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Pork Skin and Canola Oil as Strategy to Confer Technological and Nutritional Advantages to Burgers

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Abstract

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The effect of pork backfat replacement by gels containing pork skin and canola oil on some physicochemical, technological, nutritional, and sensory parameters of burgers was evaluated. Three different batches were manufactured: a control with 100% of pork backfat, and treatments T1 and T2 where 50% of pork backfat was replaced by pork skin/water/canola oil mixtures at 45 : 45 : 10 (T1) or 40 : 40 : 20 (T2) ratios. A fat reduction up to 34% and an improvement of the fatty acid profile were achieved in the reformulated burgers. Lower diameter reduction and lower cooking loss were observed in the modified samples. Although an increase in TPA parameters (hardness, gumminess, and chewiness) and lightness (L^*) was observed, the overall acceptability of the reformulated burgers was not affected. Therefore, the use of pork skin and canola oil is an effective strategy to confer technological and nutritional advantages to low-fat burgers.

Keywords: hamburger; fat replacer; healthier meat products; sensory quality; fatty acid profile

Due to low price, convenience, and high sensory quality, beef burgers are widely consumed worldwide. In general, burgers contain up to 30% of fat with a high level of saturated fatty acids. Thus, the frequent use of this product is not indicated as part of a healthy diet, since the excessive intake of saturated fatty acids has been related to an increased incidence of hypertension, obesity, cardiovascular diseases, and some types of cancer (World Health Organization 2009).

To produce healthier burgers and meet consumer demand for a healthier diet, it is necessary to reduce the fat content and modify the fatty acid profile of the formulations. However, reducing fat is not a simple task, since animal fat plays an essential function in the sensory quality by developing characteristic taste and aroma and helps to improve the water holding capacity and imparts juiciness to the meat products (Feiner 2006). Thus, the challenge of the meat industry is to find economically viable alternatives to decrease the fat level and provide a healthier lipid profile in their products without damage to their technological and sensory quality.

An ideal fat replacer should not dramatically alter the sensory and technological properties. Thus, the combination of different ingredients acting synergistically is a strategy to decrease the fat level and provide a better lipid profile without jeopardizing the most important quality attributes of meat products. The substitution of vegetable oils for animal fat

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has appeared as one of the most useful strategies to provide a healthier lipid profile to the meat products. This approach is useful to increase monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA), and to reduce saturated fatty acids (SFAs) (Rodríguez-Carpena *et al.* 2012; Ospina *et al.* 2015). In this sense, canola oil has low levels of SFAs (7%) and linoleic acid (21%). Also, canola oil contains 11% of linolenic acid, and an excellent n-6/n-3 ratio of 1.90 (McDonald 2010). However, the use of vegetable oils in meat products can have a negative impact on important quality parameters, such as taste, aroma, and overall acceptability (Salcedo-Sandoval *et al.* 2015). Pork skin (PS) has proven to be an effective alternative to improve the texture and yield in low-fat meat products (Choe *et al.* 2013; De Oliveira Faria *et al.* 2015; Alves *et al*. 2016). Besides, PS contains high levels of collagen (Feiner 2006) and therefore can compensate the lower protein content, which is observed when non-protein ingredients are used as a fat replacer.

Until now, no studies have been realised about the combined use of PS and canola oil as a fat replacer in beef burgers. So, in this study burgers were produced with 50% fat replacement by gels containing different concentrations of PS, water, and canola oil. The impact of such a substitution on some physicochemical, technological, nutritional and sensory parameters of burgers was evaluated.

MATERIAL AND METHODS

Formulation and processing of burgers. Post-rigor beef meat (*Quadriceps femoris)* – PS and pork backfat – were obtained from a local meat market. The spices and additives were donated by Ibrac Aditivos e Condimentos (Brazil). Canola oil was provided by Cargill Agrícola S.A (Brazil). Three formulations of burgers were produced in the pilot plant. The control group was produced with 15% pork backfat. In the modified treatments (T1 and T2), a substitution of gels containing different proportions of PS, water, and canola oil (45 : 45 : 10 T1 and 40 : 40 : 20 T2) for 50% pork backfat was performed (Table 1). To produce the gels, PS was cooked at 80°C for 60 minutes. Afterwards, PS was ground (3 mm) and cooled at 37°C. Then, PS was mixed with water and canola oil (15 000 rpm, Ultra-Turrax® T25basic). After homogenisation, the gels were cooled at 4°C in a sealed flask.

Table 1. Formulation of beef burgers

Composition (%)	Batch		
	control	T1	T2
Beef meat	81.95	81.95	81.95
Pork back fat	15.00	7.5	7.5
Fat replacer gels			
Pork skin	–	3.375	3.0
Water	–	3.375	3.0
Canola oil	–	0.75	1.5
Salt	2.5	2.5	2.5
Garlic	0.5	0.5	0.5
Sodium erythorbate	0.05	0.05	0.05
Total	100	100	100

Chemical composition: beef meat – moisture 72.41 ± 0.11%, protein 20.32 ± 0.14%, fat 2.21 ± 0.11%; pork backfat – moisture 10.82 ± 0.17%, protein 8.15 ± 0.12%, fat 80.22 ± 0.22%; pork skin – moisture 54.12 ± 0.10%, protein 36.1 ± 0.13%, fat 6.01 ± 0.02%

For the preparation of burgers, beef, pork backfat and gels were separately ground (Model PJ22; Jamar Ltda, Brasil) using a 3-mm plate. Then, the raw materials were mixed with the remaining ingredients (Model MJI 35 mixer; Jamar Ltda, Brazil). Burgers (60 g) with 11 cm diameter and 2.5 cm thickness were manufactured using a conventional burger-maker (Model HP 112; Picelli, Brasil). The burgers were stored at –18°C until the analysis. Part of the analyses were performed in raw or in cooked burgers. Cooking of the samples was performed prior to the determinations using an electrical grill (Model Multi Grill; Britânia, Brazil) until the internal temperature was 75°C in the geometrical centre of each burger. A hypodermic type thermometer (Model HM-600; Highmed, Brazil) was inserted in the geometrical centre of each burger to determine the internal temperature.

Proximate composition, pH and water activity. The proximate composition (moisture, protein, fat and ash contents), pH and a_w of both the gels and raw burgers were determined in triplicate using three samples for each treatment. The proximate composition was determined according to AOAC (2005; 17th edition) and the pH and a_w were determined according to Alves *et al.* (2016).

Cooking properties. Three burgers of each treatment were cooked (procedures previously described) and cooled at 25°C. Cooking loss percentage was calculated as weight loss divided by original weight.

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The diameter reduction was calculated as percentage, according to Berry (1992) using the following equation: Diameter reduction (%) = [(diameter of the raw burger – diameter of the cooked burger)/diameter of the raw burger)] × 100.

Texture profile analysis (TPA). Texture profile analysis (TPA) was realised using a TA-TX2 Texture Analyser (Stable Micro Systems Ltd., UK) with a load cell of 25 kg as described by Bourne (1978). Three burgers of each treatment were cooked (procedures previously described) and cooled at 25°C. Twelve cylinders per batch, each 2 cm thick and 2 cm in diameter, were cut from the cooked burgers using a cylindrical knife (4 cylinders per burger). Samples were axially compressed into two consecutive cycles of 50% compression using a 36-mm-diameter probe. Data were analysed for hardness (N), springiness (mm), cohesiveness, gumminess (N), and chewiness (N × mm).

Colour instrumental determination. The colour of both raw and cooked burgers was measured according to the CIE $L^*a^*b^*$ system with a Minolta CR-400 colorimeter (Konica Minolta Sensing Inc., Japan). The spectral reflectance was included as calibration mode. An illuminant D65 and observation angle of 10° were used. L^*, a^*, and b^* values were determined as indicators of lightness, redness, and yellowness, respectively. The colour variables were measured at four points on the central part of the cut surface of three raw and three cooked burgers.

Determination of the fatty acid profile. The fatty acid profile of the raw burgers was determined in triplicate using three samples for each treatment. The lipids were extracted (Bligh & Dyer 1959) and a 50 mg sample was subjected to methylation (Hartman & Lago 1973), based on the saponification with a 0.4 M NaOH methanolic solution and acid-catalysed esterification using 1 M H_2SO_4 methanolic solution. The internal standard methyl tricosanoate (23:0) was added to the sample before the esterification procedure. The methylated samples were analysed using a gas chromatograph equipped with a flame ionisation detector (GC-FID) (Varian 3400) and autosampler Varian 4200 (both Variant, USA). An amount of 1 µl of the FAME sample was injected into a split/splitless inlet, operating in split mode, with a 1 : 50 ratio at 240°C. The carrier gas was hydrogen with a constant pressure of 15 psi, the FAME were separated in a CP-Wax 52 CB capillary column (Supelco, USA) (50 m × 0.32 mm × 0.20 µm). The programming temperature of the oven column was initially 50°C for 1 min, then it was increased to 240°C at a rate of 3°C/min, being maintained in isothermal mode for 15 minutes. The detector temperature was maintained at 240°C. FAME identification was performed by comparison of retention times of analytes with authentic FAME standards Mix-37 (P/N 47885-U). The results were expressed as mg of fatty acids per 100 g of fatty acids according to Visentainer (2012). The atherogenic (AI) and thrombogenic indices (TI) were calculated according to Ulbricht and Sauthgate (1991):

$$AI = [C12:0 + (4 \times C14:0) + C16:0]/[(\Sigma PUFA) + (\Sigma MUFA)] \quad (1)$$

$$TI = [C14:0 + C16:0 + C18:0]/[(0.5 \times \Sigma MUFA) + (0.5 \times n\text{-}6) + (3 \times n\text{-}3) + (n\text{-}3/n\text{-}6)] \quad (2)$$

Consumer test. The study protocol was approved by the Research Ethics Committee of the Federal University of Santa Maria (Brazil) under number 49104715.7.0000.5346. A sensory acceptance test using a 9-point hedonic scale was performed (1 – disliked extremely, 9 – liked extremely). One hundred and two usual consumers (49 males and 53 females) of meat products evaluated the attributes of colour, aroma, flavour, texture, and overall acceptability (Meilgaard *et al.* 2006). Before the consumer test, the burgers were cooked (procedures previously described), cut into four 4 × 4 × 2.5 cm^3 pieces, and wrapped individually in aluminium foil. The test was performed in normalized booths under fluorescence lighting. Samples were coded with three-digit random numbers and served warm (60°C) in a monadic order to the consumers. The effect of the order of presentation and the first-order carry-over effects were balanced (Macfie *et al.* 1989). Water (25°C) and salted crackers were provided to the consumers.

Statistical analysis. The entire experiment was replicated three times. A randomised complete block design was adopted and an analysis of variance (ANOVA) using the general linear model procedure was realised. The treatments were put in the model as a fixed effect, and the replications of the experiments as a random term (n = 3). Tukey's test ($P < 0.05$) were used to determine significant differences between treatments.

RESULTS AND DISCUSSION

The physico-chemical parameters of the gels made with different concentrations of PS, water, and canola oil are shown in Table 2. No difference in moisture

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Table 2. Proximate composition, pH, and a_w of the pork skin and canola oil gels

Composition	Batch		SEM	Significance
	G1	G2		
Moisture (%)	58.94[a]	57.92[a]	0.60	0.12
Protein (%)	21.30[a]	16.32[b]	0.29	0.003
Fat (%)	18.4[b]	25.07[a]	0.58	0.001
Ash (%)	0.26[b]	0.38[a]	0.02	0.002
pH	6.87[b]	7.12[a]	0.06	0.02
a_w	1.00[a]	0.99[a]	0.001	0.11

G1 – pork skin/water/canola oil gel (45:45:10); G2 – pork skin/water/canola oil gel (40:40:20); [a,b]mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly ($P < 0.05$); SEM – standard error of the mean

content was observed between the gels ($P > 0.05$). However, as expected, an increase in lipids ($P < 0.001$) and ash ($P < 0.01$) and a decrease in protein content ($P < 0.01$) were observed in the gels containing higher levels of canola oil. The gels presented the same a_w ($P > 0.05$). On the other hand, the lower percentage of PS and water and the higher canola oil quantity led to an increase in pH values of the gel ($P < 0.05$). The observed moisture, protein, and ash contents, pH and a_w values were similar to those observed by De Oliveira Faria *et al.* (2015) in gels produced with different concentrations of PS and amorphous cellulose. However, the lipid levels were higher due to the addition of canola oil.

The replacement of animal fat by the gels significantly affected the physicochemical characteristics and improved the nutritional quality of the burgers (Table 3). Significant ($P < 0.001$) differences in moisture content between treatments were observed, since the lowest moisture levels were observed in the T2 group (63.4 vs. 65.9 vs. 62.2% for control, T1, and T2 batches, respectively). As expected, a decrease in the fat percentage among batches was observed ($P < 0.001$), since the highest fat amounts were found in the control group. In addition, T1 and T2 batches presented a fat reduction by more than 30%, and thus they can be claimed as "reduced fat" (EU Regulation 2006). Campagnol *et al.* (2012) and Almeida *et al*. (2014) noticed a decrease in protein percentage when using water and amorphous cellulose as a fat replacer in cooked meat products. In this study, the treatments T1 and T2 displayed higher protein content ($P < 0.01$) in relation to the control

Table 3. Effect of the partial replacement of pork backfat by pork skin and canola oil gels on proximate composition, pH, a_w, cooking loss, diameter reduction, and textural properties of beef burgers (mean of nine replications)

Parameters	Batch			SEM	Significance
	control	T1	T2		
Moisture (%)	63.42[ab]	65.95[a]	62.21[b]	2.80	***
Fat (%)	13.88[a]	9.18[b]	9.6[b]	0.56	***
Protein (%)	18.47[c]	22.48[a]	19.36[b]	1.56	**
Ash (%)	3.27[b]	3.18[b]	4.16[a]	0.42	*
pH	6.01[a]	5.93[a]	5.98[a]	0.02	ns
a_w	0.97[a]	0.98[a]	0.97[a]	0.01	ns
Cooking loss (%)	40.46[a]	23.67[c]	28.94[b]	1.12	***
Diameter reduction (%)	23.19[a]	13.71[b]	14.02[b]	2.22	***
Hardness (N)	72.97[b]	83.24[a]	76.39[ab]	3.42	*
Springiness (mm)	0.74[a]	0.77[a]	0.76[a]	0.01	ns
Cohesiveness	0.59[a]	0.60[a]	0.60[a]	0.02	ns
Gumminess (N)	42.79[b]	50.36[a]	46.02[ab]	3.15	*
Chewiness (N × mm)	31.82[b]	38.89[a]	35.15[ab]	2.77	*

Control – 15% pork backfat; T1 – 50% replacement of pork backfat by pork skin/water/canola oil gel (45:45:10); T2 – 50% replacement of pork backfat by pork skin/water/canola oil gel (40:40:20); SEM – standard error of the mean; ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; ns – not significant; [a–c]mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly ($P < 0.05$)

group (18.5 vs. 22.5 vs. 19.4% for control, T1, and T2 batches, respectively) due to the protein content of the PS present in the gels used as a fat replacer.

The pH and a_w values of the burgers (Table 3) were not influenced by the reformulation ($P > 0.05$). By contrast, the reformulation decreased ($P < 0.001$) the cooking loss and the diameter reduction of the burgers in relation to the control group (Table 3). These results could be attributed to the high collagen percentage of the PS, formed by gels at high temperatures, improving the retention of water and fat in the meat matrix (Feiner 2006). In this study, burgers from the T2 treatment had higher ($P < 0.001$) cooking loss than those from the T1 batch, probably due to its lower protein content (Table 3).

The reformulation affected ($P < 0.05$) the TPA parameters of the burgers (Table 3). Hardness was higher ($P < 0.05$) in the T1 group in relation to the control group. This fact could be attributed to the smaller fat globules of canola oil compared to animal fat, wherein a higher surface area covered by

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proteins is bound to the matrix, making the product harder (Youssef & Barbut 2010). The T1 batch also presented higher ($P < 0.05$) gumminess and chewiness values in relation to the control treatment (Table 3). However, no significant differences in these TPA values were observed between the T2 and control groups. According to Youssef and Barbut (2010), texture parameters of meat products could be directly related to the protein content. In the present study, the lower fat to protein ratio of treatment T1 (0.4) in relation to control (0.75) and T2 (0.5) batches can explain the differences in the TPA values, since a higher content of proteins can form a denser protein network resulting in a harder and more cohesive product (Youssef & Barbut 2010). Finally, springiness and cohesiveness values were found to be similar ($P > 0.05$) for control, T1, and T2 (Table 3).

The reformulation did not affect ($P > 0.05$) the L^*, a^*, and b^* parameters of the raw burgers (Table 4). After cooking, the T2 batch presented higher ($P < 0.001$) lightness (L^*) values compared to the other ones (control and T1 treatments), with no differences ($P > 0.05$) in a^* and b^* values between the three groups. This fact could be related to the lower size of canola oil globules in relation to the animal fat globules, which reflect more light due to a larger surface area (Youssef & Barbut 2011).

Table 4. Effect of the partial replacement of pork backfat by pork skin and canola oil gels on colour properties of burgers (mean of nine replications)

	L^*	a^*	b^*
Raw burger			
Control	47.77[a]	11.43[a]	16.56[a]
T1	48.68[a]	12.09[a]	17.70[a]
T2	48.77[a]	12.66[a]	17.20[a]
SEM	0.93	0.38	0.52
Significance	ns	ns	ns
Cooked burger			
Control	42.54[b]	4.89[a]	14.53[a]
T1	44.79[b]	4.70[a]	13.82[a]
T2	47.36[a]	4.77[a]	13.67[a]
SEM	0.99	0.162	0.22
Significance	***	ns	ns

Control – 15% pork backfat; T1 – 50% replacement of pork backfat by pork skin/water/canola oil gel (45:45:10); T2 – 50% replacement of pork backfat by pork skin/water/canola oil gel (40:40:20); SEM – standard error of the mean; ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; ns – not significant; [a,b]mean values in the same column (corresponding to the same parameter) not followed by a common letter differ significantly ($P < 0.05$)

The reformulation significantly improved the fatty acid profile of the beef burgers (Table 5). For all treatments, the main SFA in quantitative terms were palmitic acid (C16:0), stearic acid (C18:0), and myristic acid (C14:0). As expected, the reformulated products showed a decrease ($P < 0.001$) in the content of these fatty acids compared to the control batch. Consequently, the T1 and T2 treatments presented a decrease in the total SFA by nearly 26 and 21%, respectively, as compared to the control group. These findings confer nutritional advantages to the modified treatments, since studies have shown a correlation between high dietary SFA content and cardiovascular disease risk (Willett 2012).

The total MUFA content of the burgers was not significantly ($P > 0.05$) affected by the reformulation. However, the modified burgers showed an increase in the content of linoleic acid (C18:2n-6) ($P < 0.01$) and linolenic acid (C18:3n-3) ($P < 0.001$) compared to the control batch due to the higher PUFA levels (28.1%) in canola oil compared to the levels in pork backfat (10.3%) (USDA 2015).

According to Wood *et al.* (2004), whole diets with a PUFA/SFA ratio lower than 0.45 may increase the incidence of cardiovascular disease. The reformulation affected ($P < 0.001$) the PUFA/SFA ratio (Table 5), since the higher ratios were observed in burgers from T1 and T2 batches compared to those obtained from the control group (0.32 vs. 0.51 vs. 0.51, for control, T1, and T2 batches, respectively).

Simopoulos (2011) recommended a 1:1 to 2:1 ratio of n-6/n-3 fatty acids as a healthy balance. The highest n-6/n-3 ratio found in this study was observed in the control group (11.0 vs. 9.1 vs. 8.8, $P < 0.001$, for control, T1 and T2 batches, respectively) (Table 5). Although the n-6/n-3 ratios observed in the modified treatments are not ideal from a health point of view, they represent a decrease by nearly 17–20% compared to the control batch.

The atherogenicity (AI) and thrombogenicity (TI) indices of the three treatments were below 1.0 (Table 5), which is considered a healthy characteristic (Subhadra *et al.* 2006). The reformulated burgers (T1 and T2 batches) presented lower AI and TI indices compared to the control (AI 0.52 vs. 0.41 vs. 0.39, $P < 0.001$, for control, T1, and T2 batches, respectively; TI 0.69 vs. 0.48 vs. 0.47, $P < 0.001$, for control, T1, and T2 batches, respectively). These

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Table 5. Effect of the partial replacement of pork backfat by pork skin and canola oil gels on fatty acid profile (expressed as mg/100 g of fatty acids) of beef burgers (mean of nine replications)

	Batch			SEM	Significance
	control	T1	T2		
C10:0	44.1^{a}	34.9^{b}	37.7^{b}	2.1	***
C12:0	61.2^{a}	48.8^{b}	49.3^{b}	3.2	**
C14:0	1 392.1^{a}	1 060.3^{b}	1 199.4^{ab}	77.4	***
C14:1	110.9^{a}	112.5^{a}	131.9^{a}	10.1	ns
C15:0	286.3^{a}	222.5^{b}	249.1^{ab}	18.1	**
C16:0	24 955.1^{a}	18 897.4^{b}	19 673.8^{b}	872.2	***
C16:1	1515.0^{a}	1328.5^{a}	1501.4^{a}	153.8	ns
C17:0	952.8^{a}	768.7^{a}	906.3^{a}	79.3	ns
C17:1	541.8^{a}	490.4^{a}	531.8^{a}	35.9	ns
C18:0	17 128.9^{a}	11 992.6^{b}	13 184.0^{b}	696.8	***
C18:1n-9	38 724.3^{a}	34 560.9^{a}	38 853.2^{a}	2 004.0	ns
C18:1n-11	3 047.6^{a}	2 739.9^{a}	3 331.0^{a}	278.9	ns
C18:2n-6	12 882.4^{b}	15 488.5^{a}	16 102.4^{a}	879.6	**
C18:3n-3	1 105.7^{b}	1 616.1^{a}	1 730.4^{a}	89.1	***
C20:0	283.2^{a}	305.8^{a}	345.7^{a}	98.7	ns
C20:1	623.1^{a}	522.0^{a}	536.6^{a}	66.2	ns
C20:2	923.0^{a}	634.8^{b}	653.1^{b}	85.8	**
C20:3n-6	172.5^{a}	188.1^{a}	226.2^{a}	8.25	ns
C20:4n-6	196.4^{a}	167.7^{a}	175.4^{a}	36.9	ns
C20:5n-3	101.5^{a}	117.3^{a}	133.5^{a}	15.4	ns
C21:0	443.5^{a}	358.6^{a}	349.0^{a}	43.6	ns
C22:0	67.66^{b}	104.5^{a}	117.1^{a}	13.6	**
C24:0	185.2^{a}	119.6^{a}	176.7^{a}	47.2	ns
C24:1	41.4^{a}	29.6^{a}	51.5^{a}	9.9	ns
∑ SFA	45 614.9^{a}	33 893.9^{b}	36 111.5^{b}	1 379.8	***
∑ MUFA	39 783.8^{a}	44 604.2^{a}	44 937.1^{a}	2 082.8	ns
∑ PUFA	14 458.5^{b}	17 577.7^{a}	18 367.8^{a}	1 027.8	**
PUFA/SFA	0.32^{b}	0.51^{a}	0.51^{a}	0.02	***
n-6/n-3	11.0^{a}	9.1^{b}	8.8^{b}	0.3	***
AI	0.52^{a}	0.41^{b}	0.39^{b}	0.02	***
TI	0.69^{a}	0.48^{b}	0.47^{b}	0.03	***

Control – 15% pork backfat; T1 – 50% replacement of pork backfat by pork skin/water/canola oil gel (45 : 45 : 10); T2 – 50% replace; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; n-6 = omega-6; n-3 = omega-3; AI – atherogenic index; TI – thrombogenic index; SEM – standard error of the mean; ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; ns – not significant; ^{a,b}mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly ($P < 0.05$)

results are in accordance with those reported by Salcedo-Sandoval *et al.* (2014), who found lower AI and TI in burgers where animal fat was replaced by an oil blend (olive, linseed and fish oils).

The effect of the reformulation on consumer acceptance is summarised in Table 6. There were no differences ($P > 0.05$) between the control and the treatments in the colour, aroma, flavour, texture and

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Table 6. Results of consumer study of low-fat burger formulations with pork skin and canola oil gels

	Batches			SEM	Significance
	control	T1	T2		
Colour	7.64[a]	7.84[a]	7.66[a]	1.21	ns
Aroma	7.58[a]	7.74[a]	7.56[a]	1.28	ns
Flavour	7.92[a]	8.02[a]	7.78[a]	1.30	ns
Texture	7.62[a]	7.80[a]	7.76[a]	1.72	ns
Overall acceptability	7.80[a]	7.98[a]	7.70[a]	1.09	ns

Control – 15% pork backfat; T1 – 50% replacement of pork backfat by pork skin/water/canola oil gel (45:45:10); T2 – 50% replacement of pork backfat by pork skin/water/canola oil gel (40:40:20); SEM – standard error of the mean; ns – not significant; [a]mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly ($P < 0.05$)

overall acceptability attributes. Thus, the differences observed in the texture profile analysis (Table 3) and colour parameters (Table 4) did not negatively affect the consumer acceptance. So, these results suggest that the gels containing different concentrations of PS, water, and canola oil provided characteristics similar to those from pork backfat.

CONCLUSIONS

The reformulated burgers showed an increase in protein content and a decrease in fat content. Also, the reformulation improved the cooking characteristics and the fatty acid profile. Moreover, the reformulation did not affect consumer acceptance. Thus, the combination of pork skin, water, and canola oil can be considered a promising alternative to confer technological and nutritional advantages to low-fat burgers. However, more studies are necessary to evaluate the impact of such reformulation on the oxidative stability during the shelf life of the products.

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