Title: Sensory characterisation and consumer acceptability of KCl and sunflower oil addition in small-calibre non-acid fermented sausages with a reduced content of NaCl and fat.

Article Type: Research Article

Keywords: Fat reduction, Salt reduction, Fermented sausages, Sensory attributes, Acceptability.

Abstract: The effect of the simultaneous reduction of fat (from 20% to 10% and 7%) and salt (from 2.5% to 1.5%) and the addition of 0.64% KCl and sunflower oil (1.5% and 3.0%) on the physicochemical, instrumental colour and texture, sensory properties and consumer acceptability of small calibre non-acid fermented sausages (fuet type) was studied. This simultaneous reduction increased weight loss, % of moisture, aw, redness (a*), instrumental texture parameters (hardness, chewiness and cohesiveness) and sensory attributes (darkness, hardness, elasticity) but did not significantly affect the consumer acceptability. The addition of 0.64% KCl to the leanest batches decreased the aw and barely affected instrumental texture parameters and consumer acceptability. Sunflower oil addition decreased hardness, chewiness and cohesiveness and increased crumbliness, but it may have negatively affected the consumer acceptability. The simultaneous reduction of fat and NaCl with the addition of 0.64% KCl was the preferred option by the consumers.
Sensory characterisation and consumer acceptability of KCl and sunflower oil addition in small-calibre non-acid fermented sausages with a reduced content of NaCl and fat.

Héctor Mora-Gallego, Maria Dolors Guàrdia*, Xavier Serra, Pere Gou, Jacint Arnau

IRTA. XaRTA, Food Technology, Finca Camps i Armet, s/n, E-17121, Monells, Girona (Spain).

* Corresponding author. Tel.: +34 902 789 449; fax: +34 972 630 980.
E-mail address: dolors.guardia@irta.cat (M. Dolors Guàrdia).

ABSTRACT

The effect of the simultaneous reduction of fat (from 20% to 10% and 7%) and salt (from 2.5% to 1.5%) and the addition of 0.64% KCl and sunflower oil (1.5% and 3.0%) on the physicochemical, instrumental colour and texture, sensory properties and consumer acceptability of small calibre non-acid fermented sausages (fuet type) was studied.

This simultaneous reduction increased weight loss, % of moisture, \( a_w \), redness (\( a^* \)), instrumental texture parameters (hardness, chewiness and cohesiveness) and sensory attributes (darkness, hardness, elasticity) but did not significantly affect the consumer acceptability. The addition of 0.64% KCl to the leanest batches decreased the \( a_w \) and barely affected instrumental texture parameters and consumer acceptability. Sunflower oil addition decreased hardness, chewiness and cohesiveness and increased crumbliness, but it may have negatively affected the consumer acceptability. The simultaneous
reduction of fat and NaCl with the addition of 0.64% KCl was the preferred option by
the consumers.

Keywords: Fat reduction, Salt reduction, Fermented sausages, Sensory attributes,
Acceptability.

1. Introduction

Dry-fermented sausages are meat products with a high-fat and sodium content. From a
physiological approach, fat is a source of vitamins and essential fatty acids and
constitutes the most concentrated source of energy in the diet (9.1 kcal/g). However, a
high-fat intake is related to obesity, high levels of cholesterol and coronary heart
diseases. For this reason, health organisations all over the world have promoted
lowering the intake of total fat as a mean of preventing heart disease (AHA, 1986;
Department of Health, 1994; NCEP, 1988). Likewise, worldwide sodium intake is
higher than the recommended level (EFSA, 2005). Excessive fat and sodium intake has
been linked to cardiovascular diseases including hypertension, stroke, and coronary
Law, 1997). Based on this scientific information, consumers and the meat industry have
become more aware of the benefits of healthier diets with reduced amounts of fat and
salt.

Reducing fat is a complex issue in meat products, especially in dry-fermented sausages,
as it affects important technological functions conferred by fat, such as the control of
water release during drying (Wirth, 1988), and sensory attributes, i.e., flavour and
texture (Bloukas, Paneras & Fournitzis, 1997; Mendoza, García, Casas & Selgas, 2001).
Several studies have shown that pork fat can be reduced and substituted with vegetable
oils, such as olive, sunflower, soy, and linseed oils, in fermented sausages while still obtaining adequate technological characteristics and acceptable sensory ratings (Del Nobile, Severini, De Pilli & Baiano, 2009; Mora-Gallego et al., 2013; Mora-Gallego et al., 2014; Muguerza, Ansoarena & Astiasarán, 2003; Olivares, Navarro, Salvador and Flores, 2010; Pelser, Linssen, Legger, & Houben, 2007).

In contrast, NaCl is an essential ingredient in processed meat products, contributing to the water-holding capacity, colour, fat binding properties and flavour (Guàrdia, Guerrero, Gelabert, Gou & Arnau, 2008). Potassium chloride (KCl) has similar functional properties to NaCl but has a different sorption isotherm than NaCl (Comaposada, Arnau & Gou, 2007), and its addition to meat products is limited by its bitter taste. Nevertheless, it has been demonstrated that a reduction in NaCl and its partial substitution by KCl is possible in fermented sausages from a technological and sensory point of view (Gelabert, Gou, Guerrero & Arnau, 2003; Gou, Guerrero, Gelabert & Arnau, 1996; Guàrdia et al., 2008).

The aim of this study was to evaluate the effect of the simultaneous reduction of fat and salt and the addition of KCl and sunflower oil to the quality and consumer acceptability of small-caliber non-acid fermented sausages.

2. Materials and methods

2.1. Sausage preparation and drying

A total of seven batches of small-caliber non-acid fermented sausages (fuet type) were prepared using two different raw materials commonly used in the meat industry for fuet production (pork-lean trimmings and pork-shoulder lean). Pork-lean trimmings were composed of fresh boneless pork ham trimmings and fresh boneless pork shoulder.
trimmings, which were weighed in appropriate amounts to achieve a lean:fat proportion of 90:10 or 80:20 depending on the target chemical fat level composition.

A control batch (CT) with 2.5% NaCl was prepared with pork-lean trimmings at a ratio of 80:20 (lean:fat). The other six batches were prepared with 1.5% NaCl and with or without the addition of KCl (0.64% KCl, equivalent to equimolar substitution of 0.5% NaCl) and with or without the addition of sunflower oil, as described below. Two of the batches were prepared with pork-lean trimmings (90:10) without the addition of KCl (batch L) and with the addition of KCl (batch L-KCl). The remaining four batches were prepared with pork-shoulder lean (7±1% of fat) without the addition of KCl (batch S), with KCl (batch S-KCl), with KCl and 1.5% sunflower oil (batch S-KCl-1.5SO) and with KCl and 3% sunflower oil (batch S-KCl-3SO).

The experimental design was intended to test the effects of the raw material, the addition of KCl and the addition of sunflower oil. The chosen sunflower oil was Borgesol because of its neutral flavour (Borges Mediterranean Group, S. L. U., Reus, Tarragona, Spain). Two replicates of the experiment were carried out. For each replicate, the lean trimmings and shoulder from 12 animals were purchased at a local supplier. Each type of raw material was roughly minced (5 cm) and homogenised. Mixtures of 15 kg/batch were prepared. The meat was minced through a 5 mm plate, and the sunflower oil was added directly to the mixer. The following additives were added per kilogram of the meat and fat mixture: 25 g of NaCl (CT batch), 15 g of NaCl (the rest of the batches), 6.4 g of KCl (for batches with KCl), 2 g of black pepper, 3 g of dextrose, 0.15 g of sodium nitrite and 0.15 g of potassium nitrate. Microbial starter Lyocarni SBI-77 (Staphylococcus xylosus, Staphylococcus carnosus, Lactobacillus sakei) (Sacco srl, Cadorago, Italy) was added (0.2 g/kg). The mixtures were mixed for 3 minutes at 0 ºC using a mixer (model 35P, Tecnotrip S.A., Terrassa, Spain). The initial
water and fat content in the raw meat mixtures (before stuffing) for each batch were estimated by near infrared spectroscopy (Association of Official Analytical Chemists [AOAC], 2007) using a FoodScan™ Lab (Foss Analytical, Denmark). The _fuets_ were stuffed with a vacuum stuffer into Ø 38 mm natural pork casings, immersed in a water bath containing a suspension of _Penicillium candidum_, and then hung and stored at 3 °C for 24 h. Thereafter, _fuets_ were dried under the following conditions: 7 days at 14-16 °C and 80-85% relative humidity (RH) until the _fuets_ were covered with mould, and then, at 12-14 °C and 70-75% RH until the end of the drying. When the batch with the highest drying rate, i.e., the L batch, achieved an optimal level of dryness according to the external appearance and tactile texture of the sausages, the final water content on a defatted-desalted-dry-matter basis (X_{DFDSMD}) was estimated from the initial composition of each raw material mixture and the weight loss of the sausages. The same X_{DFDSMD} was defined as reached by all seven batches. Consequently, a specific weight loss for each batch was established. The pH was measured in _fuets_ during the drying process (1 day and 7 days). A penetration electrode (Crison 52-32) on a portable pH-meter (CRISON PH25, Crison Instruments S.A., Alella, Spain) was used. Once the sausages of each batch reached the specific final weight loss, they were packaged in polyamide-polyethylene bags (Combivac 90, Sistemes d’Empalatge, Aiguaviva, Girona) with modified atmosphere (80% N₂:20% CO₂) and stored at 3 °C for one month before analysis.

2.2. _Instrumental colour analysis_

Instrumental colour 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). Colour measurements were performed on five sausages per batch and replicate, and an average of eight readings were obtained on new cut surfaces per sausage.

2.3. Texture profile analysis (TPA)

A RT/5 Universal MTS Texture Analyser (Sistemas de Ensayo de Materiales, Barcelona, Spain) was used to perform the Texture Profile Analysis or TPA (Bourne, 1978) on 5 *fuets* per batch and replicate. Specimens (15-mm height) were compressed twice to 75% of their original height. Force-time curves were recorded at a cross-head speed of 1 mm/s. The following TPA parameters were obtained: springiness, hardness (N/cm\(^2\)), cohesiveness and chewiness (N/cm\(^2\)). The average of three specimens per sample (*fuet*) 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 \( \times \) cohesiveness \( \times \) springiness (Bourne, 1978). After TPA analysis, the specimens were minced and vacuum-packed and kept frozen at \(-18\pm2\)ºC for further physicochemical analysis.

2.4. Physicochemical analysis

Frozen samples from the TPA analysis were thawed before physicochemical characterisation. The pH of the final product was measured in a homogenised sample solution (5 g of sample /20 ml of ultrapure H\(_2\)O) (Choi et al., 2009). Water activity \( (a_w) \) measurement was carried out at 25º C with an AquaLabSeries 3 instrument (Lab-Ferrer, Cervera, Spain). After measuring \( a_w \), the moisture content of the samples was immediately determined by drying at 103 ± 2 ºC to constant weight (Association of
149 Official Analytical Chemists [AOAC], 1990). The water content of the samples on a
defatted-desalted-dry-matter (X_{DFDSDM}) basis was also calculated from the chemical
composition of each batch (X_{DFDSDM}=kg \text{H}_2\text{O}/(kg \text{dry matter}-kg \text{fat}-kg \text{NaCl}-kg \text{KCl})).
152 Total fat content was determined by Soxhlet extraction (International Organisation for
154
155 2.5. Sensory analysis
156 The generation of the descriptors for the sliced samples of fuet was carried out by open
discussion in one session. The retained descriptors are shown in Table 1.
158 Six trained panellists (ASTM, 1981; ISO8586-1, 1993; ISO8586-2, 1994) carried out
the sensory analysis on 5 mm-thick slices of dry-fermented sausages (1 fuet per batch
and session). A non-structured scoring scale (Amerine, Pangborn & Roessler, 1965) was
161 used, where 0 meant the absence of the descriptor and 10 meant a high intensity of the
descriptor. A Quantitative Descriptive Analysis was performed in 8 sessions per
163 replicate, and an incomplete block design (4 batches per session) was applied (Steel &
Torrie, 1983). The KCl-1.5SO batch was tasted in all sessions as a common batch.
165 Samples were coded with three-digit random numbers and were presented to the
assessors while balancing the first order and the carry-over effects according to MacFie,
167 Bratchell, Greenhoff & Vallis (1989) as much as possible.
168
169 2.6. Consumer survey on acceptability
170 Eighty-four Spanish consumers not involved in the study and representing different
socio-demographic levels evaluated the acceptability of the seven different batches of
fuet following a complete block design. A non-structured scoring scale (0 = extremely
disliked and 10 = extremely liked) was used. The samples were codified with three
random numbers and presented to the consumers with the first order and carry over effects blocked (MacFie et al., 1989). No information about the products (the reduced fat and salt content) was provided to the consumers. Consumers evaluated 5 mm-thick slices at home, and instructions were included on the questionnaire regarding the use of water for rinsing the mouth between samples and testing them at room temperature.

2.7. 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 parameters included replicate and batch as fixed effects. The model for the instrumental colour and texture parameters included replicate and batch as fixed effects and the covariate water content on a defatted-desalted-dry-matter basis ($X_{\text{DFDSMD}}$). For the sensory attributes, the average scores of the panel for each fermented sausage were used. The model included the replicate, batch and sensory session as fixed effects and $X_{\text{DFDSMD}}$ as a covariate.

The acceptance rating of each consumer was standardised to block idiosyncratic use of the scoring scale. The statistical model for the consumer acceptability study included the replicate, the batch, the age, the gender, the place of residence and the education level of participants as fixed effects, and the different individuals as a random effect. Differences among means were tested with the Tukey test ($P<0.05$).

3. Results and discussion

3.1. Physicochemical analyses

‘Regulation (EC) No 1924/2006 on nutrition and health claims made on foods’ indicates that the ‘reduced fat’ claim may only be made when the fat content reduction
is at least 30%, and the ‘reduced salt’ claim may only be when the reduction is a 25%.

In the present study, the final fat content for the control (CT) was 33.22%, which is
lower than the standard *fuet* (small caliber non-acid fermented sausage with a final fat
content of approximately 42%) (Spanish Food Composition Database [BEDCA], 2007.
The fat content achieved in all of the reduced fat batches (18.56% for L, 15.09% for S,
17.43% for L-KCl, 12.96% for S-KCl, 16.44% for S-KCl-1.5SO and 16.34% for S-KCl-3SO) allows the claim ‘reduced fat content’, which represent a reduction between 55%
and 69% compared to a standard *fuet*. Regarding the NaCl reduction, all of the batches
were prepared with a 40% reduction when compared to the CT batch (1.5% compared
to 2.5%). After drying, the sodium content increased up to 1.13% - 1.21% in the final
product. This sodium content represents a reduction of between 16% and 22% with
respect to the 1.45% average sodium content in *fuet* (AESAN, 2009; Zurera-Cosano et
al., 2011) and therefore although an important reduction was obtained, the ‘reduced
sodium’ claim was not applicable.

Least-squares means for weight loss, moisture, water content on a defatted-desalted-dry-
matter basis (X<sub>DFDSDM</sub>), water activity (aw), and pH of the final product (pH<sub>final</sub>) are
shown in Table 2. The control batch (CT) showed the lowest weight loss and moisture
content due to its higher fat content, as expected. Despite having established a common
target X<sub>DFDSDM</sub> for all of the batches, the batches showed slight differences in this
parameter. To correct for these differences, X<sub>DFDSDM</sub> was included as a covariate in the
statistical analysis of instrumental colour and texture and for the sensory analysis. The
simultaneous reduction of salt (from 2.5% to 1.5%) and fat (from 33.22% to 18.56%)
resulted in a significant increase in the weight loss, moisture content and aw (Table 3; L
vs CT batches). The reduction of fat from 18.56% (L batch) to 15.09% (S batch) also
resulted in a slight increase in the weight loss, % moisture and aw. However, the
addition of 0.64% KCl to L or S batches decreased the a\textsubscript{w} to values closer to those of the CT batch. Comaposada et al. (2007) found that in minced meat products and dry-cured ham, NaCl can be substituted for KCl at molar levels of 30% and 35%, respectively, without important effects on isotherms and on the drying kinetics of the product. The final a\textsubscript{w} of batches containing sunflower oil were not significantly different from the control batch. However, the addition of sunflower oil (S-KCl vs S-KCL-1.5SO and S-KCL-3SO batches) decreased the moisture (%). This result may be related to the fact that oil can cover the meat particles, causing a slower release of water during the drying process (Bloukas, et al. 1997).

3.2. Instrumental colour analysis

The results for instrumental colour parameters (least-squares means) are shown in Table 3. The control batch (CT) showed the highest lightness (L\textsuperscript{*}), as expected, due to its higher fat content (lean trimmings 80:20), which gave these sausages a higher visible white colour. This result agrees with those reported by Mora-Gallego et al. (2013) in fat-reduced non-acid fermented sausages containing 5% backfat and diacylglycerols compared to those containing 5% sunflower oil or no added fat. The simultaneous reduction of salt (from 2.5% to 1.5%) and fat (from 33.22% to 18.56%) resulted in a significant decrease of lightness (L\textsuperscript{*}) and an increase in redness a\textsuperscript{*} (Table 5; L vs CT batch). The use of the shoulder (S batch) instead of lean trimmings (L batch) as a raw material resulted in a significant decrease in the redness (a\textsuperscript{*}). This is probably explained by the anatomical origin of the lean trimmings, i.e., redder muscles. The addition of 0.64% KCl or sunflower oil (1.5% and 3%) to the S batch did not significantly modify the instrumental colour parameters. However, the yellowness of the S-KCl batches tended to increase with the addition of sunflower, as they were not
significantly different from the yellowness of control batch when 3% sunflower oil was added.

3.3. Texture Profile Analysis (TPA)

Hardness, chewiness and cohesiveness increased with the simultaneous reduction of salt and fat (L, S batches in comparison with the control batch) (Table 3). Increases in hardness and chewiness have been previously reported by several authors when reducing the fat content in fermented sausages (Olivares et al., 2010; Salazar, García, & Selgas, 2009). Increases in cohesiveness associated with the fat reduction have been reported in fueto with 3% pork backfat and 3% sunflower oil (Mora-Gallego, Serra, Guàrdia & Arnau, 2014) and in chorizo de Pamplona with substitutions of 25% and 30% of pork backfat with emulsified olive oil (Muguerza, Gimeno, Ansorena, Bloukas, & Astiasarán, 2001).

According to Ruusunen & Puolanne (2005), salt favours gel formation in fermented sausages and leads to a desirable texture. In salami-type fermented sausage, a decrease in the NaCl from 2.5% to 2.25% resulted in less firm sausages (Petäjä, Kukkonen & Puolanne, 1985). In our study, this effect was not appreciable, most likely because the effect of the fat reduction had a higher impact on the texture properties than the salt reduction.

Regarding the influence of the water content on the instrumental texture, the covariate water content on a defatted-desalted-dry-matter basis ($X_{DFDSDM}$) was significant for hardness ($\beta = -205.6$ (N/cm$^2$)). Klettner and Roedel (1979) showed, in similar meat products, that the water loss during the drying process affects the final texture.

The addition of 0.64% KCl barely modified the texture parameters. There was only a significant increase in chewiness in the leanest batch (S) (Table 3; LKCl batch).
Although KCl has been associated with increased hardness and cohesiveness (Vignolo, Pesce de Ruiz & Oliver, 1988), the addition of 0.64% KCl may have not been high enough to produce a significant increase.

The addition of sunflower oil to the KCl batch (S-KCL-1.5SO and S-KCL-3SO) decreased the hardness, chewiness and cohesiveness. Decreases in hardness with the addition of olive oil or sunflower oil have been previously reported in fermented sausages (Del Nobile et al., 2009; Mora-Gallego et al., 2013). Thus, reduced fat *fuets* with instrumental hardness and chewiness closer to a commercial product, such as the CT batch, can be obtained by the addition of 3% sunflower oil. Batches with sunflower oil showed the highest springiness values, although they were not significantly different from the CT and S-KCl batches. Mora-Gallego et al. (2014) also reported higher springiness in reduced fat fermented sausages with 3% sunflower oil with respect to sausages with 3% pork backfat.

3.4. Sensory analysis

The results for the sensory attributes (least-squares means) are shown in Table 4. The simultaneous reduction of salt (from 2.5% to 1.5%) and fat (from 33.22% to 18.56%) significantly increased the darkness, hardness and elasticity and decreased the crumbliness and fat mouthfeel (CT vs L batches). The fat mouthfeel was rated significantly higher in the CT *fuets* than in reduced fat *fuets*, as expected. The CT batch was expected to be rated more salty because of its higher NaCl content. In addition, the increase in the meat protein content (i.e., the increase in the lean content, L vs. S batches) was expected to reduce perceived saltiness. However, no significant differences were observed for saltiness among batches.
The increase in the darkness of reduced fat fuets agrees with the higher instrumental lightness of the CT batch, as lightness is related to the greater presence of white fat particles due to higher fat content (Mora-Gallego et al., 2013). A decrease of colour intensity with increasing fat levels was also reported by Muguerza, Ansorena & Astiasarán (2003) in chorizo de Pamplona with 15%, 20% and 25% soy oil used as a pork backfat substitute.

The reduction of fat from 33.32% in the CT batch to 15.09% in the S batch resulted in fuets that were rated less round. The higher rating for round shape obtained by the CT batch was due to its higher fat and lower water contents, which produced less moisture release during the drying process, reducing the typical formation of longitudinal wrinkles, shrunken diameters and dry edges in reduced fat sausages (Wirth, 1988).

According to Muguerza, Fista, Ansorena, Astiasarán, & Bloukas (2002), excessive fat reduction leads to an unacceptable appearance because of the presence of a wrinkled surface and casing hardening. In addition, fat reduction caused harder and rubbery products due to higher weight losses (Keeton, 1994). Mendoza et al. (2001) and Bovolenta et al. (2008) also reported greater hardness in low-fat fermented sausages.

KCl has similar functional properties to NaCl, but its addition to meat products is primarily limited by its bitter taste (Askar, El-Samahy & Tawfik, 1994). In the present study, the amount of KCl added was set according to the results previously obtained by Gou et al. (1996), Gelabert et al. (2003), Guàrdia et al. (2006) and Guàrdia et al. (2008).

As expected, the addition of 0.64% KCl did not result in a significant increase in bitterness, and no other sensory attributes were affected by this addition.

The addition of sunflower oil (S-KCL-1.5SO and S-KCL-3SO) decreased darkness, hardness, elasticity and chewiness and increased the brown colour and crumbliness to values closer to those of the CT batch. These results agree with those reported by Mora-
Gallego et al. (2013) in reduced fat non-acid fermented sausages with 5% sunflower oil with respect to those containing 5% pork backfat. As suggested by Mora-Gallego et al. (2013), sunflower oil can cover the meat particles, reducing the binding between meat proteins and thus lead to a less elastic and more crumbly texture in the mouth. As expected, batches containing sunflower oil (S-KCl-1.5SO and S-KCl-3SO) were scored with the highest intensity of oil flavour, although this score was not significantly different from the CT score. Regarding the tactile texture, the sunflower oil batches showed a tendency to increase the ease of removal of the casing from the sausage surface (ease to peel; Table 4), which may result from the exudation of sunflower oil that reduced the protein/casing interaction throughout the drying process (Bloukas et al., 1997; Mora-Gallego et al., 2013). The covariate $X_{DFSDM}$ showed a significant negative slope for the sensory attribute hardness, as it did for instrumental hardness. Similar to hardness, crumbliness was affected by the covariate $X_{DFSDM}$.

3.5. Acceptability study

No significant effect of the socio-demographic variables (age, gender, place of residence and education level) on the consumer acceptability was detected (results not shown). In contrast, significant differences between batches were observed (Table 4). The simultaneous reduction of salt (from 2.5% to 1.5%) and fat (from 33.22% to 15.09%) resulted in a significant increase in the acceptability (CT vs. S batches). Olivares et al. (2010) also found that fermented sausages with 16.5% of the fat content in the raw mixture produced high consumer acceptability (this content was half of the usual fat content in fermented sausages) when compared with those with high fat content (19.3%).
There was neither a positive nor a negative effect due to the KCl addition on the consumer acceptability, likely because the amount of KCl added (0.64%) was not detected by the consumers. The added amount of KCl was lower than the 1.4% used in the study of Guàrdia et al. (2008), which achieved a 50% reduction of the NaCl content in fermented sausages by molar substitution with KCl (1.4%) without changing the acceptability of the product. This result, together with the positive effect of the KCl on food safety ($a_w$ decrease), suggests that it may be possible to increase the amount of KCl added without decreasing the consumer acceptability of fuets. Regarding sunflower oil addition, there was a slight tendency towards decreased acceptability as sunflower oil increased (SKCl vs S-KCL1.5SO and S-KCL3SO).

Bølling et al. (2010) showed that nutritional information affects consumer acceptance. In the present work, acceptability only refers to a hedonic evaluation of the fuets because consumers had no additional information about the reduced fat and salt content of the products nor about the addition of sunflower oil as fat substitute. Therefore, the acceptability may change if consumers were informed of the fat and salt levels of the different batches (Shepherd, Sparks, Bellier, & Raats, 1991) and the addition of KCl. The impact of nutritional information on the label with respect to fat and salt reduction would be interesting to test.

4. Conclusions

The addition of 0.64% KCl to small-caliber non-acid fermented sausages with the simultaneous reduction of the fat and salt content decreased the $a_w$ and did not have negative effects on either sensory attributes or consumer acceptability. The addition of sunflower oil improved the appearance and texture attributes by achieving values closer to those of the control batch but by modifying the oil flavour. Regarding consumer
acceptability, the simultaneous reduction of fat (from 20% to 10% and 7%) and salt (from 2.5% to 1.5%) was acceptable to the consumers. The addition of sunflower oil showed a tendency to decrease acceptability.

Acknowledgements

The authors gratefully acknowledge the European Community financial participation under the Sixth Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project Q-PORKCHAINS FOOD-CT-2007-036245. The content of the paper reflects only the view of the authors; the Community is not liable for any use that may be made of the information contained in this paper. The authors would also like to acknowledge the contribution of Anna Claret to the consumers’ study and the contribution of Quim Arbonés, Jordi Garcia, Cristina Canals, Marta Baret and Bernardo Guerra in the manufacture of the sausages and in the preparation, processing and analysis of the samples.

References


properties of a typical fermented meat product (Pitina) obtained from Alpagota sheep.

Meat Science, 80, 771–779.


ntifico_13.pdf
Table 1. Definition of the sensory attributes included in the sensory profile.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slice Appearance</strong></td>
<td></td>
</tr>
<tr>
<td>Darkness</td>
<td>Evaluation of the intensity of the darkness on the surface of a fresh cut slice</td>
</tr>
<tr>
<td>Brightness</td>
<td>Brightness intensity evaluated on the surface of a fresh cut slice</td>
</tr>
<tr>
<td>Brown color</td>
<td>Evaluation of the intensity of the brown color on the surface of a fresh cut slice</td>
</tr>
<tr>
<td>Round shape</td>
<td>Evaluation of the roundness of the slice</td>
</tr>
<tr>
<td><strong>Odor attributes</strong></td>
<td></td>
</tr>
<tr>
<td>Odor intensity</td>
<td>Intensity of overall odor of the sample</td>
</tr>
<tr>
<td>Ripened odor</td>
<td>Pleasant odor developed by dry-cured meat products</td>
</tr>
<tr>
<td><strong>Taste and Flavor</strong></td>
<td></td>
</tr>
<tr>
<td>Flavor intensity</td>
<td>Evaluation of the overall flavor intensity of the sample</td>
</tr>
<tr>
<td>Sweetness</td>
<td>Basic taste sensation elicited by sugar</td>
</tr>
<tr>
<td>Saltiness</td>
<td>Basic taste sensation elicited by NaCl</td>
</tr>
<tr>
<td>KCl bitterness</td>
<td>Bitter taste sensation elicited by KCl</td>
</tr>
<tr>
<td>Oil flavor</td>
<td>Flavor elicited by vegetable oil</td>
</tr>
<tr>
<td>Piquantness</td>
<td>Stinging sensation in the mouth and throat</td>
</tr>
<tr>
<td>Ripened flavor</td>
<td>Pleasant flavor characteristic of dry-fermented sausages</td>
</tr>
<tr>
<td><strong>Tactile texture</strong></td>
<td></td>
</tr>
<tr>
<td>Ease to peel</td>
<td>Degree of easiness displayed when removing the casing of the slice</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>Amount of pressure required to completely compress the sample</td>
</tr>
<tr>
<td>Elasticity</td>
<td>Degree of return to the original position of the sample when a compression force is applied between molars</td>
</tr>
<tr>
<td>Crumbliness</td>
<td>Textural property characterized by the easiness with which a sample can be separated into smaller particles during chewing</td>
</tr>
<tr>
<td>Chewiness</td>
<td>Textural property characterized by the difficulty to break the samples into pieces in order to be swallowed</td>
</tr>
<tr>
<td>Pastiness</td>
<td>Evaluation of the feeling of paste perceived during chewing</td>
</tr>
<tr>
<td>Fat mouthfeel</td>
<td>Evaluation of the fat feeling of the sample perceived during chewing</td>
</tr>
</tbody>
</table>
Table 2
Physicochemical parameters (least-squares means) of *fuets* (small-caliber non-acid fermented sausages) according to the batch.

<table>
<thead>
<tr>
<th>Fuet batch&lt;sup&gt;A&lt;/sup&gt;</th>
<th>Weight loss (%)&lt;sup&gt;B&lt;/sup&gt;</th>
<th>Moisture (%)</th>
<th>Water content&lt;sup&gt;C&lt;/sup&gt;</th>
<th>pH&lt;sub&gt;final&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>44.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>29.35&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.893&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.60&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>L</td>
<td>49.08&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>38.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.949&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.72&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>S</td>
<td>51.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.973&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.90&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>L-KCl</td>
<td>48.50&lt;sup&gt;d&lt;/sup&gt;</td>
<td>39.95&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>1.039&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.98&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>S-KCl</td>
<td>50.91&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.067&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.79&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>S-KCL-1.5SO</td>
<td>50.51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39.23&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.980&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>6.84&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>S-KCL-3SO</td>
<td>49.36&lt;sup&gt;c&lt;/sup&gt;</td>
<td>39.18&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.973&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.79&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>RMSE&lt;sup&gt;B&lt;/sup&gt;</td>
<td>0.337</td>
<td>0.884</td>
<td>0.0462</td>
<td>0.079</td>
</tr>
</tbody>
</table>

<sup>A</sup> Within row, least-squares means with a common letter are not significantly different (*P* > 0.05).
<sup>B</sup> Root Mean Square Error of the linear model.
<sup>C</sup> Water content on a defatted-desalted-dry-matter basis (kg water / (kg dry matter – kg fat – kg NaCl – kg KCl)).
Table 3
Instrumental color (CIE-Lab) and Texture Profile Analysis (TPA) parameters (least-squares means) of fuets according to the batch.

<table>
<thead>
<tr>
<th>Fuets batch</th>
<th>CT</th>
<th>L</th>
<th>S</th>
<th>L-KCl</th>
<th>S-KCl</th>
<th>S-KCl-1.5SO</th>
<th>S-KCl-3SO</th>
<th>Covariate X_{DFDSDM} (β)</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n = 5 fuets/batch)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CIE-Lab color</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightness (L*)</td>
<td>48.3a</td>
<td>39.7c</td>
<td>40.9bc</td>
<td>43.8ab</td>
<td>41.2bc</td>
<td>41.7bc</td>
<td>42.9bc</td>
<td>-</td>
<td>1.63</td>
</tr>
<tr>
<td>Redness (a*)</td>
<td>9.71b</td>
<td>11.73a</td>
<td>9.72b</td>
<td>10.93abd</td>
<td>10.02ab</td>
<td>10.89ab</td>
<td>10.74ab</td>
<td>-</td>
<td>0.86</td>
</tr>
<tr>
<td>Yellowness (b*)</td>
<td>3.88a</td>
<td>2.72ab</td>
<td>1.17b</td>
<td>2.17ab</td>
<td>1.30b</td>
<td>1.95b</td>
<td>2.40ab</td>
<td>-</td>
<td>0.761</td>
</tr>
<tr>
<td><strong>TPA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness (N/cm²)</td>
<td>79.1d</td>
<td>217.8a</td>
<td>180.4ab</td>
<td>213.3a</td>
<td>219.0a</td>
<td>152.7bc</td>
<td>121.8cd</td>
<td>-205.6</td>
<td>21.82</td>
</tr>
<tr>
<td>Chewiness (N/cm²)</td>
<td>2.76d</td>
<td>10.96ab</td>
<td>8.14bc</td>
<td>11.74abd</td>
<td>13.60a</td>
<td>9.23bc</td>
<td>7.16c</td>
<td>-</td>
<td>1.68</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.127c</td>
<td>0.201ab</td>
<td>0.190ab</td>
<td>0.211ab</td>
<td>0.224a</td>
<td>0.190ab</td>
<td>0.183b</td>
<td>-</td>
<td>0.016</td>
</tr>
<tr>
<td>Springiness</td>
<td>0.283ab</td>
<td>0.255b</td>
<td>0.235b</td>
<td>0.260b</td>
<td>0.282ab</td>
<td>0.329a</td>
<td>0.319a</td>
<td>-</td>
<td>0.022</td>
</tr>
</tbody>
</table>

Within row, least-squares means with a common letter are not significantly different (P > 0.05).

A CT: lean trimmings 80:20 (lean:fat) + 2.5% NaCl.
L: lean trimmings 90:10 (lean:fat) + 1.5% NaCl.
S: shoulder 3D (approx. 7% fat) + 1.5% NaCl.
L-KCl: lean trimmings 90:10 (lean:fat) + 1.5% NaCl + 0.64% KCl.
S-KCl: shoulder 3D (approx. 7% fat) + 1.5% NaCl + 0.64% KCl.
S-KCl-1.5SO: shoulder 3D + 1.5% NaCl + 0.64% KCl + 1.5% sunflower oil.
S-KCl-3SO: shoulder 3D + 1.5% NaCl + 0.64% KCl + 3% sunflower oil.

B Significant regression coefficient (P < 0.05) of the covariate water content on a defatted-desalted-dry-matter basis (kg water / (kg dry matter – kg fat – kg NaCl – kg KCl)).

C Root mean square error of the linear model.
Table 4
Sensory attributes (least-squares means) and consumer acceptability of *fuets* (small-caliber non-acid fermented sausages) according to the batch: type of fat and the NaCl reduction and/or substitution by KCl.

<table>
<thead>
<tr>
<th>Attributes B</th>
<th>CT</th>
<th>L</th>
<th>S</th>
<th>L-KCl</th>
<th>S-KCl</th>
<th>S-KCL-1.5SO</th>
<th>S-KCL-3SO</th>
<th>Covariate X_{DF,SDM} (β)c</th>
<th>RMSED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Odor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>5.9</td>
<td>5.7</td>
<td>6.2</td>
<td>5.5</td>
<td>5.9</td>
<td>6.2</td>
<td>6.1</td>
<td>-</td>
<td>0.37</td>
</tr>
<tr>
<td>Ripened</td>
<td>4.7</td>
<td>4.8</td>
<td>4.5</td>
<td>4.3</td>
<td>4.0</td>
<td>5.0</td>
<td>4.9</td>
<td>-</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Appearance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round shape</td>
<td>5.9</td>
<td>4.4a</td>
<td>3.1b</td>
<td>3.4ab</td>
<td>3.2ab</td>
<td>4.0ab</td>
<td>-</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Darkness</td>
<td>4.3</td>
<td>6.7ab</td>
<td>6.9a</td>
<td>7.0a</td>
<td>6.9a</td>
<td>5.7b</td>
<td>-9.8</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Brightness</td>
<td>5.3</td>
<td>3.4</td>
<td>4.1</td>
<td>3.6</td>
<td>4.2</td>
<td>4.0</td>
<td>-</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Brown color</td>
<td>1.6</td>
<td>1.0abc</td>
<td>0.8bc</td>
<td>0.4c</td>
<td>0.5bc</td>
<td>1.3ab</td>
<td>1.8a</td>
<td>-</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Tactile texture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease to peel</td>
<td>7.3</td>
<td>7.5ab</td>
<td>7.6ab</td>
<td>7.0b</td>
<td>7.9ab</td>
<td>8.0a</td>
<td>8.3a</td>
<td>-</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Flavor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>6.0</td>
<td>5.8</td>
<td>6.1</td>
<td>6.1</td>
<td>6.3</td>
<td>6.4</td>
<td>5.7</td>
<td>-</td>
<td>0.29</td>
</tr>
<tr>
<td>Sweetness</td>
<td>2.7</td>
<td>2.0</td>
<td>1.9</td>
<td>1.6</td>
<td>1.5</td>
<td>1.6</td>
<td>1.8</td>
<td>-</td>
<td>0.29</td>
</tr>
<tr>
<td>Saltiness</td>
<td>3.0</td>
<td>2.8</td>
<td>2.8</td>
<td>2.6</td>
<td>2.7</td>
<td>2.9</td>
<td>3.0</td>
<td>-</td>
<td>0.32</td>
</tr>
<tr>
<td>KCl bitterness</td>
<td>0.2b</td>
<td>0.5b</td>
<td>0.7b</td>
<td>0.9ab</td>
<td>1.3ab</td>
<td>1.3a</td>
<td>1.4a</td>
<td>-</td>
<td>0.24</td>
</tr>
<tr>
<td>Oil flavor</td>
<td>0.3</td>
<td>0.2ab</td>
<td>0.3ab</td>
<td>0.1b</td>
<td>0.1b</td>
<td>0.6a</td>
<td>0.7a</td>
<td>-</td>
<td>0.23</td>
</tr>
<tr>
<td>Piquantness</td>
<td>2.5</td>
<td>3.0</td>
<td>2.9</td>
<td>2.7</td>
<td>2.7</td>
<td>3.1</td>
<td>3.1</td>
<td>-</td>
<td>0.42</td>
</tr>
<tr>
<td>Ripened</td>
<td>4.9</td>
<td>4.5</td>
<td>4.8</td>
<td>4.4</td>
<td>4.3</td>
<td>5.1</td>
<td>4.7</td>
<td>-</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>3.7c</td>
<td>5.0ab</td>
<td>5.0ab</td>
<td>5.4a</td>
<td>5.8a</td>
<td>4.4bc</td>
<td>3.6d</td>
<td>-7.3</td>
<td>0.27</td>
</tr>
<tr>
<td>Elasticity</td>
<td>1.0</td>
<td>2.2ab</td>
<td>2.1ab</td>
<td>2.5a</td>
<td>3.1a</td>
<td>1.7bc</td>
<td>1.2c</td>
<td>-</td>
<td>0.36</td>
</tr>
<tr>
<td>Crumbliness</td>
<td>6.2ab</td>
<td>5.1cd</td>
<td>5.1cd</td>
<td>4.7d</td>
<td>4.4d</td>
<td>5.9bc</td>
<td>6.9a</td>
<td>6.9</td>
<td>0.37</td>
</tr>
<tr>
<td>Chewiness</td>
<td>3.8abc</td>
<td>4.7ab</td>
<td>4.7ab</td>
<td>5.1a</td>
<td>5.4a</td>
<td>3.8bc</td>
<td>3.4c</td>
<td>-</td>
<td>0.41</td>
</tr>
<tr>
<td>Pastiness</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.3</td>
<td>0.5</td>
<td>0.4</td>
<td>0.8</td>
<td>-</td>
<td>0.23</td>
</tr>
<tr>
<td>Fat mouthfeel</td>
<td>4.8a</td>
<td>2.6b</td>
<td>2.6b</td>
<td>2.4b</td>
<td>2.4b</td>
<td>2.6b</td>
<td>2.5b</td>
<td>-</td>
<td>0.42</td>
</tr>
<tr>
<td>Consumer acceptability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.83</td>
</tr>
</tbody>
</table>

(n=84)
Within row, least-squares means with a common letter are not significantly different ($P > 0.05$).

A  CT: lean trimmings 80:20 (lean:fat) + 2.5% NaCl.
L: lean trimmings 90:10 (lean:fat) + 1.5% NaCl.
S: shoulder 3D (approx. 7% fat) + 1.5% NaCl.
L-KCl: lean trimmings 90:10 (lean:fat) + 1.5% NaCl + 0.64% KCl.
S-KCl: shoulder 3D (approx. 7% fat) + 1.5% NaCl + 0.64% KCl.
S-KCl-1.5SO: shoulder 3D + 1.5% NaCl + 0.64% KCl + 1.5% sunflower oil.
S-KCl-3SO: shoulder 3D + 1.5% NaCl + 0.64% KCl + 3% sunflower oil.

B  Sensory analysis was carried out using 4 $fuets$/batch for the Quantitative Descriptive Analysis

C  Significant regression coefficient ($P < 0.05$) of the covariate water content on a defatted-desalted-dry-matter basis ($\text{kg water} / (\text{kg dry matter} – \text{kg fat} – \text{kg NaCl} – \text{kg KCl})$).

D  Root mean square error of the linear model.

E  Consumer acceptability was carried out by 84 consumers using 21 $fuets$/batch.