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Effect of vegetable oils on fatty acid composition and cholesterol content of chicken frankfurters

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Abstract. To study the effect of pork adipose tissue substitution with vegetable oils in chicken frankfurters, six frankfurter formulations were produced: control; with pork backfat; with olive oil; with rapeseed oil; with sunflower oil; with palm oil, and; with a mixture of 12% rapeseed oil and 8% palm oil. Fatty acid composition and cholesterol content and some oxides thereof were determined in the final products. The use of vegetable oils resulted in improvement of the fatty acid composition and nutritional of frankfurters. Frankfurters with vegetable oils contained significantly less cholesterol and some of its oxides, compared to the frankfurters with pork fat. The formulation with palm oil had the least favourable fatty acid composition. The use of 12% rapeseed oil improved the ratio of fatty acids in frankfurters with a mixture of rapeseed and palm oils. Complete pork fat replacement with vegetable oils in chicken frankfurter production is technologically possible. The mixture of 12% rapeseed oil and 8% palm oil is a good alternative to pork fat from health aspects. Further research is needed to find the most appropriate mixture of vegetable oils, which will produce frankfurters with good sensory characteristics, a more desirable fatty acid ratio and high nutritional value.

1 Introduction

Meats and processed meats are associated with nutrients and nutritional profiles that are often considered negative, including high levels of saturated fatty acids, cholesterol, sodium and high fat and caloric contents [1]. Animal fats have long been utilized in processing meat products. However, the use of animal fat in meat products has emerged as a topic of increasing concern to consumers [2]. Diets rich in animal fat are associated with several types of obesity, hypertension, cardiovascular and coronary heart diseases [3].

In recent years, consumer demands for healthier meat and meat products with reduced levels of fat, cholesterol, decreased contents of sodium chloride and nitrite, improved composition of fatty acid profile and incorporated health-enhancing ingredients are rapidly increasing worldwide [4]. Modern eating habits have changed towards a diet high in saturated fatty acids and unbalanced in polyunsaturated fatty acids, with a high n-6/n-3 ratio [5]. However, this ratio should be ideally <5 [5].



Frankfurters are non-fermented, emulsion type cooked sausages [6], and are one of the most popular traditional meat products in the world [7]. However, their consumption likely has negative health effects regarding the amounts and types of animal fats that they contain [8].

The potential health risks associated with the consumption of high fat foods has led to development of new formulations to modify traditional food products so they contain less fat [9]. The substitution of animal fat with vegetable oils has been suggested to improve the fatty acid profile and to decrease the cholesterol levels of meat products. Vegetable oils have positive effects on the cardiovascular system [3].

Therefore, the objective of the present investigation was to examine the effects of pork backfat substitution with several vegetable oils and fats on fatty acid composition, cholesterol content and some oxides thereof.

2 Materials and Methods

Frankfurters made from chicken (boneless breast and thigh) were used in the present research. Six different frankfurters were produced, compositions of which are given in table 1. The control frankfurters were prepared with pork backfat (Po). The other five types of frankfurters were prepared with olive oil (O); rapeseed oil (R); sunflower oil (S); palm oil (Pa), and a mixture of 12 % rapeseed oil and 8 % palm oil (Mi).

Table 1. Frankfurter formulation (%).

Ingredients	Po	O	R	S	Pa	Mi
Chicken breasts without skin	23	23	23	23	23	23
Chicken thighs without skin	23	23	23	23	23	23
Pork backfat	20					
Olive oil		20				
Rapeseed oil			20			12
Sunflower oil				20		
Palm oil					20	8
Nitrite curing salt	1.7	1.7	1.7	1.7	1.7	1.7
Ice	32	32	32	32	32	32
Sodium tripolyphosphate	0.2	0.2	0.2	0.2	0.2	0.2
Mixture of spices	0.2	0.2	0.2	0.2	0.2	0.2
Sodium isoascorbate	0.075	0.075	0.075	0.075	0.075	0.0705
Soy protein isolate	2	2	2	2	2	2

Artificial collagen edible casings, 23 mm in diameter (Naturin GmbH, Weinheim, Germany), were used for stuffing the batter. Heat treatment was performed in smokehouse at 78°C until an internal temperature of 72°C was achieved.

Fatty acids in the frankfurters were detected based on their methyl ester content according to the method described by Park and Goins [10]. Separation of fatty acid methyl esters was performed on a gas chromatograph (Agilent Technologies 6890) with a flame-ionization detector and capillary column type HP-88 (100 m x 0.25 mm x 0.20 µm).

The cholesterol content of the frankfurters was determined by the modified method according to Ubhayasekera et al. [11]. After saponification of cholesterol with the basic reagent, cleaning of the sample was carried out by the SPE procedure using Strata Si-1 columns (Phenomenex 8B-5 Ø12-HBJ). The cholesterol content was determined by high pressure liquid chromatography.

For determination of cholesterol oxides, the method by Ubhayasekera et al. [11] was used. Once cholesterol was separated, the sample was cleaned and SPE (Strata Si-1, Phenomenex) was

performed. Cholesterol oxides were determined by gas chromatography with capillary column HP-5ms (30 m x 0.32 mm x 0.25 μ m).

The program package SAS/STAT [12] was used for statistical processing of data and significance, means were separated using Duncan's test.

3 Results and Discussion

3.1 Fatty acid profile of frankfurters

The fatty acid composition of frankfurters is presented in table 2. The highest content of saturated fatty acids (SFA) (46.23%) was observed in frankfurters with palm oil (Pa), which was even higher than the SFA content in frankfurters with pork fat (41.73%) (Po). The lowest SFA content (12%) was observed in frankfurters with rapeseed oil (R). The frankfurters with olive oil (O), sunflower oil (S) and mixture of 12% rapeseed oil and 8% palm oil (Mi) had lower contents of SFA as well, compared to the control treatment (Po). The differences between frankfurter formulations were statistically significant ($P < 0.001$). It is clear that the type of vegetable oil used affected the fatty acid composition of the frankfurters. Among the SFAs, the most common was palmitic acid, with the highest content (39.93%) in Pa frankfurters and the lowest (8.08%) in S frankfurters. Stearic acid was found at percentages among SFA from 2.88% (in R frankfurters) to 13.46% (Po). The differences between frankfurters were statistically significant ($P < 0.001$).

Table 2. Fatty acid composition of frankfurters (mean \pm standard deviation).

% of total fatty acids	Treatments					
	Po	O	R	S	Pa	Mi
C10:0	0.09 \pm 0.01 ^a	0.01 \pm 0.00 ^c	0.01 \pm 0.00 ^c	0.01 \pm 0.00 ^c	0.02 \pm 0.00 ^b	0.01 \pm 0.00
C12:0	0.09 \pm 0.00 ^b	0.01 \pm 0.00 ^d	0.01 \pm 0.00 ^d	0.01 \pm 0.00 ^e	0.16 \pm 0.00 ^a	0.08 \pm 0.00
C14:0	1.57 \pm 0.11 ^a	0.22 \pm 0.03 ^d	0.11 \pm 0.02 ^d	0.11 \pm 0.01 ^d	1.13 \pm 0.24 ^b	0.50 \pm 0.07
C16:0	25.98 \pm 0.73	13.81 \pm 0.14	8.16 \pm 0.28 ^e	8.08 \pm 0.30 ^e	39.93 \pm 0.58 ^a	21.90 \pm 0.3
C16:1n-9c	2.42 \pm 0.06 ^a	1.24 \pm 0.01 ^b	0.45 \pm 0.02 ^{dc}	0.32 \pm 0.00 ^d	0.61 \pm 0.19 ^c	0.48 \pm 0.05
C18:0	13.46 \pm 0.09 ^a	3.38 \pm 0.09 ^d	2.88 \pm 0.08 ^e	4.04 \pm 0.03 ^c	4.50 \pm 0.25 ^b	3.51 \pm 0.11
C18:1n-7c	0.18 \pm 0.02 ^a	0.02 \pm 0.04 ^d	0.05 \pm 0.00 ^{cb}	0.04 \pm 0.00 ^{cd}	0.08 \pm 0.00 ^b	0.06 \pm 0.00
C18:1n-9c	36.22 \pm 0.26 ^e	67.17 \pm 0.04 ^a	46.24 \pm 0.15 ^b	23.51 \pm 0.20 ^f	37.27 \pm 0.12	42.97 \pm 0.4
C18:2c9t12	0.00 \pm 0.00 ^d	0.02 \pm 0.00 ^c	0.03 \pm 0.01 ^b	0.00 \pm 0.00 ^d	0.04 \pm 0.00 ^a	0.03 \pm 0.00
C18:2c9c1	13.85 \pm 0.50	10.54 \pm 0.15 ^e	32.73 \pm 0.10 ^b	61.20 \pm 0.52 ^a	11.02 \pm 0.38 ^e	23.71 \pm 0.1
C18:3n-6	0.05 \pm 0.00 ^a	0.02 \pm 0.00 ^{cd}	0.02 \pm 0.00 ^{cb}	0.01 \pm 0.00 ^d	0.02 \pm 0.00 ^b	0.02 \pm 0.00
C18:3n-3	0.24 \pm 0.03 ^c	0.39 \pm 0.03 ^b	0.44 \pm 0.00 ^a	0.23 \pm 0.01 ^c	0.38 \pm 0.04 ^b	0.39 \pm 0.01
C20:4n-6	0.64 \pm 0.12 ^a	0.24 \pm 0.02 ^c	0.21 \pm 0.02 ^c	0.18 \pm 0.02 ^c	0.45 \pm 0.09 ^b	0.23 \pm 0.04
C20:5n-3	0.38 \pm 0.26 ^b	0.33 \pm 0.01 ^{cb}	0.00 \pm 0.00 ^d	0.02 \pm 0.00 ^d	0.82 \pm 0.01 ^a	0.16 \pm 0.01
C22:5n-3	0.12 \pm 0.00 ^a	0.02 \pm 0.01 ^d	0.03 \pm 0.00 ^c	0.03 \pm 0.00 ^{dc}	0.05 \pm 0.01 ^b	0.03 \pm 0.00
C22:6n-3	0.58 \pm 0.38 ^{ba}	0.40 \pm 0.02 ^{bc}	0.05 \pm 0.00 ^d	0.05 \pm 0.00 ^d	0.73 \pm 0.05 ^a	0.21 \pm 0.01
Σ SFA	41.73 \pm 0.64	17.82 \pm 0.03	12.00 \pm 0.24 ^f	13.14 \pm 0.29 ^e	46.23 \pm 0.11 ^a	26.62 \pm 0.4
Σ MUFA	41.68 \pm 0.28	70.04 \pm 0.08 ^a	54.16 \pm 0.19 ^b	24.88 \pm 0.20 ^f	39.93 \pm 0.27 ^e	48.26 \pm 0.3
Σ PUFA	16.59 \pm 0.40	12.14 \pm 0.05 ^f	33.84 \pm 0.10 ^b	61.98 \pm 0.49 ^a	13.84 \pm 0.23 ^e	25.12 \pm 0.1
n-6	14.59 \pm 0.36	10.80 \pm 0.13 ^f	32.97 \pm 0.10 ^b	61.42 \pm 0.50 ^a	11.51 \pm 0.30 ^e	24.03 \pm 0.1
n-3	1.32 \pm 0.68 ^b	1.14 \pm 0.06 ^b	0.52 \pm 0.01 ^c	0.33 \pm 0.02 ^c	1.97 \pm 0.09 ^a	0.80 \pm 0.04
n-6/n-3	12.90 \pm 5.36	9.46 \pm 0.63 ^d	63.78 \pm 1.23 ^b	185.88 \pm 12.74	5.85 \pm 0.39 ^d	30.02 \pm 1.4
PUFA/SFA	0.40 \pm 0.02 ^e	0.68 \pm 0.00 ^d	2.82 \pm 0.06 ^b	4.72 \pm 0.14 ^a	0.30 \pm 0.00 ^e	0.94 \pm 0.02

Trans FA	0.28±0.02 ^b	0.15±0.01 ^d	0.36±0.01 ^a	0.09±0.00 ^e	0.10±0.01 ^e	0.23±0.01
IA	0.56±0.01 ^b	0.18±0.00 ^d	0.10±0.00 ^e	0.10±0.00 ^e	0.83±0.01 ^a	0.33±0.01

^{a-f} – Means within a row with different superscript letters are significantly different ($P < 0.001$).

Po – Pork backfat (control); O – Olive oil; R – Rapeseed oil; S – Sunflower oil; Pa – Palm oil; Mi – Mixture of 12% rapeseed oil and 8% palm oil.

SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids; IA – Atherogenic index.

Frankfurters produced with sunflower oil (S) had convincingly the lowest content (24.88%) of monounsaturated fatty acids (MUFA). That was due to the low content of these acids in the sunflower oil itself. The highest content of these acids was found in frankfurters with olive oil (O) (70.04%). There were significant differences ($P < 0.001$) between the amounts of MUFA in the different frankfurters. The most abundant MUFA was the *cis*-form of oleic acid, which ranged from 23.51% (S frankfurters) to 67.17% (M frankfurters). In terms of the total percentage of all the fatty acids, it was also the most common fatty acid in the frankfurters.

Polyunsaturated fatty acids (PUFA) were the most plentiful (61.98%) in the frankfurters produced with sunflower oil (S). This was a result of the high content of PUFA in sunflower oil. A somewhat high PUFA content (33.84%) was also measured in the frankfurters with rapeseed oil (R). Therefore the frankfurters with Mi, the composition of which also contained rapeseed oil, were characterized by a slightly higher content of PUFA than the other frankfurters, with the exception of the frankfurters with S and R. Frankfurters produced with olive oil (M) had the lowest content of PUFA (12.14%). Frankfurters with Pa had the highest content of n-3 fatty acids (1.97%), and those with S had the lowest (0.33%). Differences between frankfurters were significant ($P < 0.001$).

The ratio of n-6 to n-3 fatty acids is dependent on the type of oil used in the frankfurters. It can be concluded that only frankfurters with Pa (5.85) and O (9.46) had a favourable n-6/n-3 ratio. Other frankfurters had unfavourable n-6/n-3 ratios. Frankfurters with S had the most unfavourable n-6/n-3 ratio (185.88).

The lowest value of PUFA/SFA ratio (0.30) was found in the frankfurters with Pa (table 2). This value is inconvenient because the PUFA/SFA ratio was lower than 0.5. An unfavourable PUFA/SFA ratio (0.4) was also found in the Po frankfurters. The highest PUFA/SFA ratio (4.72) was found in frankfurters with S. Other frankfurter formulations also had favourable PUFA/SFA ratios which were higher than 0.5. Differences between frankfurters were statistically significant ($P < 0.001$).

The highest content of *trans*-fatty acids was found in the rapeseed oil formulation (0.36%) and the lowest (0.09%) in the sunflower oil formulation. In control frankfurters (Po), *trans*-fatty acids comprised 0.28% of the fatty acids. Frankfurters produced with beef fat contained more *trans*-fatty acids while frankfurters with sunflower oil contained less [13]. Frankfurters formulated with olive oil had lower *trans*-fatty acids content than control frankfurters with pork fat [14].

The value of the atherogenic index (IA) is also dependent on the type of oil used in frankfurter production (table 2). Values of IA higher than 0.5 are considered undesirable. Unfavourable IA values were determined in the palm oil treatment (0.83) and pork fat treatment (0.56). The remaining treatments had a favourable IA values. The most desirable IA value (0.10) was found in the frankfurters containing rapeseed (R) or sunflower (S) oils. There were significant differences ($P < 0.001$) among the frankfurter formulations.

The results of the present investigation showed that the oils or fats used significantly affected the fatty acid composition and the nutritional value of frankfurters. Other researchers also concluded that by replacing animal fats with vegetable oils in the beef frankfurter production, the nutritional content of product was improved due to alteration of the fatty acid composition [15]. Frankfurters produced with sunflower oil, unlike those produced with beef fat, were characterized by a better fatty acid composition [13,16]. Generally, from a nutritional point of view, it can be concluded that frankfurters produced with vegetable oils are far more favourable than those produced with pork fat, because they contain less saturated and more unsaturated fatty acids.

3.2 Cholesterol content and cholesterol oxides in the frankfurters

The cholesterol content of the frankfurters ranged from 37.96 to 48.41 mg/100 g (table 3). In frankfurters produced with vegetable oils, the cholesterol content was lower compared to those with pork fat. Differences between frankfurters were statistically significant ($P < 0.001$). This means that pork fat significantly increased the cholesterol levels in the frankfurters. This stems from the fact that plant cells do not contain cholesterol, as opposed to animal cells that do contain cholesterol.

Table 3. Content of cholesterol content and some cholesterol oxides in the frankfurters (mean±standard deviation).

Parameters (mg/100g)	Treatments					
	Po	O	R	S	Pa	Mi
Cholesterol	48.41±0.89 ^a	38.90±0.38 ^{bc}	37.96±0.64 ^d	39.24±0.17 ^{bc}	38.66±0.22 ^c	39.48±0.06 ^b
7b-hydroxy cholesterol	1.37±0.37 ^a	0.78±0.06 ^b	1.55±0.76 ^a	0.33±0.13 ^c	1.59±0.12 ^a	1.22±0.13 ^a
5a-hydroxy cholesterol	0.00±0.00 ^a	0.00±0.00 ^a	0.00±0.00 ^a	0.00±0.00 ^a	0.00±0.00 ^a	0.00±0.00 ^a
20a- hydroxy cholesterol	1.73±0.11 ^{ab}	1.79±0.31 ^a	1.55±0.13 ^b	0.51±0.30 ^c	0.09±0.02 ^d	0.19±0.03 ^d
25a- hydroxy cholesterol	0.03±0.02 ^a	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b	0.00±0.00 ^b

^{a-d} – Means within a row with different superscript letters are significantly different ($P < 0.001$).

Po – Pork backfat (control); O – Olive oil; R – Rapeseed oil; S – Sunflower oil; Pa – Palm oil; Mi – Mixture of 12% rapeseed oil and 8% palm oil.

In general, the cholesterol content in all six frankfurter formulations was low. The relatively low cholesterol content was due to the use of chicken thighs and breasts without skin, by which a good part of the cholesterol in the poultry meats was eliminated. Lower fat content in the raw material results in lower fat and cholesterol contents in the finished products [17]. The lowest cholesterol content (37.96 mg/100 g) was measured in the frankfurters with rapeseed oil (R). Frankfurters produced with pork fat (Po) had the highest content (48.41 mg/100 g) of cholesterol, which was expected. The cholesterol content of commercial chicken frankfurters amounts to 100 mg/100 g [18]. In another study, vegetable oil and rice bran fibre-containing reduced-fat frankfurters had significantly lower cholesterol contents than the control frankfurters with pork fat [14].

From table 3, it is clear there was no 5a-hydroxy cholesterol in frankfurters (levels were below the limit of detection). 25a-hydroxy cholesterol was present in trace amounts (0.03 mg/100 g) only in control frankfurters (Po). 7b-hydroxy cholesterol and 20a-hydroxy cholesterol were present in all frankfurter formulations. The content of 7b-hydroxy cholesterol ranged from 0.33 to 1.59 mg/100 g, while the content of 20a-hydroxy cholesterol in frankfurters ranged from 0.09 to 1.79 mg/100 g. There were significant differences ($P < 0.001$) between frankfurters.

4 Conclusion

Total pork fat replacement with vegetable oils is possible in chicken frankfurter production. In general, frankfurters produced with vegetable oils had significantly more favourable fatty acid composition and nutritional value (PUFA/SFA ratio, n-6/n-3 ratio and IA value).

The cholesterol content and some cholesterol oxides in frankfurters with vegetable oils were significantly ($P < 0.001$) lower in comparison with pork fat frankfurters.

From a nutritional health aspect, frankfurters produced with palm oil had the least favourable fatty acid composition due to the unfavourable fatty acid composition of palm oil. However, a mixture of

12% rapeseed oil and 8% palm oil is a good alternative to pork fat. The use of palm oil improved the sensory characteristics of frankfurters (data not shown), while rapeseed oil has improved the fatty acid composition and the nutritional value of the products.

In order to improve the fatty acid composition and nutritional value of frankfurters produced with a similar mixture of rapeseed and palm oils, further research is needed. A better mixture of vegetable oils will contribute to the preservation of sensory characteristics while improving the fatty acid composition and nutritional value of chicken frankfurters.

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