Journal of Food Technology 3(2): 220-225, 2005

Effect of Fat Sources on the Physico-Chemical Nutritional and Textural Properties of Beef Sausages

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Abstract: The effects of incorporation of beef fat, pork fat, mutton fat and 50 % pork fat /50 % hydrogenated sunflower oil (HSO) at 20 % level on the properties of beef sausages were investigated. The type of fats had significant effect ($P < 0.05$) on water content, fat content and fat retention of the beef sausages. The highest water holding capacity (WHC) and cooking yield were recorded for the mutton fat sausages. The pork fat/HSO sausage had the lowest cholesterol content. The sausages with HSO had a highest polyunsaturated fatty acids while those with beef fat had a highest monounsaturated fatty acids. The sausage formulated with the pork fat HSO recorded the highest lightness while redness value of the beef fat blend was the lowest. The inclusion of HSO in sausages significantly ($P<0.05$) decreased hardness of the sausages.

Key words: Beef, Lipid sources, Mutton, Oil, Pork, Properties, Texture

Introduction

Animal fats have long been utilised in processing meat products such as sausages. But the use of animal fat in meat product have emerged as topics of increasing concern to consumers. This concern has been due to negative publicity about the caloric value, cholesterol and saturated fatty acid content of animal fats. As result, some consumers have avoided meat and meat products. Various research have been carried out to reduce the animal fat in meat products. This include the use of non-meat ingredients such as water (Claus and Hunt, 1991 and Dzudie *et al.,* 2000) carbohydrate (Dzudie, Hardy and Scher, 2002), gums (Lin and Keeton, 1998) and plant oils (Tan *et al.,* 2001 and Javidipour and Vural, 2002).

Fat plays an important role on formation of stable meat emulsion in meat products. Plants oil have a high content of unsaturated fatty acids and are liquid at room temperature. Technological aspect associated with the incorporation of plant oils in meat product included problems with the texture. Bishop *et al.*(1993) reported that bologna sausage with pre-emulsified corn oil was softer than bologna sausage with pork fat. In order to simulate the consistency of high-melting point fats, plant oils undergo a process of hydrogenation. Substituting of partially hydrogenated plant oil to beef fat in ground beef patties reduced calorie and cholesterol content without any change in palatability of the products (Liu *et al.* 1991).

The substitution of 60% non-hydrogenated peanut oil to beef fat significantly ($P < 0.05$) reduced cholesterol content in meat (Marquez *et al.*, 1989). Up to now much of the research has been focused on fat content (Bishop *et al.*, 1993; Cavestany *et al.*, 1994 and Troy *et al.*, 1999), little is available concerning the effect of fat sources (species) on the physico-chemical properties of sausages.

The aim of the study was to investigate and compare the effect of various animal fats and hydrogenate sunflower-oil on the physico-chemical, nutritional and textural traits of beef sausages.

Materials and Methods

Processing: Fresh beef knuckles (quadriceps muscles) and beef, mutton and pork fat trimmings were obtained from a local meat purveyor. Muscles were trimmed of subcutaneous and intermuscular fat. Lean (5 % fat) and animal fats (85 % fat) were separately ground through a 6 and 3 mm plate of a meat grinder (model 133, Moulinex, Alençon, France). Ground meat and animal fat were vaccum packaged in oxygen impermeable bag (Albal-12 sacs, multi-couche, haute résistance, Chezy sur Marne, France) and frozen at -18°C for subsequent use. A day before sausage preparation, hydrogenated sunflower oil (HSO) was purchassed from a local super market

Sausages were formulated to contain 20 % fat, 10 % added water, 2 % nitrite salt (99.4 % NaCl and 0.6 % $NaNO_2$) and 3 % seasoning (Cafca chair, Bovida, Nancy, France) on a finished weight basis. Four types of sausages were formulated with beef fat, pork fat, mutton fat and 50 % pork fat/50 % hydrogenated sunflower oil (80% fat) respectively.

Prior to formulation and preparation, ground beef lean and fats were tempered at 2°C for 48 hr. Lean beef was chopped for 1 min in a two-blade bowl cutter (model UMC 5, A Stephan U.Sôlne GmbH. Co. Hameln West

Germany) along with nitrite salt and seasoning. The fat sources (beef, pork, mutton and HSO) and half of the water were added as ice to the bowl cutter and chopped for an additional 2 min. The remaining water was then added and the mix was again minced for 2 min. The meat batter was transferred to a bowl cutter (mode 5100, Magimix, Vincennes, France) and processed for 3 min. The mixture was removed from the bowl cutter, stuffed into 34 cm-diameter natural casing and formed into links 15 cm in length. Cooking was performed in a 75° C water bath to an internal temperature of sausages of 70 °C as determined with a Ebserbo thermometer (model HI 8054, Gesvrine, France). The cooked sausages were then cooled under water for 5 min. After cooking and cooling, the sausages were peeled by hand, vaccum packaged in oxygen impermeable bags (Albal-12 sacs, multi-couche, haute résistance, Chezy sur Marne, France) and stored for 24 h at 2°C for subsequent analysis. All the four treatments were processed on the same day and were replicated three times.

Sausage Composition: Raw and cooked sausages were ground through a 2 mm plate of a Moulinex meat grinder (model 133, Moulinex, Alençon, France). Water, protein and fat contents were determined (AOAC, 1990). Water content was determined as weight loss of 3 g sample after drying for 18 hr at 102°C. Crude protein was analyzed by micro kjeldahl method (N x 6.25). Fat was determined by weight loss after 16 h extraction in a soxhlet apparatus with petroleum ether.

Cooking Yield and Fat retention: Cooking yield was determined by difference in weight of three sausages from each treatment, weighed prior to cooking and after cooking and cooling as follows

$$\% \text{ cooking yield} = \frac{\text{cooking weight}}{\text{raw weight}} \times 100$$

To ascertain the amount of fat that was retained in sausages after cooking, the following calculation (Berry,1992) was performed:

$$\% \text{ Fat retention} = \frac{\text{Cooked wt x \% fat in cooked sausage}}{\text{raw wt x \% fat in raw sausages}} \times 100$$

pH: After blending 10 g minced raw sausage in 100 ml of distilled water, pH was measured with a Hanna pH-meter (model 8520, Hanna Instrument, Nantes, France)

Water Holding Capacity: The Tsai and Ockerman (1981) press technique was used with modification to measure the water holding capacity (WHC) of the raw sausages. A sample (0.5 g) was placed on filter paper (whatman # 1, stored over saturated KCl) which was placed between two plexigla sheets and pressed for 20 min by 1 kg weight. The area of pressed meat and a spread of juice was measured and the water holding capacity was calculated as follows (Tsai and Ockerman,1981).

$$\% \text{ Free Water} = \frac{\text{(Total surface area - meat film area) (mm}^2\text{)(61.1)}}{\text{Total water(mg) in meat sample}} \times 100$$

$$\% \text{ WHC} = 100 - \% \text{ Free Water}$$

Cholesterol Analysis: Cholesterol content of cooked sausages was determined using the Boehringer Mannheim total cholesterol kit procedure (N° 139050, Boehringer Mannheim GmbH D-68298 Mannhein, Germany). Samples (2.5 g) were heated in 10 mL of methanol potassium hydroxide solution (1.0 mol / l) under a reflux condenser for 25 min while stirring. The supernatant was then transferred into a 25 mL volumetric flask and the residue was boiled twice with 6 mL isopropanol each under a reflux condenser for 5 min. The solution was collected in the volumetric flask, cooled and diluted to the mark with isopropanol. The mixture was then filtered and the clear solution used for assay.

Fatty Acid Analysis: Fatty acid compositions of cooked sausages were determined by capillary gas chromatography. Fatty acid methyl esters were prepared by base catalysis method : 6.45 g of KOH was dissolved in 50 mL of methanol. In the test tube, we introduced 0.5 g of fat and 4.5 mL of methanol. The mixture was shaken carefully and 0.25 mL of KOH in methanol was added to it with continuous shaking for 1 min. This solution was then left

to rest for 3 hrs. One mL of the solution was injected into the gas chromatograph (model 2000, Perichrom /AJ GmbH, Saux-les-chartreux, France). The column used was 3 mm x 311 mm fifted with DEGS 4 % on chromasorb 80/100 mesh conditioned at 200 °C. The oven temperature was 180 °C , injector and detector temperature were 230 °C. Loss of charge was 1 bar from nitrogen gas (0.5 mL/min) supply. Flow rates of air and hydrogen were 150 and 30 mL/min, respectively. Identification of peaks was based on GC retention times of known compounds (Standards kit of fatty acid methyl esters,Sigma,USA) and their comparison with that of a known butter chromatogram (Bormaz *et al.*, 1992)

Color measurement Cooked sausages were evaluated for L* (lightness), a* (redness) and b*(yellowness) values using a Minolta chroma-meter (model CR 210 Minolta Camera Co. Osaka, Japan) with 50 mm diameter aperture, referenced vs white calibration plate (L* 97.67, a*0.06, b*1.77).

Texture Measurements: All instrumental texture analyses were measured on chilled (2°C) samples. Texture analysis (TPA) was performed on the Instron Testing Machine (model 1122, Instron Co., Canton, MA, USA) as described by Bourne (1978). Five sausages cores (diam. 3.0 cm, height 2.0cm) per treatment were axially compressed to 50 % of original height for two cycles. Force time deformation curves were derived with a 1000 N load cell applied at a crosshead of 50 mm/min. Attributes were calculated as follows: hardness (Hd) = peak force (N) required for first compression; cohesiveness (Ch) = ratio of active work done under the second compression curve to that done under the first compression curve (dimensionless); springiness (Sp) = base width of second compression/base width of first compression (dimensionless); chewiness (Cw) = Hd x Ch x Sp (N).

Statistical Analysis: A completely randomized design was followed, and three batches per experimental treatment (three replications) were randomly and independly processed and analysed. One way analysis of variance was performed (Steel and Torrie, 1980). When variance analysis revealed a significant effect ($P < 0.05$), Duncan's mean separation technique (Duncan,1955) was employed.

Results and Discussion

Significant differences ($P < 0.05$) were observed in proximate composition in raw and cooked sausages according to fat sources (Table 1). The raw and cooked sausages containing beef and mutton fats had a higher ($P < 0.05$) water content and a lower fat content than those containing pork fat and pork fat/HSO blend. It is well known that the water content of meat products is inversely related to their fat content. Turkey-type salami containing the least amount of fat contained the highest moisture content (Javidipour and Vural, 2002). The higher pH and WHC of beef fat and mutton fat sausages is consistent with their higher water content and cooking yield. No significant differences ($P > 0.05$) in protein contents were observed in raw and cooked sausages as related to fat sources. A previous study of the effects of non-hydrogenated high-oleic acid sunflower oil (HOSO) on low-fat frankfurters revealed no significant differences in protein and fat contents of pork fat and HOSO sausages (Park *et al.*, 1990). These authors also reported a significant ($P<0.05$) higher water content in pork fat sausages than in HOSO ones. Incorporation of different palm fat at 20 and 25 % level did not affect the protein contents of chicken frankfurters (Tan *et al.*, 2001)

The differences in the fat contents between the different types of sausages was due to the effect of cooking on water loss and fat retention. The fat contents were significantly higher ($P<0.05$) in the pork fat and pork fat / HSO sausages agreeing with their lower moisture and higher fat retention compared to the beef fat and mutton fat sausages.

The lowest pH values were recorded for the 50 % pork fat/50 % HSO sausage and the highest for the beef fat and mutton fat sausages. Paneras and Bloukas (1994) reported that pork backfat had higher pH value than non-hydrogenated olive oil and frankfurters formulated with pork backfat had higher pH values compared to vegetable oil frankfurters. The WHC was higher in the beef and mutton fat sausages than in the pork and 50 % pork/50 % HSO sausages while WHC was intermediate in the pork sausages. Cooking yields were significantly higher for sausages containing beef mutton fat compared to those containing pork fat and pork fat/HSO blend. PARK *et al.* (1990) did not find any significant difference in processing yields between pork fat frankfurters and high-oleic sunflower oil sausages. They concluded that shrinkage was not affected by the type of fat. Cooking losses in ground beef patties were lower for beef patties than those containing 50% fat as peanut-oil (Liu *et al.*, 1991). St John *et al.* (1986) who evaluated the effect of reduced fat and elevated monounsaturated fat on quality of frankfurters, reported that processing yields increased as the amount of unsaturated fat increased in formulations. In the present study, the significant differences observed among the sausages with regard to the cooking yield can be attributed to the differences in their pH and WHC.

The type of fats significantly affected ($P < 0.05$) the cholesterol contents of the sausages (Table 2). The pork fat / HSO sausage had the lowest cholesterol content compared to the other types of sausages. These results were expected since oil does not contain cholesterol. Marquez *et al.* (1989) reported that substituting non-hydrogenated

peanut oil to 60 % beef fat decreased significantly cholesterol content of the products.

As expected, the type of fats significantly affected the fatty acid profiles of beef sausages (Table 3). The beef fat sausages had a higher monounsaturated fatty acids and the mutton sausages had the higher saturated fatty acids than all others sausages. From a nutritional point, monounsaturated fatty acids lower total plasma cholesterol and may decrease coronary heart disease (NCEP,1988). Incorporation of HSO into sausages significantly decreased total saturated fatty acids, palmitic acid (16:0) proportion. and stearic acid (18:0). Substituting HSO to pork fat reduced the amount of oleic acid (18:1) in the sausages. Similar results with 10 and 20 % fat as canola oil were previously reported (St. John *et al.* (1986)). Partial replacement of pork fat with HSO significantly ($P<0.05$) increased the content of linoleic acid (18:2). Inclusion of 2 % rice-bran oil in beef roasts increased the amount of linoleic acid (Kim *et al.*, 2000). Compared to the other fat sources, pork fat sausages had significantly higher linolenic acid (18:3). Linolenic acid, althouth nutritionally desirable, is considered a cancer risk in high concentration It also leads to oxidative loss of nutrients and the development of rancidity (Briggs and Schweigert, 1990).

Instrumental color measurements indicated that the 50 % pork fat/50 % HSO sausages had a higher "L" values than animal fat sausages (Table 4). The "a" value (red color) of beef sausages containing Pork/HSO was similar to those of pork fat and mutton fat sausages. The sausages formulated with beef fat had the lowest "a" value. The type of fats had no significant effect ($P > 0.05$) on "b" values (yellow color) of the sausages. Bishop *et al.* (1993), who studied the effect of pork fat (30%) and pre-emulsified corn oil (15%) (EO) on quality of bologna, found that bologna containing pork fat had a lower "L" values than EO treatments. Frankfurters with 60 % fat as peanut oil had higher "L" values than beef sausages (Marquez *et al.*, 1989).Tan *et al.* (2001) found that chicken frankfurters formulated with palm olein recorded.

Table1: Proximate composition and fat retention of raw and cooked beef sausages (g/10g sausages)

	fat source			
	Beef	Mutton	Pork	Pork/HSO
raw	61.9±0.4^{a}	61.9±0.6^{a}	60.5 ± 0.6^{b}	57.52±0.4^{c}
Water cooked	58.2 ± 0.5^{a}	58.8 ± 0.7^{a}	58.8 ± 0.7^{a}	58.8±0.7^{a}
raw	14.29 ± 0.53^{a}	15.6 ± 0.8^{a}	14.05 ± 0.4^{a}	15.3 ± 0.5^{a}
Protein cooked	16.7 ± 0.8^{a}	17.6 ± 0.8^{a}	16.8 ± 0.5^{a}	16.3 ± 0.9^{a}
Fat cooked	18.7 ± 0.7^{c}	17.4 ± 0.6^{c}	21.7 ± 0.5^{b}	20.3± 0.7^{a}
Fat retention	75.6 ± 1.75^{c}	65.1 ± 1.9^{d}	91.1 ± 1.3^{a}	82.1±1.7^{b}

Means ± S.D of 3 samples

abcd On the same row means bearing different superscripts differ significantly ($P < 0.05$).

Table 2: Means for pH, WHC, Cooking yields and Cholesterol content of beef sausages

	fat source*			
	Beef	Mutton	Pork	Pork /HSO
pH (raw)	5.70 ± 0.03^{a}	5.76 ± 0.03^{a}	5.65 ± 0.02^{c}	5.59 ±0.04^{d}
WHC, % (raw)	86.2 ± 0.8^{a}	87.3 ± 0.8^{a}	76.7 ± 0.9^{b}	73.2 ± 0.7^{c}
Cooking yields,%	87.5 ± 0.7^{a}	88.4 ± 0.6^{a}	79.3 ± 0.8^{b}	76.2 ± 0.7^{c}
Cholesterol (mg/100 g cooked sausage)	53.5 ± 1.4^{b}	57.6 ± 1.1^{a}	56.4± 1.3^{a}	47.1 ± 1.2^{c}

*Means ± S.D of 3 samples

abcd On the same row means bearing different superscripts differ significantly ($P < 0.05$)

Table 3: Means for fatty acid profiles of cooked beef sausages (% of total fatty acids)

	fat source*			
Fatty acid	Beef	Mutton	Pork	Pork/HSO
C14:0	4.3 ± 0.1^{b}	6.1 ± 0.4^{a}	1.5 ± 0.1^{d}	2.2 ± 0.1^{c}
C16:0	24.1 ± 0.7^{a}	27.2 ± 0.8^{b}	23.1 ± 0.6^{a}	15.0 ± 0.4^{c}
C16:1	4.4 ± 0.2^{a}	3.4 ± 0.2^{b}	2.9 ± 0.1^{c}	1.5 ± 0.0^{d}
C18:0	15.1 ± 0.4^{b}	17.7 ± 0.4^{a}	12.4 ± 0.2^{c}	10.1 ± 0.3^{d}
C18:1	46.1 ± 1.5^{a}	39.1 ± 1.4^{b}	44.7 ± 1.6^{a}	31.1 ± 0.8^{c}
C18:2	4.6 ± 0.2^{c}	4.2 ± 0.2^{c}	13.1 ± 0.4^{b}	38.5 ± 0.9^{a}
C18:3	0.4 ± 0.0^{d}	0.7 ± 0.0^{b}	0.9 ± 0.0^{a}	0.6 ± 0.0^{c}
C20:0	0.4 ± 0.0^{b}	0.9 ± 0.0^{a}	0.2 ± 0.0^{c}	0.1 ± 0.0^{d}
C20:1	0.4 ± 0.0^{c}	0.21 ± 0.0^{d}	0.9 ± 0.0^{a}	0.5 ± 0.0^{b}
C20:4	-	0.1 ± 0.0^{b}	0.2 ± 0.0^{a}	0.1 ± 0.0^{b}
Total saturated	43.9^{b}	52.0^{a}	37.1 c	27.4^{d}
Total monounsaturated	50.9^{a}	42.7^{c}	48.5^{b}	33.2^{d}
Total polyunsaturated	5.1^{c}	5.2^{c}	14.27^{a}	39.2^{b}

*Means ± S.D of 3 samples

abcd On the same row means bearing different superscripts differ significantly ($P < 0.05$)

Table 4: Instrumental measurements of color of cooked sausages

	Fat source*			
	Beef	Mutton	Pork	Pork /HSO
L	54.1 ± 0.3^{c}	55.9 ± 0.5^{b}	56.2 ± 0.4^{b}	59.4 ±0.2^{a}
a	12.1 ± 0.1^{b}	16.6 ± 0.1^{a}	16.5 ± 0.2^{a}	16.7 ± 0.1^{a}
b	9.1 ± 0.1^{a}	9.02 ± 0.1^{a}	9.1 ± 0.1^{a}	9.1 ± 0.1^{a}

Means ± S.D of 3 samples
abc On the same row means bearing different superscripts differ significantly ($P < 0.05$).

Table 5: Means for textural profile analysis

	Fat source*			
	Beef	Mutton	Pork	Pork /HSO
Hardness, N	118.9 ± 3.2^{c}	133.2 ± 2.8^{a}	96.6 ± 2.1^{b}	89.3 ± 2.5^{d}
Cohesiveness	0.4 ± 0.1$^{a}_{c}$	0.6 ± 0.1^{a}	0.6 ± 0.1^{b}	0.6 ± 0.1^{a}
Springiness	0.6 ± 0.1	0.8 ± 0.1^{a}	0.6 ± 0.1^{c}	0.7 ± 0.1^{b}
Chewiness, N	37.1 ± 2.9^{b}	74.7 ± 3.4^{a}	39.4 ± 2.6^{b}	40.8 ± 2.4^{b}

*Means ± S.D of 3 samples
abcd Means in the same row bearing different superscripts differ significantly ($P < 0.05$)

the highest lightness. They also reported that increasing fat concentration in frankfurters resulted in higher values of L an b values of frankfurters. Hammer (1992) had related the lightness to the degree of fat dispersion in frankfurters. Therefore The light falling on the surface of the sausage containing HSO was more broken up than that of those of animal fats ,thus proceeding a grater impression of lightness.

Results from texture analyses of beef sausages are shown in Table 5. The fatty acid composition have affected the texture profile of the sausages. The pork/ HSO sausage with the highest polyunsaturated fatty acids was softer than the other sausages. The penetrometer value increased as unsaturated fatty acid contents increased in the Turkish-type salami (Javidipour and Vural, 2002). Bishop *et al.* (1993) reported that bologna sausage with pre-emulsified corn oil was softer than bologna sausage with pork fat. Hardness and chewiness were significantly higher ($P < 0.05$) for the mutton fat sausages when compared to the other sausages. The higher hardness value observed with the mutton sausage was probably due to the higher melting point of saturated fatty acids compared to unsaturated fatty acids. Springiness and chewiness were not significantly different ($P > 0.05$) between beef fat and pork fat sausages. Park *et al.* (1989) reported that low-fat beef/pork frankfurters containing high oleic acid sunflower oil had higher hardness and springiness values compared to high-fat beef/pork frankfurters.

Conclusion

Different types of animal fats such as beef, pork and mutton fats and HSO were used to produce beef sausages. The type of fats had no influence on protein content of the cooked sausages. Cholesterol content was the lowest in the pork fat/ HSO sausages. The product containing HSO was comparable to the pork and mutton fat sausages in red color. Fatty acid compositions showed that substituting HSO to pork fat reduced the percentage of saturated fatty acids from 37.1 % in the pork fat sausages to 27.4 % in the pork fat/HSO blend. Substitution of oil to animal fat substantially decreased hardness from 133.2 N in mutton sausages to 89.3 N in pork/HSO sausages. The soft texture of pork/HSO can be a limiting factor for the use of HSO in sausages.

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