996; Kim & Brewer, 1996). Potassium chloride (KCl) and potassium lactate (K-lactate) have been proposed as NaCl substitutes in fermented sausages with satisfactory results regarding sensory attributes and consumer acceptability (Gelabert et al., 2003, Gou et al., 1996; Guàrdia, Guerrero, Gelabert, Gou, & Arnau, 2006; 2008), but the drying process could be affected (Arnau, Muñoz, & Gou, 2012; Muñoz, Arnau, Costa-Corredor, & Gou, 2009). Regarding the shelf-life of meat products, lipid oxidation is a major concern in food technology due to the loss of quality associated to this process, with negative effects on flavor, texture, mouth feel, juiciness and overall sensation of lubricity (Muguerza, Fista, Ansorena, Astiasarán, & Bloukas, 2002; Navarro, Nadal, Izquierdo, & Flores, 1997). High fat contents and prolonged storage times result in high lipolytic activity and lipid oxidation that can affect the color of fermented sausages (Soyer & Ertas, 2007). Packaging in modified atmosphere (vacuum and gas packaging) has been introduced as a commercial practice for the retail selling of dry fermented sausages to increase their shelf-life (Rubio, Martínez, García-Cachán, Rovira, & Jaime, 2008).

This work aims to assess the effect of pork fat reduction and its substitution by sunflower oil on the physicochemical, instrumental and sensory properties throughout storage time of small caliber non-acid fermented sausages (*fuet* type) with reduced sodium content (with partial substitution of NaCl by KCl and K-lactate) and without direct addition of nitrate and nitrite.

2. Materials and methods

2.1. Sausage preparation and drying

Two replicates of the experiment were carried out. Pork-shoulder lean (8% fat content) and backfat (89% fat content) were purchased at a local supplier. For each replicate, three batches (15 kg/batch) of small caliber non-acid fermented sausages (*fuet* type) were manufactured using pork-shoulder lean and three different added fat contents: 20% backfat (which corresponds to 17.8% added fat; BF20), 3.3% backfat (which corresponds to 3% added fat; BF3) and 3% sunflower oil (SO3). The BF20 batch (20% backfat) was prepared by mixing and mincing the backfat together with the shoulder lean (both at –1ºC±1ºC) through a 5 mm plate. In the case of the BF3 batch (3.3% added backfat) 0.5 kg of backfat were minced in a bowl chopper (Dito-Sama K55, Dito-Sama S.A., Aubusson, France) with 1 kg of shoulder lean (without salt addition) for 2 min until forming a finely comminuted paste that was later added to the rest of the shoulder lean of the batch and ground through a 5 mm plate. The same process was carried out for the SO3 batch in which 0.45 kg of sunflower oil (3%) was added as backfat substitute and minced together with 1 kg of shoulder lean in a bowl chopper and then ground with the rest of lean. The sunflower oil used was Koipesol (Koipesol Semillas S.A., Sevilla, Spain). The following additives and ingredients per kilogram of mixture were added to the ground mixtures of lean and fat and mixed under vacuum for 3 min in a mixer (Tecmaq20) : 14 g NaCl (which represents a 30-35% NaCl reduction with respect of the NaCl added to a standard product: 20-22 g/kg; Mora-Gallego et al., 2013; Guàrdia et al., 2008), 4.22 g potassium chloride (15% equimolar NaCl substitution regarding a standard product with 22 g/kg NaCl), 13.25 g potassium lactate (78% purity; PURAC bioquímica, S. A., Montmeló, Barcelona, Spain) (21% equimolar NaCl substitution regarding a standard product with 22 g/kg NaCl), 3 g white pepper, 30 g lactose, 2 g dextrose, 10 g water and 2.20 g Natplus 223 (a natural flavoring containing Swiss chard and carrot juice concentrate powder; Chr. Hansen S. L., Barcelona, Spain) as a natural source of nitrate instead of direct addition of nitrate and nitrite. Also, a microbial starter Lyocarni SBI-77 (*Staphylococcus xylosus, Staphylococcus carnosus*, *Lactobacillus sakei*) (Sacco srl, Cadorago, Italy) with nitrate reductase activity was added (0.2 g/kg). The meat mixture was stuffed into Ø 38 mm pork natural casings and dipped in a *Penicillium candidum* suspension (PC HP 6 LYO 10 D, DANISCO; Grama Aliment SL, Les Preses, Spain), which is a general practice in the industry to obtain the typical external appearance in the product. The sausages were stored in a drying room: 1 day at 15 ± 1 ºC and 90 ± 2.5% relative humidity (RH), and 2 days at 20 ± 1 ºC and 90 ± 2.5% (fermentation stage) and to allow the mould growth. Subsequently, drying was carried out at 13 ± 1 ºC and with decreasing RH from 85 % to 75% ± 2.5% until reaching a weight loss of approx 49%. Once the sausages of each batch reached the

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target final weight loss, they were packaged in polyamide-polyethylene bags with modified atmosphere (MAP; 80% N_2:20% CO_2) and stored at 3 °C for one month for moisture equalization before analysis (time = 1 month). A subsample of the sausages continued the storage at 3 ºC in MAP up to three months to evaluate the product characteristics during shelf-life (time = 3 months).

2.2. Instrumental color analysis

Instrumental color measurements were carried out with a colorimeter Konica Minolta Chroma Meter CR-400 (AQUATEKNICA, S.A., Valencia, Spain) with illuminant D65 (2° standard observer and specular component included) in the CIE-LAB space: *L**(lightness), *a**(redness) and *b**(yellowness) (Commission Internationale de l'Éclairage [CIE], 1976). Color measurements were performed on five sausages per batch and averaging eight readings on new cut surfaces per sausage.

2.3. Instrumental texture analysis

2.3.1. Texture profile analysis (TPA)

A RT/5 Universal MTS Texture Analyzer (Sistemas de Ensayo de Materiales, S.A., Barcelona, Spain) was used to perform the Texture Profile Analysis or TPA (Bourne, 1978). Specimens (15 mm height) were compressed twice to 75% of their original height. Force-time curves were recorded at a crosshead speed of 1 mm/s. The following TPA parameters were obtained: springiness, hardness (N/cm^2), cohesiveness and chewiness (N/cm^2). The mean of three specimens per sample was used for statistical analyses. Hardness values were corrected for the different sample areas and expressed as N/cm^2. Chewiness (N/cm^2) was calculated as follows: corrected hardness × cohesiveness × springiness (Bourne, 1978).

2.3.2. Stress relaxation test (SR)

Stress relaxation (SR) test was performed on all the samples with the same equipment used for the TPA test. Specimens (15 mm height) were compressed to 25% of their original height at a crosshead speed of 1 mm/s. The force versus time after the compression was recorded at 2 and 90 s (relaxation time). The relaxation curves obtained for each specimen were normalized, i.e., the force decay $Y(t)$ was calculated as follows:

$$Y_{(t)} = \frac{F_0 - F_{(t)}}{F_0},$$

Where F_0 (N) is the initial force and $F(t)$ is the force recorded after t seconds of relaxation. F_0, F_2 and F_{90} values were corrected for the different sample areas and expressed as N/cm^2. The force decay at 2 s (Y_2) and 90 s (Y_{90}) were calculated (Morales, Guerrero, Serra, & Gou, 2007). The mean of three specimens per sample was used for statistical analysis. After texture analysis the specimens were minced and vacuum-packed and kept frozen at –18 ºC for further physicochemical analysis.

2.4. Physicochemical analysis

The pH was measured in the meat mixture before stuffing, and in sausages during the drying process (3 days, 7 days and in the final product). A pH penetration electrode (Crison 52-32) on a portable pH-meter (CRISON PH 25, Crison Instruments S.A., Alella, Spain) was used. The pH of the final product was measured in a homogenized sample solution (5 g sample / 20 ml ultrapure H_2O) (Choi et al., 2009). Water activity (a_w) measurement was carried out at 25 ºC with an AquaLab Series 3 instrument (Lab-Ferrer, Cervera, Spain). After measuring a_w, the moisture content of the samples (%)

was immediately determined by drying until reaching constant weight (Association of Official Analytical Chemists [AOAC], 1990).

2.5. Sensory analysis

The generation of the descriptors for the sliced samples was carried out by open discussion in two sessions. The descriptors retained were: darkness (evaluation of the intensity of the darkness on the surface of the sample), brightness (brightness intensity evaluated on the surface of the sample), discoloration (evaluation of the intensity of discoloration due to oxidation processes in the external part of the slice), round shape (evaluation of the roundness of the slice), odor intensity (intensity of overall odor of the sample), ripened odor (pleasant odor developed by dry-cured meat products), flavor intensity (evaluation of the overall flavor intensity of the sample), sweetness (basic taste sensation elicited by sugar), saltiness (basic taste sensation elicited by NaCl), KCl bitterness (bitter taste sensation elicited by KCl), oil flavor (flavor elicited by vegetable oil), piquantness (stinging sensation in the mouth and throat), ripened flavor (pleasant flavor characteristic of dry-fermented sausages), hardness (amount of pressure required to completely compress the sample), elasticity (degree of return to the original position of the sample when a compression force is applied between molars), crumbliness (textural property characterized by ease with which a sample can be separated into smaller particles during chewing), chewiness (textural property characterized by the difficulty to break the sample into pieces in order to be swallowed) and fat mouthfeel (scoring of the perception of fat feeling during chewing). The tactile texture attribute of ease to remove the casing (degree of easiness displayed when removing the casing of the slice) was also retained. Overall sensory quality (scoring of the sensory quality of the sample by reference to the standard of quality for a product) was also assessed.

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Six trained panelists (ASTM, 1981; ISO8586-1, 1993; ISO8586-2, 1994) carried out the sensory analysis on 5 mm-thick slices of non-acid fermented sausages. A non-structured scoring scale (Amerine, Pangborn & Roessler, 1965) was used, where 0 meant absence of the descriptor and 10 meant high intensity of the descriptor. A Quantitative Descriptive analysis of sausages at 1 month and 3 months was performed in 4 sessions per storage time and replica and a complete block design was used (Steel & Torrie, 1983). Samples were coded with three-digit random numbers and were presented to the assessors balancing the first order and the carry-over effects according to MacFie, Bratchell, Greenhoff and Vallis (1989), as much as possible. Samples were wrapped in film to avoid surface drying and evaluated within 1 hour after slicing.

2.6. Statistical analyses

The analyses of variance were performed with the General Linear Model (GLM) procedure of the SAS statistical package (Statistical Analysis System [SAS], 2003). The model for the physicochemical and instrumental color and texture parameters included fat type-level, MAP storage time, replica of the experiment and their interactions as fixed effects. For the sensory attributes, the average scores of the panel for each fermented sausage were used. The model included fat type-level, MAP storage time, replica of the experiment and their interactions as fixed effects. The interactions not statistically significant ($P > 0.05$) were dropped from the models. Differences among means were tested with the Tukey test.

3. Results and discussion

3.1. Effect on physicochemical parameters

According to the 'Regulation (EC) No 1924/2006 on nutrition and health claims made on foods', the 'reduced fat' claim may only be made where the fat content reduction is at least 30%, and the 'reduced salt' claim where the reduction is a 25%, in both cases compared to a similar product. In the present study the final fat content of the BF3 (initial fat content: 9.9%; final fat content: 19.5%) and SO3 batches (initial fat: 10%; final fat: 19.6 %) represent more than 40% fat reduction in comparison to the BF20 batch (initial fat: 22.4%; final fat: 44.0%) and to a standard *fuet* (small caliber non-acid fermented sausage) with a final fat content of around 42% (Spanish Food Composition Database [BEDCA], 2007). Regarding the reduction of sodium, all the batches included 1.40% NaCl in their formulation which increased to 2.54% (after drying) in the final product. This NaCl content represents over 30% reduction with respect to the 3.68% average NaCl content in small caliber non-acid fermented sausage *fuet* type (Zurera-Cosano et al., 2011). Furthermore, no direct addition of nitrate and nitrite was included in the formulation; instead a vegetable juice concentrate was used as a natural source of nitrate (Sebranek & Bacus, 2007; Sebranek, Jackson-Davis, Myers, & Lavieri, 2012).

Least-squares means for weight loss (%), moisture (%), water activity (a_w), and pH of the final product are shown in Table 1. These parameters were not affected by the storage time. Reduced fat small caliber non-acid fermented sausage (*fuets*) containing 3.3% backfat (BF3) and those with 3% sunflower oil (SO3) did not show differences for moisture, as they included a similar initial fat content in their formulations and reached the same weight loss. *Fuets* with 20% initial backfat content (BF20) showed significantly lower moisture content and a_w values for the same weight loss than reduced fat *fuets* (BF3 and SO3), as expected. However, reduced fat *fuets* could be considered microbiologically stable products, taking into account the a_w values obtained (Vignolo & Fadda, 2007). Regarding the pH, no significant effect of the fat type-level

(20% backfat; 3.3% backfat; 3% sunflower oil) was observed among batches during the drying process (data not shown), except for the final product (pH_{final}). The pH mean values were 6.0 in the initial mixture, 5.3 at 3 days of process due to the starter effect (fermentation stage), 5.4 at 7 days of processing (initial drying stage) and continued increasing during the drying process, probably because of the effect of the K-lactate addition (Gelabert et al., 2003; Guàrdia et al, 2008) and the production of ammonia from amino acids (Grazia, Romano, Bagni, Roggiani, & Guglielmi, 1986; Lücke, 1986; Roncalés, Aguilera, Beltrán, Jaime, & Peiro, 1991). The final pH was significantly affected by the fat type-level with reduced fat *fuets*, with higher water content, showing higher pH than BF20.

3.2. Effect on instrumental color

Results for instrumental lightness (L*) (least-squares means) are shown in Table 2. Both, the fat level and the storage time had a significant effect on lightness (L*). As expected, BF20 *fuets* showed higher L* values than BF3 and SO3 reduced fat *fuets*. Several studies have reported significantly higher L* values with increasing fat level in Greek traditional sausages (Papadima & Bloukas, 1999) and *sucuk*, a Turkish traditional fermented sausage (Soyer, Ertas, & Üzümcüoglu, 2005). Concerning storage time, *fuets* showed significantly higher L* values at 3 months than at 1 month, which could be related to product discoloration but this was not confirmed in the sensory analysis. These results agree with Rubio et al. (2008) who also reported higher L* values in *salchichón* after MAP storage.

Results for instrumental redness (a*) and yellowness (b*) which were affected by the interaction fat type-level × storage time are shown in Table 3. Reduced fat *fuets* showed redder color (a*) than BF20 at 1 month storage due to their higher lean amount, as expected. Whereas BF20 sausages showed significantly higher b* values probably because of their higher lipid content (Papadima & Bloukas, 1999; Soyer et al., 2005). The SO3 *fuets* could be expected to show an increase of b* values at 3 months, due to the higher unsaturated fatty acids content of sunflower oil, which would make them prone to color changes because of oxidation (Jiménez-Colmenero, 2007). Nevertheless, SO3 *fuets* showed similar values than BF20 *fuets*. Similarly, Muguerza et al. (2003) reported that yellowness was not significantly affected by soy oil addition (15, 20 and 25% pork fat substitution) in *chorizo de Pamplona*, which could be explained by the antioxidant effect of vitamin E in the oil used.

3.3. Effect on instrumental texture

Table 2 shows the results (least-squares means) for the parameters of the Texture Profile Analysis (TPA) and the Stress Relaxation (SR) tests which were not affected by interactions (i.e.: springiness in TPA test, and Y_2 and Y_{90} in SR test). The rest of parameters affected by the interaction fat type-level × storage time are shown in Table 3. The BF20 *fuets* (20% backfat) were significantly harder showing higher TPA hardness and F_0 (SR test initial force) than reduced fat *fuets* at 1 month of storage (Table 3). The higher hardness in BF20 in comparison with reduced fat *fuets* was attributed to their lower water content, which conferred them higher hardness. According to several studies (Ruiz-Ramírez, Arnau, Serra, & Gou, 2005; Serra, Ruiz-Ramírez, Arnau & Gou, 2005) lower water contents increase hardness in dry-cured meat products. Similarly, Muguerza et al. (2001) reported lower TPA hardness in *chorizo de Pamplona* with 20, 25 and 30% substitution of pork backfat by olive oil, which showed higher water content than the control without fat reduction. In contrast, TPA hardness and SR initial force (F_0) decreased in BF20 *fuets* at 3 months, whereas no significant differences for these parameters were observed in reduced fat *fuets*. Fat reduction increased cohesiveness significantly, with SO3 *fuets* showing the highest values followed by BF3 and BF20. Muguerza et al. (2001) also reported higher cohesiveness in fat-reduced *chorizo de Pamplona* with 25 and 30% substitution of pork backfat by olive oil. Sunflower oil has been also reported to increase cohesiveness in dry-fermented sausages (Mora-Gallego et al., 2013). SO3 *fuets* showed the highest springiness (Table 2), although fat reduction decreased springiness in BF3 *fuets* with respect to BF20. Mendoza et al. (2001) reported lower springiness in dry-fermented sausages with 6.3 % fat with respect to 12.5 and 25% fat. Springiness showed a significant increase at 3 months of MAP storage time. Similar results were reported by Rubio et al. (2007), who found that springiness increased during 150 days of MAP storage time (20% CO_2 / 80% N_2) in *salchichón*. SO3 and BF20 *fuets* showed higher chewiness than BF3 *fuets* at 1 month. Increases of TPA chewiness with the fat reduction have been previously reported by some authors (Olivares et al., 2010; Salazar, García, & Selgas, 2009). Chewiness is related to hardness, as it is the product of hardness, cohesiveness and springiness (Bourne, 1978). Taking this into account, it could be expected that BF20 *fuets* would show higher chewiness than the rest because of their higher hardness. Nevertheless, SO3 *fuets* showed a slightly higher chewiness value. It could be that the higher cohesiveness and springiness of SO3 led these *fuets* to reach higher chewiness values. Chewiness decreased significantly in all batches after 3 months storage. In the SR test, the force decay at 2 s (Y_2) and at 90 s (Y_{90}) decreased with the fat reduction and increasing storage time. Y_{90} showed differences depending on the type of added fat in reduced fat *fuets*, being higher in SO3 than in BF3. Lower F_0 values and higher Y_2 and Y_{90} values have been related to soft texture in dry-cured ham, i.e. higher softness

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(Morales et al., 2007). Nevertheless, in our study the hardest BF20 *fuets* also showed the highest Y_2 and Y_{90}.

3.4. Effect on the sensory attributes

Table 4 shows the results for the effect of the fat type-level on the sensory attributes of small caliber non-acid fermented sausages (*fuets*) irrespective of the storage time. The storage time effect (1 month vs. 3 months) is not shown because most sensory attributes were not significantly affected by storage time. Regarding the slice appearance, the batches containing 3% sunflower oil (SO3) were significantly darker than the 20% backfat batch (BF20), with 3.3% backfat (BF3) showing intermediate values, all in agreement with instrumental lightness (L*) values (Table 2). Darker dry-fermented sausages were also obtained with fat reduction by Mendoza et al. (2001), Olivares, Navarro, Salvador, & Flores (2010) and Mora-Gallego et al. (2013). The BF20 *fuets* were scored with the highest brightness followed by SO3 and BF3 *fuets*. The higher brightness in SO3 with respect to BF3, despite having a similar fat content, is probably due to the oil exudation in sausages with vegetable oil (with lower melting point) in their formulation (Bloukas, Paneras, & Fournitzis, 1997; Mora-Gallego et al., 2013). No discoloration differences were observed among batches. Regarding the slice shape, the control batch (BF20) was rated rounder than the reduced fat batches, because the higher fat content slows the drying rate and results in sausages with fewer wrinkles (Wirth, 1988). Fat has an important role as a solvent for aroma compounds in dry-fermented sausages (Leland, 1997). Although several authors have reported lower aroma scores in dry-fermented sausages with fat reduction (Mendoza et al., 2001; Olivares et al., 2010), no significant differences were observed for odor intensity between BF20 and the reduced fat *fuets*. Furthermore, SO3 *fuets* obtained higher odor intensity scores than

BF3 fuets, which agrees with the results reported by Mora-Gallego et al. (2013) in reduced fat non-acid fermented sausages with 5% sunflower oil with respect to 5% backfat. Regarding flavor, BF20 *fuets* obtained higher flavor intensity and ripened flavor scores than BF3 batch. It could be expected that reduced fat products were lower-rated for flavor attributes, concerning the important role of fat in the balance, intensity and release of flavor in meat products (Hughes, Cofrades, & Troy, 1997). In dry-fermented sausages, lipids are hydrolyzed by lipases with production of free fatty acids (Countron-Gambotti & Gandemer, 1999; Gandemer, 2002), which are susceptible to oxidation reactions that result in the release of volatile compounds (Zanardi, Ghidini, Battaglia, & Chizzolini, 2004). Vegetable oils, such as sunflower oil, contain higher percentage of polyunsaturated fatty acids (PUFAs) than pork backfat. These PUFAs contribute to increase autoxidation in dry-fermented sausages (Ansorena & Astiasarán, 2004) and, therefore, to the release of volatile compounds that could increase the flavor intensity and ripened flavor in SO3 *fuets* to a similar level than the standard fat BF20 *fuets*. Ripened odor and ripened flavor scores increased significantly with the storage time (+0.4 and +0.6, respectively, data not shown). The bitterness associated to KCl increased significantly with fat reduction. When fat is substituted by lean, the salty flavor associated to NaCl is perceived more because there is higher water to salt ratio (Wirth, 1988). Similarly, as the *fuets* included a mixture of NaCl and KCl, the bitterness associated to KCl would be more intensely perceived in the reduced fat *fuets*, which also would be favored by the lower mouth coating effect of fat (lower fat mouthfeel). Oil flavor was higher in SO3 than in BF3 batches, as expected. Nevertheless, no differences for oil flavor were found between SO3 and BF20 batches. The BF20 *fuets* had to lose a higher amount of water than the reduced fat *fuets* to achieve the same weight loss. The decrease in water content can break adipocyte membranes causing fat

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exudation (Arnau & Gou, 2001; Ten Cate, 1969). This fat would melt at mouth temperature (≈37 ºC), as pork backfat melting point is between +30 ºC and +40 ºC (Ospina-E et al., 2010; Suzuki et al., 2003), conferring to BF20 a similar oil flavor than SO3 *fuets*. This fat exudation would also be responsible for the higher brightness of the slice in BF20 *fuets*. Regarding the texture in mouth, BF20 *fuets* obtained the highest hardness score (in agreement with TPA hardness and the SR test initial force: F_0), followed by BF3 and SO3 *fuets*. Among reduced fat batches, BF3 *fuets* were rated harder than SO3 *fuets*, which agrees with previous results by Mora-Gallego et al. (2013) in fermented sausages with 5% pork backfat which were rated harder than those containing 5% sunflower oil. Likewise, Muguerza et al. (2001) and Muguerza, Ansorena, & Astiasarán (2003) found higher hardness values in *chorizo de Pamplona* elaborated with pre-emulsified olive oil (20, 25 and 30% fat substitution) and the same product elaborated with soy oil (20% substitution). The reduced fat BF3 and SO3 *fuets* obtained significantly higher elasticity scores than BF20 *fuets*. On the contrary, BF20 showed higher TPA springiness than BF3. The TPA springiness has been related to the attribute elasticity used in sensory analysis (Szczesniak, 1963). The increase in elasticity and decrease in TPA springiness with fat reduction have been previously reported in reduced fat fermented sausages (Mora-Gallego et al., 2013). These differences have been attributed to the different way to obtain both measurements: TPA springiness is a direct measurement in the texture analyzer, whereas elasticity is a sensory attribute of multiparametric nature perceived in the mouth. The SO3 and BF20 *fuets* were rated more crumbly than BF3 *fuets*. The sunflower oil added as liquid in SO3 *fuets* and the exudated fat in BF20 *fuets* (both melting at mouth temperature) would reduce the binding among meat particles. In this sense, Bloukas et al. (1997) reported oil exudation in reduced fat dry-fermented sausages with olive oil as fat substitute, which could indicate lower binding with meat particles than pork fat. The SO3 *fuets* obtained the lowest score for chewiness, showing that differences for chewiness would depend more on the type of fat than the fat level. As expected BF20 *fuets* obtained higher fat mouthfeel scores. Concerning tactile texture, BF20 *fuets* showed the higher easiness to remove the casing from the sausage surface (ease to peel, Table 4) followed by SO3 and finally BF3 *fuets*, in agreement with previous results (Mora-Gallego et al., 2013). Fat and oil exudation would cause casing separation from the meat particles (Bloukas et al., 1997). The *fuets* after 3 months of storage showed significantly higher ease to peel scores than at 1 month (7.3 vs. 6.3, data not shown) probably due to fat exudation during storage as a result of the lipolytic activity (Soyer & Ertas, 2007), and also to the water content homogenization which would reduce hardness in the surface leading to easier casing separation. Finally, it is interesting to note that no significant differences were observed for the attribute overall sensory quality.

4. Conclusions

Reduced sodium small caliber non-acid fermented sausages (*fuets*) with reduced fat content (20%) and with acceptable sensory characteristics can be obtained by adding to the shoulder lean (8% fat content) during the grinding either 3.3% backfat (3% fat content) or 3% sunflower oil, both previously finely comminuted with lean. In addition, sunflower oil is confirmed to be suitable for partial pork backfat substitution in very lean fermented sausages, conferring desirable sensory properties similar to those of sausages with standard fat content. The sensory quality of the reduced sodium and fat small caliber non-acid fermented sausages (*fuets*) was maintained after three-month storage in modified atmosphere at +3ºC. A current consumer study will evaluate the acceptability of small caliber non-acid fermented sausages with reduced fat and sodium contents.

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Table

Table 1
Physicochemical parameters (least-squares means) of small caliber non-acid fermented sausages (*fuet*) with reduced NaCl content according to the fat type-level.

	Backfat 20% (BF20)	Backfat 3.3% (BF3)	Sunflower oil 3% (SO3)	RMSE[A]
n [B]	*20*	*20*	*20*	
Weight loss (%)	49.05	48.90	49.02	0.422
Moisture (%)	26.24[b]	41.16[a]	41.21[a]	1.149
a_w	0.816[b]	0.907[a]	0.901[a]	0.0094
pH_{final}	5.75[c]	6.50[a]	6.37[b]	0.151

[abc]Within row, least-squares means with a common letter are not significantly different ($P > 0.05$).
[A] Root mean square error of the linear model.
[B] n= 5 samples × 2 storage time × 2 replicates = 20.

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Table 2
Instrumental color and texture parameters (least-squares means) of small caliber non-acid fermented sausages (*fuet*) with reduced NaCl content according to the fat type-level and the storage time.

	Fat type-level			Storage time		
	Backfat 20% (BF20)	Backfat 3.3% (BF3)	Sunflower oil 3% (SO3)	1 month	3 months	RMSE[A]
n [B]	*20*	*20*	*20*	*30*	*30*	
Color CIE-Lab						
Lightness (L*)	45.4[a]	40.3[b]	38.7[c]	40.8[b]	41.2[a]	1.66
TPA test [C]						
Springiness	0.243[b]	0.208[c]	0.260[a]	0.228[b]	0.246[a]	0.0146
SR test [D]						
Y_2 [E]	0.410[a]	0.381[b]	0.386[b]	0.397[a]	0.388[b]	0.0066
Y_{90} [F]	0.688[a]	0.650[c]	0.657[b]	0.674[a]	0.656[b]	0.0061

[abc]Within row, least-squares means with a common letter are not significantly different ($P > 0.05$).
[A] Root mean square error of the linear model.
[B] n= 5 samples × 2 storage time × 2 replicates = 20; n= 5 samples × 3 fat type-level × 2 replicates = 30.
[C] Texture Profile Analysis.
[D] Stress Relaxation.
[E] Force decay at 2 s.
[F] Force decay at 90 s.

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Table 3
Instrumental color and texture parameters (least-squares means) of small caliber non-acid fermented sausages (*fuet*) with reduced NaCl content according to the interaction fat type-level × storage time.

	Backfat 20% (BF20)		Backfat 3.3% (BF3)		Sunflower oil 3% (SO3)		
	1 month	3 months	1 month	3 months	1 month	3 months	RMSE[A]
n [B]	*10*	*10*	*10*	*10*	*10*	*10*	
Color CIE-Lab							
Redness (a*)	10.6[d]	11.2[cd]	12.7[a]	11.8[bc]	12.3[ab]	11.2[cd]	0.61
Yellowness (b*)	1.66[ab]	2.14[a]	1.63[b]	1.36[b]	1.22[b]	1.22[b]	0.38
TPA test [C]							
Hardness (N/cm^2)	208.1[a]	155.7[b]	157.6[b]	149.4[b]	149.5[b]	145.4[b]	22.76
Cohesiveness	0.13[c]	0.13[c]	0.16[b]	0.19[a]	0.19[a]	0.18[a]	0.014
Chewiness (N/cm^2)	24.0[a]	5.1[c]	18.4[b]	6.6[c]	24.2[a]	7.4[c]	2.35
SR test [D]							
F_0 (N/cm^2) [E]	28.6[a]	21.1[b]	11.1[cd]	9.1[d]	11.8[c]	9.8[cd]	1.97

[abcd]Within row, least-squares means with a common letter are not significantly different ($P > 0.05$).
[A] Root mean square error of the linear model.
[B] n= 5 samples × 2 replicates = 10.
[C] Texture Profile Analysis.
[D] Stress Relaxation.
[E] Initial force.

Table 4
Effect of the fat type-level on the sensory attributes (least-squares means) of small caliber non-acid fermented sausages (*fuet*) with reduced NaCl content, irrespective of the storage time ($P > 0.05$).

Attributes[A]	Backfat 20% (BF20)	Backfat 3.3% (BF3)	Sunflower oil 3% (SO3)	RMSE[B]
n [C]	*16*	*16*	*16*	
Slice appearance				
Darkness	5.8[b]	6.1[ab]	6.3[a]	0.88
Brightness	5.4[a]	3.2[c]	4.1[b]	1.85
Discoloration	1.3	1.7	1.6	2.05
Round shape	7.4[a]	3.8[c]	4.2[b]	0.98
Odor				
Intensity	5.6[ab]	5.5[b]	5.9[a]	1.11
Ripened	4.7	4.4	4.7	1.35
Taste/Flavor				
Intensity	6.4[a]	5.9[b]	6.1[ab]	1.27
Sweetness	2.2	2.0	1.8	1.36
Saltiness	2.7	2.7	2.8	1.47
Bitterness (KCl)	1.0[c]	1.5[b]	1.8[a]	1.12
Oil	0.6[a]	0.0[b]	0.6[a]	0.95
Piquantness	2.9[b]	3.4[ab]	3.6[a]	1.39
Ripened	5.0[a]	4.2[b]	4.6[ab]	1.62
Texture in mouth				
Elasticity	0.8[c]	2.2[a]	1.4[b]	1.20
Hardness	4.5[a]	4.1[b]	3.6[c]	1.16
Crumbliness	6.4[a]	5.6[b]	6.6[a]	0.95
Chewiness	3.8[a]	3.9[a]	3.1[b]	1.06
Fat mouthfeel	4.0[a]	2.1[b]	2.0[b]	1.88
Tactile texture				
Ease to peel	8.1[a]	5.4[c]	6.8[b]	1.19
General				
Overall sensory quality	6.3	6.0	6.2	0.96

[abc]Within row, least-squares means with a common letter are not significantly different ($P > 0.05$).
[A] Non-structured scoring scale (0= absence and 10= high intensity of the descriptor).
[B] Root mean square error of the linear model.
[C] n= 4 samples × 2 storage time × 2 replicates = 16.

Highlights

Fat reduction in reduced NaCl small caliber non-acid fermented sausages was evaluated

Sausages with reduced final fat content from 44% to 20% showed good sensory quality

Sausages with partial fat substitution (3% sunflower oil) showed good sensory quality

Sensory quality of reduced NaCl and fat sausages maintained after 3-month MAP storage

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