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Physicochemical and sensory properties of healthier frankfurters as affected by walnut and fat content

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Abstract

This study evaluates the physicochemical and sensory properties of healthier frankfurters with 25% added walnut (WF) versus low-fat frankfurters (6% pork fat) (LF) and traditional frankfurters (18% pork fat) (NF). Results reveal that cooking losses were unaffected ($p \geqslant 0.05$) by the formulation of frankfurters. The addition of walnut led to higher ($p < 0.05$) redness and yellowness values, while colour parameters did not differ significantly between LF and NF sausages. Frankfurters with added walnut (WF) presented higher ($p < 0.05$) hardness and chewiness values than LF and NF frankfurters. Differences in composition were also accompanied by changes in the microstructure of the gel/emulsions. Frankfurters with added walnut presented a flavour significantly different from meat and scored lower ($p < 0.05$) on texture preferences. However, all frankfurters scored the same for overall acceptability.
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Keywords: Frankfurters; Functional meat products; Low-fat; Walnut; Physicochemical characteristics; Sensory properties

1. Introduction

Regular consumption of 43 g/2000 kcal/day of walnuts is widely recognised as being beneficial for the prevention of coronary heart disease (FDA, 2004). Given that the daily intake of walnuts by the Spanish population (1.73 g/person/day – MAPA, 2005) falls short of the recommendations proposed by the Food and Drug Administration (FDA) for the prospective health benefits, a good strategy to augment the presence of walnuts in the diet could be to incorporate them into frequently-consumed meat products such as frankfurters. For instance, Olmedilla-Alonso, Granado-Lorencio, Herrero-Barbudo, and Blanco-Navarro (2006) estimate that regular consumption of meat products with walnut, including frankfurters, is compatible with a balanced diet and may have a beneficial impact on intermediate biomarkers of cardiovascular disease (CVD).

In a previous study Ayo et al. (2007) reported an improvement in the nutritional profile after adding 25% of walnuts to frankfurters and comparing these with commercial products with both low (6%) and normal (18%) fat contents but of animal origin. This study evidenced the presence of several bioactive components in frankfurters with added walnuts which were not present in the others frankfurters, suggesting that they have potential as functional meat products that may reduce the risk of heart disease. However, while there are clear potential health benefits to be gained from adding walnuts to frankfurters, we need to find out how these reformulations affect the physicochemical and sensory properties of frankfurters in comparison with commercial products.

Healthier meat product formulations need to contain less saturated fat and/or promote the presence of specific healthy compounds (incorporating non-meat ingredients like walnut) and this affects the quality attributes of cooked meat emulsions. The effect depends on the reformulation

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strategy. Carballo, Ayo, and Jiménez-Colmenero (2003) examined the ways in which the addition of different amounts of walnut (7–21%) affected the physicochemical properties of frankfurters. In this case animal fat and protein was substituted by walnut while the total protein content (meat + vegetable) was kept constant. Another possible formulation strategy, which has frequently been tried in the development of healthier meat products (Cengiz & Gokoglu, 2005; Grigelmo-Miguel, Abadías-Serós, & Martín-Belloso, 1999), is to induce changes in composition (fat or non-meat ingredient) while the meat protein content remains constant. This would help us to understand the effect of a non-meat ingredient (e.g., walnut) on physicochemical properties, but there have been no studies dealing with the characteristics of frankfurter formulated with added walnut and unaltered meat protein content.

In light of these considerations and the nutritional profile defined (Ayo et al., 2007), the objective of the present study was to analyse the physicochemical and sensory properties of frankfurters, with 25% walnut (WF), and to compare them with low-fat (6% pork fat) (LF) and normal fat (18%) (NF) frankfurters with constant meat protein content.

2. Materials and methods

2.1. Ingredients

Post-rigor pork meat (mixture of *M. biceps femoris, M. semimembranosus, M. semitendinosus, M. gracilis* and *M. aductor*) and pork backfat were obtained. Excess fat and connective tissue were trimmed from pork meat. Lean pork and backfat were separately ground through a 6-mm plate and frozen at −20 °C until product formulation. Frozen meat and backfat were thawed at 3 ± 2 °C for 18 h prior to use. Walnut (La Morella Nuts, S.A., Tarragona, Spain) was ground and refined (heated at 80 °C for 1 h) down to a particle size of approximately 12 μm.

2.2. Preparation of frankfurters

Three different frankfurter formulations were prepared in a private processing plant with formulations given in Table 1. Partially thawed lean meat was placed in a chilled bowl cutter (Stephan Universal Machine UM5, Hameln, Germany) and homogenised for 1 min. The following common ingredients were added and mixed with chopped meat for another minute: sodium chloride (2.5%), sodium polyphosphate (0.18%) and sodium nitrite (0.015%) (Panreac Quimica, S.A. Barcelona, Spain) were mixed in for 1 min. Pork fat, water and/or sodium caseinate (ANVISA, Madrid, Spain) or walnut was then added and the mixture was chopped for another minute. Total mixing time was standardised to 6 min and the last 3 min were under vacuum conditions. The final temperature was below 10 °C in all cases.

After that, the batter was stuffed using a manual stuffing machine (Mainca, Berkshire, UK) into 20 mm diameter cellulose casings (Viscase S.A., Bagnold Cedex, Francia), hand-linked at 20 cm intervals, weighed and finally heat processed in an Eller smokehouse (model Unimatic 1000, Micro 40, Eller, Merano, Italy) to an internal temperature of 70 °C, monitored throughout by thermocouples inserted in the thermal centre of the sausages. The frankfurters were cooled with cold water (2 °C) to a final temperature lower than 10 °C and the casings removed. Frankfurters (70–75 g) were vacuum packed (Cryovac® BB4L, oxygen permeability 30 cm^3 m^{-2} 24 h^{-1} at 23 °C, 0% RH and 1 bar), scalded for 3 min in a water bath at 90 °C and finally cooled and stored at 2 ± 2 °C until analysis. Two replications of the experiment were conducted at separate times.

2.3. Proximate analysis and pH

Moisture and ash contents were determined in representative samples according to the Association of Official Analytical Chemists methods (A.O.A.C, 2000). Protein content was estimated by LECO FP-2000 Organic Nitrogen Determinator (Leco Corporation, St Joseph, USA). Total fat was evaluated by an extraction with chloroform/methanol/water, according to Bligh and Dyer (1959). Four replicates per formulation were analysed for each measurement. pH measurements were determined in quadruplicate by blending 10 g of frankfurters with 100 ml distilled water. Readings were taken with a pH meter (Radiometer PHM 93, Copenhagen, Denmark).

2.4. Cooking loss

Cooking loss (CL) was determined by calculating the weight difference of five links of frankfurter for each treatment before and after 3 min at 90 °C in a water bath and removal of remaining exudates with absorbent paper and then expressed as a percentage of initial sample weight.

2.5. Colour

The internal colour of the frankfurters was analysed with a HunterLab model D25-9 (D45/2°) colorimeter (Hunter Associates Laboratory Inc., VA, Reston, USA). CIELAB L^*, a^* and b^* values were determined as indicators of lightness, redness and yellowness. Data presented

Table 1
Formulation (%) of frankfurters

Treatments[a]	Pork meat	Pork backfat	Walnut	SC[b]	Water
NF	58	20	0	0	19.3
LF	58	4	0	2	33.3
WF	58	0	25	0	14.3

[a] NF: normal-fat frankfurter (18% animal fat). LF: low-fat frankfurter (6% animal fat) and WF: frankfurter with 25% added walnut.
[b] Sodium caseinate.

are means of 10 measurements of 10 replicates with 2.0 cm of diameter and 2.0 cm of height.

2.6. Texture profile analysis

Texture profile analysis (TPA) was performed in a TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA) in the next 24 h of refrigerated (3 °C) storage as described by Bourne (1978). A 75 mm cylindrical cell was used to compress the samples. Sample geometry was standardised to a 1.5 cm diameter and 2.0 cm height. Eighteen cores were axially compressed by a two-cycle compression test to 40% of their original height. Force–time deformation curves were recorded with a 50 N load cell applied at a crosshead speed of 0.8 mm/s. Attributes were calculated as follows: Hardness (Hd) = peak force (N) required for first compression; springiness (Sp) = distance (mm) the sample recovers after the first compression; cohesiveness (Ch) = ratio of the positive force area during the second compression to that during the first compression (dimensionless); and chewiness (Cw) = work (N mm) necessary to chew the sample for swallowing (Hd × Sp × Ch). Measurements of samples were carried out at room temperature.

2.7. Microstructure

Small pieces of frankfurter were fixed with a mixture (1:1 v/v) of paraformaldehyde (4%) and glutaraldehyde (0.2%), in 0.1 M phosphate buffer pH 7.2 and post-fixed with OsO_4. After washing, samples were dehydrated in increasing concentrations of acetone, critical-point-dried and sputter-coated with a layer of gold/palladium in a metallizer (Balzer, SCD004).

Micrographs of the samples were taken at 20 kV with a scanning electron microscope (Jeol, JSC 6400, Akishima, Tokyo, Japan). A large number of micrographs were taken in order to select the most representative ones.

2.8. Sensory evaluation

Frankfurters were assessed by a 14-member in-house panel using a hedonic test. The panel was selected in preliminary sessions from staff who had received training (two sessions) with the products and terminology. Samples 2.5 cm long from each formulation were heated then immediately presented to panellists in random order, under a red light to minimise colour differences caused by the presence of walnut. Judges were instructed to evaluate the flavour, texture and overall acceptability on a 9-point open scale. Each point was converted to a numerical value from 0 = dislike extremely to 9 = like extremely. The "off-flavour" parameter was defined as non-meat and non-fat flavour untypical of the product and was evaluated on a 5-point closed scale where 1 = no different flavour to 5 = no typical flavour. Panellists were asked to give reasons for preference or rejection of the samples.

2.9. Statistical analysis

Analysis of variance was conducted separately (one-way ANOVA) for the dependent variables of the experimental results. Differences in mean and *F*-tests were considered significant when $p < 0.05$. The Tukey test was employed to test for statistically significant differences between samples. All statistical procedures of the data were computed using the program Statgraphics Plus v 5.0 (STSC Inc., Rockville, MD, USA).

3. Results and discussion

3.1. Proximate analysis and pH

Proximate analysis of the different frankfurter formulations is shown in Table 2. Since meat content – and hence also added meat protein – was constant for all frankfurters as established, differences in protein content can be mainly attributed to the added sodium caseinate (LF) and walnut (WF). WF had the highest protein content ($p < 0.05$) coming from the added walnut (17.72% ± 1.16). The reduction of fat content in LF frankfurters was largely at the expense of moisture level. In samples NF and WF, fat content was comparable to that of commercial frankfurters (15–20% fat). WF frankfurters contained the lowest ($p < 0.05$) moisture content and the highest ($p < 0.05$) fat content, as expected. The addition of walnut significantly raised the ash level (Table 2). These results were consistent with other findings in meat batters with different levels of walnut (Ayo, Carballo, Solas, & Jiménez-Colmenero, 2005). Substitution of pork backfat by water produced significant but no quantitatively major changes in the pH (NF: 6.43, LF: 6.33). Likewise, the incorporation of walnut did not influence ($p > 0.05$) the pH of the WF frankfurters (6.37), as compared with LF and NF. Cofrades, Ayo, Serrano, Carballo, and Jiménez-Colmenero (2006) reported that increasing the amount of walnuts, while keeping the meat protein content constant, had no significant effect on the pH of meat batters.

3.2. Cooking loss

Cooking loss was unaffected ($p \geqslant 0.05$) by differences in formulations (NF: 3.35%, LF: 2.92% and WF: 3.33%).

Table 2
Proximate analysis (%) of frankfurters (NF: normal fat; LF: low-fat; WF: with added walnut)

Samples	Moisture	Protein	Fat	Ash
NF	61.78^a	13.40^a	16.15^a	2.57^a
LF	75.03^b	15.17^b	6.90^b	2.48^b
WF	55.77^c	16.59^c	18.51^c	3.14^c
SEM	0.14	0.15	0.07	0.01

Different letters in the same column indicate significant differences ($p < 0.05$). SEM = standard error of the mean.

Some authors have reported that the inclusion of milk proteins (sodium caseinate) in meat products contributes to emulsion stability (Van den Hoven, 1987) and increases the water holding capacity of frankfurters (Hung & Zayas, 1992), which would account for cooking losses being similar in LF and NF frankfurters. Also, no differences in cooking losses were observed when walnut was added. This behaviour is presumably related to the low moisture content of WF frankfurters (Table 2). All the experimental results for cooking losses were in a range of around 3%, which is considered acceptable for frankfurter-type sausages (Claus, Hunt, Kastner, & Kropf, 1990; Cofrades, Carballo, & Jiménez-Colmenero, 1997).

3.3. Colour

A number of authors (Claus, Hunt, & Kastner, 1989; Paneras, Bloukas, & Papadima, 1996) have reported that when fat content was reduced L^* and b^* values decreased and a^* values increased, however, on a number of occasions no differences have been found in some colour values as a result of changes in fat level (Barbut & Mittal, 1995). In the present study, the colour parameters of cooked frankfurters prepared with pork fat (NF and LF) were not affected by the pork fat level (Table 3). However, LF frankfurters had slightly higher a^* values ($p \geqslant 0.05$) than NF frankfurters. This may have some connection with meat content and consequently with myoglobin content that stays constant in NF and LF treatments. Van den Hoven (1987) reported that milk proteins improved colour changes in low-fat high moisture frankfurters.

The substitution of animal fat by walnut did not significantly affect the lightness of the sausages. Also, Ayo et al. (2005) detected no walnut-induced changes of L^* in meat batters, although Jiménez-Colmenero et al. (2003) and Carballo et al. (2003) respectively reported a decrease of L^* in cooked restructured steaks and in frankfurters with added walnut.

An association has been reported between the addition of increasing amounts of walnut to cooked meat products and increments of redness and yellowness values (Ayo et al., 2005; Cofrades et al., 2004; Jiménez-Colmenero et al., 2003). This is further confirmed in the present study, where walnut made up 25% of the frankfurters (Table 3). Redness and yellowness were higher ($p < 0.05$) in WF than in LF and NF frankfurters.

Table 3
Effect of walnut addition on colour parameters of frankfurters (NF: normal fat; LF: low-fat; WF: with added walnut)

Samples	L^*	a^*	b^*
NF	65.3^a	3.11^a	9.75^a
LF	65.6^a	3.17^a	9.77^a
WF	65.4^a	5.35^b	11.1^b
SEM	0.18	0.09	0.08

Different letters in the same column indicate significant differences ($p < 0.05$). SEM = standard error of the mean.

3.4. Texture profile analysis

Table 4 provides a summary of the TPA parameters. LF and WF frankfurters were significantly harder and chewier than the NF frankfurter. The frankfurters with 25% walnut registered the highest ($p < 0.05$) values of hardness and chewiness, and the lowest ($p < 0.05$) values of springiness.

A number of authors, analysing the effect of reducing the fat content on the texture of meat based emulsion products, have reported that as long as meat protein content is held constant, the product is softer (Cavestany, Jiménez-Colmenero, Solas, & Carballo, 1994; Claus et al., 1990; Gregg, Claus, Hackney, & Marriot, 1993). In this experiment, however, even though the meat protein content was similar (according to formulation conditions) in LF and HF treatments, the reduction of fat content was accompanied by a slight but significant hardening of the product (Table 4). These results are consistent with the findings of other authors, who have reported hardening of the meat matrix when sodium caseinate is added to low-fat frankfurters as a fat replacer (Girard, Culioli, Maillard, Denoyer, & Touraille, 1990; Hung et al., 1992).

There are several factors that can influence the texture of a WF frankfurter. One of the first aspects to consider is increased protein content (Table 4), which in the given formulation conditions, is attributable to the walnut. Walnut protein is composed essentially of albumin (6.8%), globulin (17.6%), prolamin (5.3%) and glutelin (70.1%). Non-meat ingredients containing these kinds of proteins are commonly used in processed meats to improve textural properties (Sze-Tao & Shate, 2000). The effect of this non-meat ingredient will depend to a large extent on how it interacts with muscle proteins. Vegetable proteins of this kind generally require slightly higher temperatures (95 °C) than the temperature applied in this study to unfold muscle proteins (Feng & Xiong, 2002). This behaviour therefore encouraged the formation of the kind of molecular associations implicated in protein gel network formation, thus producing harder textures.

A second aspect to consider are the differences in fat/moisture and protein/moisture ratios. When walnut was added, the protein content of the WF frankfurter increased, the moisture level decreased and the fat level

Table 4
Influence of walnut on texture profile analysis of frankfurters (NF: normal fat; LF: low-fat; WF: with added walnut)

Samples	Hardness (N)	Springiness (mm)	Cohesiveness	Chewiness (N × mm)
NF	8.91^a	6.75^a	0.450^a	27.3^a
LF	9.95^b	6.85^a	0.465^b	31.7^b
WF	18.7^c	6.29^b	0.438^a	51.5^c
SEM	0.28	0.04	0.005	1.03

Different letters in the same column indicate significant differences ($p < 0.05$). SEM = standard error of the mean.

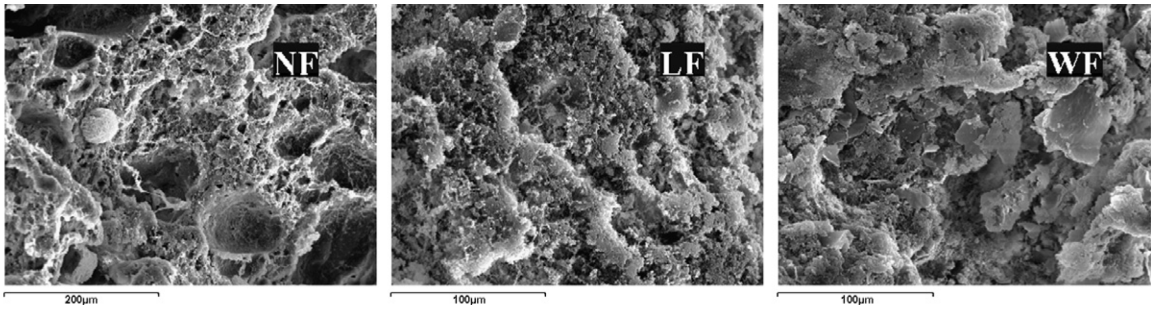

Fig. 1. Scanning electron micrograph of frankfurters: NF: normal fat frankfurters, LF: low-fat frankfurters and WF: walnut frankfurter.

increased ($p < 0.05$) with respect to LF and NF. Some authors have reported that these changes produce an "effective" concentration of the muscle protein available for gel formation and is thus related to harder structures (Claus et al., 1990). Cofrades et al. (2006) concluded that walnut had no effect on hardness ($p \geqslant 0.05$) of cooked meat batters in the absence of salt when meat protein content remained constant and the amount of added water was reduced as the proportion of walnut increased. Then again, Jiménez-Colmenero et al. (2003), Cofrades et al. (2004) and Ayo et al. (2005) have suggested that walnut does not contribute to textural properties and they report softer structures when walnut content was increased and meat content reduced accordingly in the formulation of different meat products. This behaviour was attributed to a combination of several factors: primarily a reduced presence of myofibrillar proteins and a diluting effect of non-meat ingredients (walnut) in meat protein systems and the poorer gelling properties of walnut globular proteins at processing temperatures (70 °C), which interfered to some extent in myofibrillar meat protein interactions.

In comparison with NF frankfurters, the addition of walnut to frankfurters showed no effect on cohesiveness (Table 4), although LF frankfurters were significantly more cohesive.

3.5. Microstructure

The microscopic structure was different in the three formulations (Fig. 1). NF frankfurters presented irregular denser formations giving rise to structures of a spongy (honeycomb-like) appearance similar to that described by other authors (Carballo, Fernández, Barreto, Solas, & Jiménez Colmenero, 1996). It has been reported that the reduction in fat level (while keeping meat protein constant) and the consequent increase in moisture (decrease in protein density) produced a microstructure with a less dense matrix, giving rise to a less hard and chewy structure (Carballo et al., 1996). However, no such behaviour was detected in this experiment (Table 4; Fig. 1), probably due to the presence of caseinate. Micrographs of WF frankfurters (Fig. 1) show that walnut was fully incorporated into the meat matrix, producing harder and chewier structures (Table 4).

Table 5
Sensory analysis of frankfurters (NF: normal fat; LF: low-fat; WF: with added walnut)

Samples	Off-flavour	Flavour	Texture	Overall acceptability
NF	1.60^a	6.06^a	6.52^a	6.07^a
LF	1.80^a	6.67^a	7.11^a	6.62^a
WF	4.27^b	6.45^a	4.13^b	5.23^a
SEM	0.21	0.58	0.53	0.59

Different letters in the same column indicate significant differences ($p < 0.05$). SEM = standard error of the mean.

3.6. Sensory evaluation

The addition of walnut to frankfurters was significantly ($p < 0.05$) perceived by judges (4.27 in a 5 points scale) as conferring a non-meat flavour (Table 5). Although panellists found that the flavour was different from the expected meat gel/emulsion products, this did not affect ($p > 0.05$) flavour preferences. In the textural evaluation, no differences ($p > 0.05$) were observed between NF and LF frankfurters, but WF frankfurters scored lower ($p < 0.05$) than both LF and NF. This may have to do with the fact that WF was the hardest formulation. However, there were no significant differences among any of the frankfurters (NF, LF or WF) in terms of overall acceptability (scored in a moderate range of 5.23–6.62). In general, when walnut is added to frankfurters and restructured beef steak, some effects on sensory quality are perceived (Cofrades et al., 2004; Jiménez-Colmenero et al., 2003). In the present case the panel were able to detect the addition of walnut as a slight off-flavour (walnut-like) but this was not perceived as a negative element, since in this experiment, like others, these products achieved positive scores for overall acceptability (Cofrades et al., 2004; Jiménez-Colmenero et al., 2003).

4. Conclusions

In addition to traditional presentations, the meat industry has a number of options available to modify the qualitative and quantitative composition of its products for health purposes. Given a high degree of acceptability among broad sectors of the population and a wide range of possibilities for reformulation, the frankfurter sausage offers attractive opportunities for the development of healthier meat products. Walnut offers potential heart-healthy benefits thanks to its peculiar nutritional profile, conferring useful properties when added to meat products such as frankfurters, as established elsewhere (Ayo et al., 2007). Our results indicate that the reformulation of frankfurters with added walnut, in order to develop healthier cooked meat products, altered their physicochemical properties but the resulting product possessed acceptable physicochemical and sensory properties when compared with low-fat and traditional commercial frankfurters.

In short, it is feasible to produce potentially functional frankfurters with 25% added walnut that would meet consumer demands for healthier meat products.

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