Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2018, *24* (3), 193-201

Journal of Agroalimentary Processes and Technologies

The effects of fat replacement by vegetable oils and walnuts on meatloaf composition

Gabriel – D. Mocanu[1,*], Oana – V. Nistor[1], Doina G. Andronoiu[1], Elisabeta Botez[1]

[1] *Food Science, Food Engineering, Biotechnology and Aquaculture Department, Faculty of Food Science and Engineering"Dunarea de Jos" University of Galati, 800201, 111 Domneasca Street, Galati, Romania*

Abstract

The present study analyses the effects of adding walnuts and various vegetable oils (sea buckthorn, walnut and sunflower) used as back-fat replacers on the chemical composition, cooking loss, fatty acid composition, lipid oxidation, total antioxidant capacity, texture profile and sensory properties of meatloaf. In the study, the values of the fat content, cooking loss, energy, thiobarbituric acid reactive substances for the meatloaf containing walnuts and vegetable oils were lower than those of the control sample. The sample containing walnuts and sea buckthorn oil had the highest total antioxidant capacity, followed by the sample containing walnuts and sunflower oil. The highest values of textural and sensorial characteristics were obtained by the samples containing walnuts and sunflower oil. The incorporation of vegetable oils and walnuts has successfully reduced the animal fat content in the finite products while improving other characteristics (energy value, reducing cooking loss, inhibition of lipid oxidation, total antioxidant capacity).

Keywords: meatloaf, walnuts, vegetable oils, energy values, texture, sensorial analysis

1. Introduction

Meat and meat products are important sources of proteins, fats, essential amino acids, minerals, vitamins, and other nutrients in human food sources. In meat products, fat plays a major role in forming stable emulsions, reducing cooking loss, improving water holding capacity and binding properties, forming rheological and structural properties, and providing juiciness and hardness to the products [1, 2, 3]. However, the high fat content of such products leads to consumption restrictions for individuals who are prone to cardiovascular diseases, hypertension, coronary heart diseases and/or are overweight [4, 5, 6]. Yet, fat is an important constituent of human nutrition and contributes to the flavor, tenderness, juiciness, appearance, texture and shelf-life of meat products. Thus, the challenge for the meat industry is to develop low-fat meat products without compromising their sensory and texture characteristics [7, 8, 9].

In this regard, the reduction of fat content in meat products and the substitution of animal fat with vegetable oils and non-meat ingredients such as walnuts should result in healthy products. Several vegetable oils have already been used as fat substitutes, such as olive, flaxseed, corn, soybean, and canola oil. The replacement of animal fat with vegetable oils in meat products has been found to be an efficient and successful strategy aimed at enhancing the nutritional value of these products, as vegetable oils are cholesterol-free and have a higher ratio of unsaturated to saturated fatty acids than animal fats [3, 10].

Corresponding author: *e-mail:* Danut.Mocanu@ugal.ro

Walnuts (*Juglans regia L.*) are rich in monounsaturated fatty acids (oleic acid) and also have a higher content of polyunsaturated fatty acids (linoleic and α-linolenic acids) than typical vegetable oils. In addition to the distinctive fatty acid profile, numerous epidemiological studies have shown the contribution of other components with beneficial cardioprotective effects. These include a low lysine:arginine ratio, high levels of vitamin E, arginine, folate, dietary fibre, phytosterols, tannins and polyphenols [11].

It has been reported that walnuts, as part of a cardio-healthy diet, may reduce the risk of coronary heart disease. This effect has been associated with the blend of nutrients and phytochemicals found in walnuts [12]. The objective of this study was to investigate the effect of replacing animal fat by various vegetable oils and walnuts on the proximate composition, cooking loss, free fatty acids, lipid oxidation, total antioxidant capacity, texture profile and sensory properties of the meatloaf. To further evince the importance of using low-fat matters, only high protein content compounds, like milk powder and soy powder milk were chosen for the composition of the meatloaf.

The proximate composition, energy value, cooking loss, free fatty acids and texture profile of reformulated meats are employed to characterize the main properties and qualities of the reformulated meat products.

2. Materials and Methods

2.1. Chemicals

All chemicals and reagents used in the present work were purchased from Merck (Darmstadt, Germany) and Sigma Chemicals (Steinheim, Germany). The reagents were of analytical purity.

2.2. Materials

To obtain the meatloaf, fresh pork meat (moisture 72%, fat 6.3%, protein 20.4%) and pork fat (moisture 12.6%, fat 85.6%) were purchased from a local processor at 48 h postmortem. The sea buckthorn oil was obtained from S.C. Hofigal Export Import (Bucharest, Romania). The sunflower oil, walnut oil and all other additives (soy powder milk, sodium chloride and pepper) were purchased from a local supermarket in Galati (Romania). Walnuts (S.C. Romtransilvan, Oradea, Romania) were ground down to a particle size of approximately 12 μm by means of a food processor (Philips Essence HR7766, CE) at 29.2 Hz for approximately 2 min.

2.3. Meatloaf preparation

Four different meatloaf formulations were prepared (Table 1). The control meatloaf (C) was made from fresh pork meat, pork back fat, sodium chloride and pepper, while the SSF (meatloaf with walnuts and sunflower oil), SSB (meatloaf with walnuts and sea buckthorn oil) and SWN (meatloaf with walnuts and walnut oil) samples contained walnuts, vegetable oil and soy powder milk.

Sunflower oil was chosen because it has a high amount of polyunsaturated fatty acids (PUFA), while sea buckthorn oil and walnut oil are a good source of antioxidants. Soy powder milk was used to enhance the functional properties, such as emulsification, water-and fat-binding capacity and the textural properties of the meatloaf. The amount of walnuts and vegetable oils used to obtain the meatloaf was taken out of the pork back fat. The main steps in the preparation of the meatloaf are shown in Figure 1. The cooking process was carried out in a Sharp R – 94 ST convection oven (Germany) at 180°C for 50 minutes. To provide the optimal characteristics of cooking process, the oven has preheated for 10 minutes [13].

2.4. Proximate composition

The chemical composition of meatloaves was determined by means of procedures prescribed by Association of Official Analytical Chemists [14] for dry matter, protein, fat and ash determination. Carbohydrates were estimated by difference. The analyses were performed in triplicate.

2.5. Energy values

The total calories (kcal) estimated for the meatloaf were calculated on the basis of 100 g portions using the Atwater values for fat (9 kcal/g), protein (4.02 kcal/g), and carbohydrate (3.87 kcal/g) [3, 15].

2.7. Fatty acid profile

The fatty acids were determined by the gas chromatographic method according to [17] and [18]. The results were expressed as g fatty acid per 100 g of the total fatty acid analyzed. Each sample was run in triplicate.

2.8. Lipid oxidation and total antioxidant capacity

The lipid oxidation of all samples was assessed in triplicate and evaluated by measuring the formation of thiobarbituric acid-reactive substances (TBARs), following the method of Serrano *et al*. [19]. The results were expressed as mg malondialdehyde (MDA)/kg of meatloaf sample. The total antioxidant capacity (TAC) was estimated in terms of radical scavenging activity (ABTS$\bullet^{+}$), according to the procedure described by Miller *et al*. [20], with further amendments by Re *et al*. [21]. The results were expressed in µmol Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid)/g of sample. Each sample was run in triplicate.

2.9. Texture profile analysis

The texture profile of the meatloaf samples was determined at room temperature (22°C). The hardness (N), fracturability (N), cohesiveness (dimensionless), springiness (mm), chewiness index (N) and gumminess (N) were measured by means of the method of Bourne [22], using a CT3 Texture Analyzer (Brookfield Viscometer Ltd, Harlow, United Kingdom). The samples (block with 10 mm length, 10 mm width and 14 mm depth) were compressed to 50% of their original height by means of a cylindrical probe (TA11/1000) having a 25.4 mm diameter, a 1000 g load cell, and a cross-head speed of 2.0 mm/s. Two cycle compressions were carried out and the data were collected using the TexturePro CT software (Brookfield Viscometer Ltd, Harlow, United Kingdom). All analyses were performed in duplicate.

2.10. Sensory evaluation

The sensory evaluation of the meatloaf samples were performed in duplicate by 15 untrained panelists. The main criterion for the panelists' choice was "regular consumption of meat products". A hedonic test with a 9-point scale (1 = extreme negative and 9 =extreme positive) was used for the evaluation. This analysis was conducted following the method of Akwetey *et al*. [13]. Each meatloaf sample was evaluated using the following descriptors: appearance, colour, taste, hardness, springiness, cohesiveness, gumminess, chewiness. The meatloaf samples were sliced to approximately equal sizes of 2.0 cm^2 and then served to the panelists.

2.11. Statistical analysis

The results were expressed by means of ± standard error as a result of three separate determinations. The one-way analysis of variance (ANOVA) was carried out on the experimental results. The differences were considered significant at $p < 0.05$. The statistical data processing was performed by means of the program STATGRAPHICS Centurion XVI Version 16.1.11 (Statistical Graphics, Princeton, New Jersey, United States).

Table 1. Formulation (g) of experimental products.

Sample*	Meat	Fat	Walnuts	Vegetable oil**			Soy powder milk	Salt	Pepper	Water
				SFO	SBO	WNO				
C	450	150	–	–	–	–	–	3	2	45
SSF	450	117	30	3	–	–	30	3	2	15
SSB	450	117	30	–	3	–	30	3	2	15
SWN	450	117	30	–	–	3	30	3	2	15

*C – Control meatloaf; SSF – meatloaf with walnuts and sunflower oil; SSB – meatloaf with walnuts and sea buckthorn oil; SWN – meatloaf with walnuts and walnut oil.
**Vegetable oil: SFO – sunflower oil; SBO – sea buckthorn oil; WNO – walnut oil.

3. Results and Discussion

3.1. Proximate composition, energy value and cooking loss of meatloaf

The proximate composition, energy value and cooking loss of the meatloaf formulated with various vegetable oils (sea buckthorn, walnut and sunflower) and walnuts are shown in Table 2. The differences in dry matter, fat and ash content of the meatloaf were significant when compared to the control sample ($p < 0.05$). The dry matter content was higher (45.67 ± 0.002 g/100g) in the sample with vegetable oil and walnuts (SWN) than in the control sample (40.79 ± 0.004 g/100g), because these samples were formulated with added walnuts and soy powder milk which had high water retention and improved emulsion stability [19, 23]. Similar trends were observed by Choi *et al*. [24] when different amounts of vegetable oil and dietary fiber were added to meat emulsions. The fat content decreased in the samples formulated with vegetable oil and walnuts compared to the control meatloaf containing animal fat. The fat content was lower in the samples formulated with vegetable oil and walnuts (replacing pork fat) than in the control sample containing animal fat (23.29 ± 0.007 g/100g).

The sample with sunflower oil and walnuts (SSF) had the lowest fat content of all the samples (21.38 ± 0.001g/100g). These results are in agreement with the findings of Luruena-Martinez *et al*. [4] who reported similar quality characteristics for low-fat meat products with locust bean and xanthan gum along with the replacement of pork fat by olive oil. The addition of walnuts and vegetable oils significantly increased the ash level of the meatloaf. The ash content ranged from 0.87 ± 0.005 g/100g for the control sample (C) to 1.31 ± 0.015 g/100g for the meatloaf with walnuts and sunflower oil (SSF). Choi *et al*. [25] obtained significantly increased values for the ash content with the addition of rice bran fiber to low-fat meat products, and Ayo *et al*. [12] reported that the ash content significantly increased with the addition of walnuts to low-fat meat products. The protein and carbohydrate content in meatloaf samples were not significantly different ($P > 0.05$). SSF had the highest protein content (20.75 ± 0.015 g/100g), deriving from the added soy powder milk and walnuts. Meatloaf had a carbohydrate content ranging from 2.09 ± 0.061 g/100g to 2.19 ± 0.021 g/100g, where the highest carbohydrate content (2.19 ± 0.021 g/100g) was found in the sample with seabuckthorn oil and walnuts (SSB).

The differences in the energy values between the meatloaves formulated with vegetable oils and walnuts were significant ($p < 0.05$) (Table 2). The energy values of the meatloaf containing vegetable oil and walnuts ranged from 283.96 ± 0.09 kcal/100 g (SSF) to 286.43 ± 0.03 kcal/100 g (SWN). The control sample (meatloaf made with fresh pork meat and pork back fat) shows a decrease of energy value than samples with vegetable oils and walnuts. These results agree with Álvarez *et al*. [26] who reported that canola-olive oil, rice bran and walnuts has influence on the energy values for low-fat meat products.The cooking loss is affected by the type of fat [24], additives [27], the cooking method and the amount of fat in meat products [3]. The higher fat products lose less water upon cooking [28] because high-fat products contain less water. The effects of the replacement of pork back fat by vegetable oils and walnuts on the cooking loss of the meatloaf are shown in Table 2. The cooking loss was lower in the meatloaf formulated with vegetable oils and walnuts as compared to the control sample. The cooking loss for all the meatloaf samples ranged from 9.31% for the SSF sample to 13.14% for the C sample. Also, Shand [29] suggested that decreased cooking loss is related to an increase in binding ability between meat protein, fat, and moisture, and Aktas & Genccelep [30] observed that a reduction in cooking loss is associated with emulsion stability. Choi *et al.* [24] reported that cooking losses for low-fat meat emulsion systems were affected by the type of vegetable oil and dietary fiber used.

3.2. Fatty acid composition

Table 3 shows the fatty acid composition of meatloaf containing various vegetable oils and walnuts. In all the samples, palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1ω9) and linoleic acid (18:2ω6) were more abundant than other fatty acids.

Table 2. Proximate composition, energy values and cooking loss of meatloaf containing various vegetable oils and walnuts

Parameters	***Meatloaf sample***			
	C	**SSF**	**SSB**	**SWN**
Dry matter g/100g	40.79 ± 0.004	45.54 ± 0.001	45.37 ± 0.003	45.67 ± 0.002
Protein (g/100g)	16.63 ± 0.011	20.75 ± 0.015	20.40 ± 0.011	20.59 ± 0.015
Fat (g/100g)	23.29 ± 0.007	21.38 ± 0.001	21.56 ± 0.001	21.73 ± 0.003
Ash (g/100g)	0.87 ± 0.005	1.31 ± 0.015	1.22 ± 0.005	1.26 ± 0.015
Carbohydrate (g/100g)	-	2.10 ± 0.040	2.19 ± 0.021	2.09 ± 0.061
Energy value (kcal/100g)	276.46 ± 0.06	283.96 ± 0.09	284.52 ± 0.07	286.43 ± 0.03
Cooking loss, %	13.14 ± 0.02	9.31 ± 0.05	9.72 ± 0.05	9.76 ± 0.07

All values are mean ± standard deviation

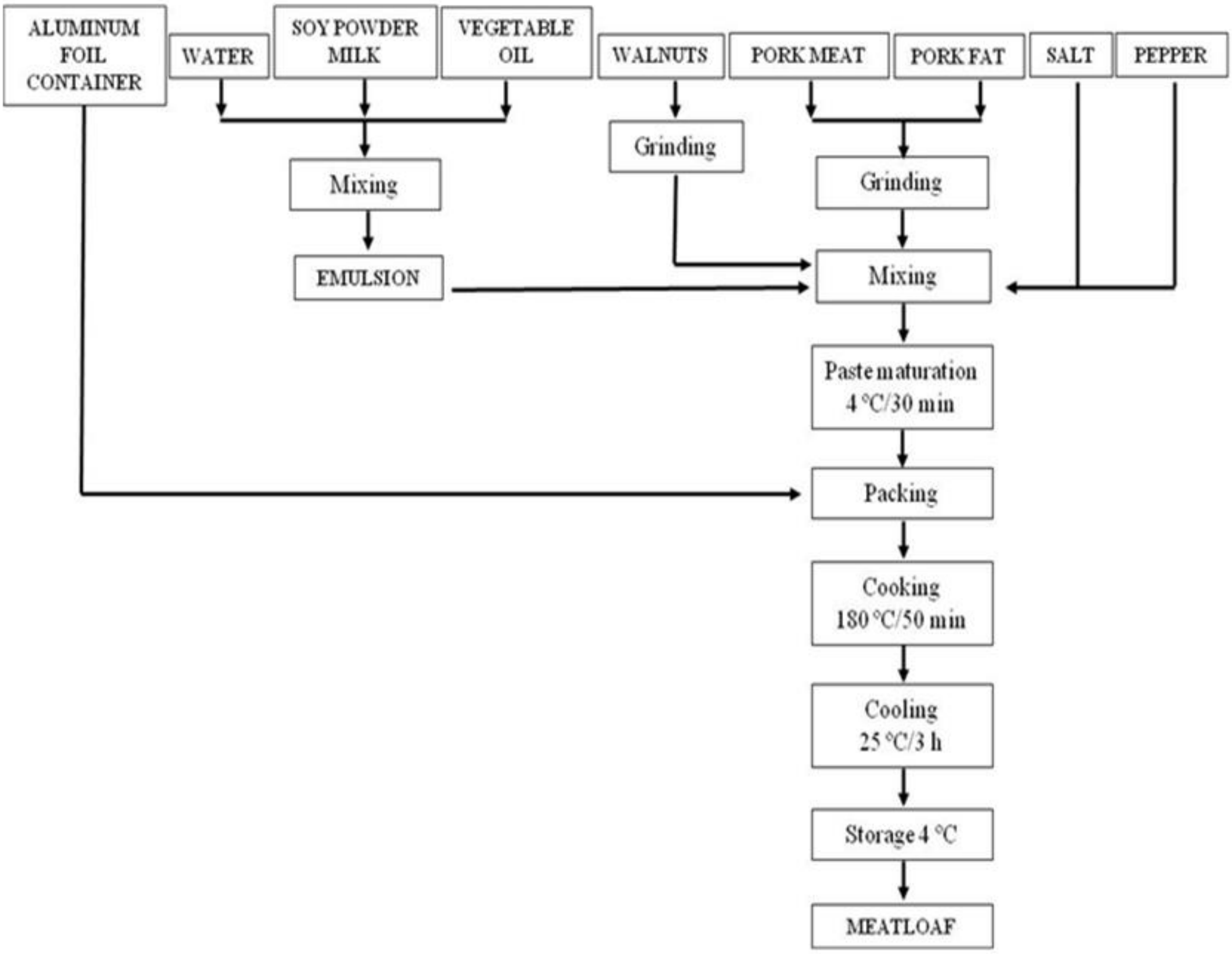

Figure 1. Flow chart of main steps for preparing meatloaf

Table 3. Fatty acid profile of meatloaf

Fatty acids, g/100g	*Meatloaf sample*			
	C	**SSF**	**SSB**	**SWN**
Myristic (14:0)	1.09 ± 0.031	0.54 ± 0.034	1.01 ± 0.036	0.59 ± 0.028
Palmitic (16:0)	22.41 ± 0.055	16.81 ± 0.025	17.64 ± 0.029	12.38 ± 0.031
Stearic (18:0)	9.18 ± 0.025	6.76 ± 0.028	5.81 ± 0.023	4.38 ± 0.026
Palmitoleic (16:1)	3.69 ± 0.017	2.79 ± 0.015	3.39 ± 0.011	1.29 ± 0.021
Oleic (18:1ω9)	42.46 ± 0.025	47.65 ± 0.017	48.2 ± 0.023	25.28 ± 0.035
Linoleic (18:2ω6)	17.33 ± 0.017	15.24 ± 0.021	21.59 ± 0.011	47.42 ± 0.021
Linolenic (18:3ω3)	0.81 ± 0.021	0.92 ± 0.017	0.82 ± 0.015	7.49 ± 0.011
Arachidonic (C20:4ω6)	0.66 ± 0.015	0.73 ± 0.015	0.41 ± 0.020	0.43 ± 0.023
Σ SFA	32.68 ± 0.11	24.11 ± 0.081	24.46 ± 0.075	17.35 ± 0.080
Σ MUFA	46.15 ± 0.032	50.44 ± 0.031	51.59 ± 0.034	26.57 ± 0.037
Σ PUFA	18.84 ± 0.030	16.89 ± 0.050	22.83 ± 0.037	55.35 ± 0.040
PUFA/SFA	0.57	0.70	0.93	3.18

All values are mean ± standard deviation

SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids

Table 4. Effects of various vegetable oils and walnuts on the textural attributes of meatloaf

Textural parameters	*Meatloaf sample*			
	C	**SSF**	**SSB**	**SWN**
Hardness (N)	3.14±0.27	5.48±0.31	4.72±0.18	4.71±0.13
Springiness (mm)	3.95±0.18	2.83±0.15	2.79±0.10	2.58±0.11
Fracturability (N)	2.85±0.13	5.37±0.03	4.88±0.06	4.49±0.02
Chewiness Index (N)	0.69±0.09	1.78 ±0.06	1.78±0.07	1.79±0.05
Gumminess (N)	0.72±0.14	1.81±0.04	1.40±0.06	1.79±0.07
Cohesiveness (dimensionless)	0.25±0.05	0.37±0.02	0.30±0.01	0.38±0.02

All values are mean ± standard deviation

The partial substitution of pork back fat led to reducing the content of saturated fatty acids (SFA) from 32.68% in the control sample to 17.35-24.46% in the samples with vegetables oils and walnuts. This reduction could be attributed to the decrease of cholesterol levels which lowers the blood pressure and thus could prevent heart conditions. It is important to notice the high quality of the fatty acids added from vegetable oils. Even the monounsaturated fatty acids (MUFA) increase in the SSF and SSB samples is almost insignificant when compared to the control sample; the replacement of the fat by vegetable oils aims at improving the lipid profile. The amount of MUFA (monounsaturated fatty acids) ranged from 26.57% to 51.59%, and the SSB sample had the highest total MUFA.

Similar results were obtained by Paneras & Bloukas [31] who replaced pork back fat by vegetable oils (olive, corn, sunflower or soybean) to obtain reduced-fat frankfurters. The highest values for PUFA (polyunsaturated fatty acids) were obtained for the SWN sample – the meatloaf containing walnuts and walnut oil (55.35%). When the pork back fat was replaced by vegetable oils and walnuts, the PUFA/SFA ratio was higher (3.18) in the sample with vegetable oil and walnuts (SWN) than in the control sample (0.57). Wood *et al*. [32] suggested that the PUFA/SFA ratio for whole diets should be higher than 0.45.

3.3. Oxidative stability of meatloaf

The results for the TBARs index (mg MDA/kg of sample), summarized in Figure 2, and ranged from 0.71 to 1.13 mg MDA/kg of the sample. The amount of the $TBAR_S$ was significantly higher in the control sample than in the samples with vegetable oils and walnuts.

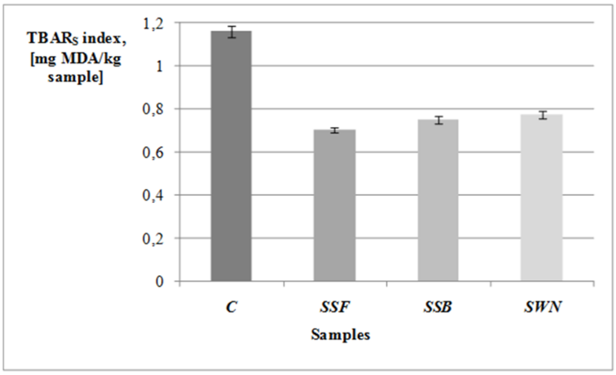

Figure 2. Effect of vegetable oils and walnuts on lipid oxidation of meatloaf

C – Control meatloaf, SSF – meatloaf with walnuts and sunflower oil, SSB – meatloaf with walnuts and sea buckthorn oil, SWN – meatloaf with walnuts and walnut oil

The vegetable oils and walnuts used in the present study as replacers of animal back-fat enhanced the oxidative stability of meatloaves. All samples with vegetable oils and walnuts had $TBAR_S$ values within acceptable limits (< 1.0). These results agree with Yildiz-Turp & Serdaroglu [33], who reported similar quality characteristics for sucuk – a fermented Turkish sausage with beef fat replacement by hazelnut oil. The TBARs value was the lowest (0.71 mg MDA/kg of the sample) in the samples formulated with sunflower oil and walnuts (SSF). Some researchers [34, 35] demonstrated that replacing beef fat by olive oil and hazelnut oil improved the quality characteristics of fermented sausage.

3.4. Antioxidant activity of meatloaf

The total antioxidant capacity (TAC) of the meatloaf samples is shown in Figure 3 and expressed in μmols of Trolox per g of meatloaf sample. The high antioxidant activity of the meatloaf could be attributed to the antioxidant compounds available in vegetable oils and walnuts (phenolic compounds, vitamins, phytosterols). For the total ABTS•$^{+}$ scavenging capacity of the meatloaf samples the minimum values (16.83 ± 0.52 μM Trolox/g) were observed for the control sample (C), and the maximum values (23.51 ± 0.18 μM Trolox/g) for the sample containing sea buckthorn oil and walnuts (SSB).

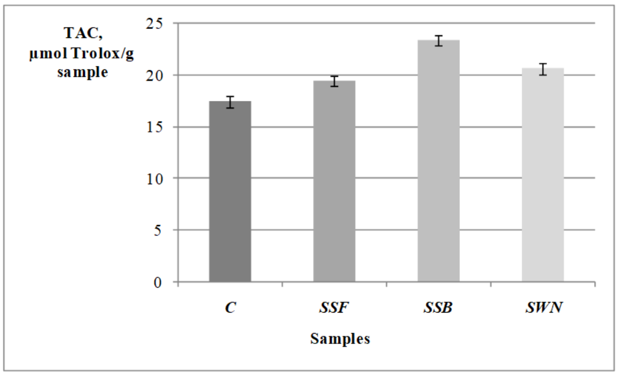

Figure 3. Total antioxidant capacity of meatloaf determined using ABTS as antioxidant probe
C – Control meatloaf, SSF – meatloaf with walnuts and sunflower oil, SSB – meatloaf with walnuts and sea buckthorn oil, SWN – meatloaf with walnuts and walnut oil

The incorporation of vegetable oils and walnuts into meat products may improve the shelf life of the products due to their antioxidant properties. Luruena-Martinez *et al*. [4] suggested that the partial substitution of pork fat by olive oil led to an increase of the total antioxidant capacity in meat products. Comparing the ABTS•$^{+}$ results of the meatloaf samples, the total antioxidant capacity of the samples with vegetable oils and walnuts increased by approximately 1.2 – 1.4% as compared to the control sample. Different components (phenolic compounds, vitamins, phytosterols) from vegetable oils and walnuts are responsible for this total antioxidant capacity.

3.5. Texture profile analysis

Table 4 shows the texture characteristics for the samples of reformulated meatloaf under study. The hardness and fracturability were higher for all the samples with vegetable oils and walnuts as compared to the control sample ($p < 0.05$). Springiness was the highest for the control sample (C) and the lowest for all the samples with vegetable oils and walnuts. The values of springiness for these samples ranged from 2.58 ± 0.11 mm for the SWN sample to 2.83 ± 0.15 mm for the meatloaf with walnuts and sunflower oil (SSF). The cohesiveness of the samples with vegetable oils and walnuts was higher (0.38 ± 0.02 for the SWN sample) than the control sample (0.25 ± 0.05). Similar results were reported by Luruena-Martinez *et al*. [4] for low-fat frankfurters with olive oil and locust bean/xanthan and Choi *et al*. [3] for reduced-fat meat systems with grape seed oil and rice bran fibre. The values of the gumminess and chewiness index for the control sample were lower, increasing for the samples with vegetable oils and walnuts. The mean values for gumminess ranged from 0.72 ± 0.14 N (C) to 1.81 ± 0.04 N (SSF), and the chewiness index ranged from 0.69 ± 0.09 N (C) to 1.79 ± 0.05 N (SWN). The increase of the gumminess and chewiness index can be accounted for by the adding of soy powder milk and, which constitute external sources of protein. This agrees with Claus *et al*. [36] and Gregg *et al*. [37] which analyzed the effect of reducing the fat content on the texture of meat based emulsion products.

3.6. Sensory evaluation

Figure 4 shows the results of sensory evaluation of meatloaves. Each meatloaf sample was evaluated in terms of appearance, colour, taste, hardness, springiness, cohesiveness, gumminess and chewiness. The control sample has the lowest scores for taste and appearance. The mean scores for taste ranged from 6.15 (C) to 8.82 (SWN) and the appearance scores ranged from 5.72 (C) to 8.81 (SWN). Similar results were obtained by Muguerza *et al*. [38] and Choi *et al*. [3] for the effects of replacing pork back fat by vegetable oils. The sample with sea buckthorn oil and walnuts (SSB) obtained the highest colour scores. These results may be due to the presence of sea buckthorn oil whose colour is orange.

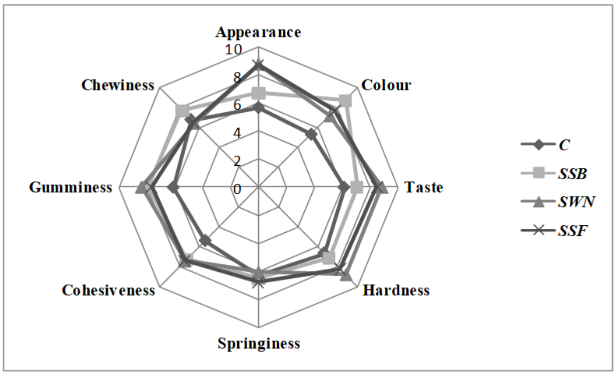

Figure 4. Sensory properties of meatloaf sample
C - Control meatloaf, SSF - meatloaf with walnuts and sunflower oil, SSB - meatloaf with walnuts and sea buckthorn oil, SWN - meatloaf with walnuts and walnut oil

The hardness, cohesiveness, gumminess and chewiness index were higher ($p < 0.05$) for all the samples with vegetable oils and walnuts as compared to the control sample. The scores of these parameters obtained by sensorial analysis were similar to the values determined by texture profile analysis. Some researchers [31, 39] demonstrated that replacing the pork back fat by vegetable oils (olive, corn, sunflower or soybean) can influence the textural properties of low-fat frankfurters.

4. Conclusion

Commercially available vegetable oils, such as sunflower, walnut and sea buckthorn oils, and walnuts were used as substitutes for pork back fat in the production of meatloaf. Sea buckthorn oil and walnut oil added to the meatloaf are a good source of antioxidants, while sunflower oil was chosen because it contains a high amount of polyunsaturated fatty acids. The use of vegetable oils and walnuts decreases the lipid oxidation in meatloaf samples. The addition of various vegetable oils and walnuts may contribute to the development of a type of meatloaf with desirable quality characteristics.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

References

1. E., S. Cofrades, and D.J. Troy, Effects of fat level, oat fiber and carrageenan on frankfurters formulated with 5%, 12% and 30% fat. *Meat Science*, **1997**, *45*(3), 273–281.
2. Pietrasik Z. and Z. Duda, Effects of fat content and soy protein/carrageenan mix on the quality characteristics of comminuted, scalded sausages. *Meat Science*, **2000**, *56*(2), 181–188.
3. Choi Y.S., J.H. Choi, D.J. Han, H.Y. Kim, M.A. Lee, J.Y. Jeong, H.J. Chung, and C.J. Kim, Effects of replacing pork back fat with vegetable oils and rice bran fiber on the quality of reduced-fat frankfurters. *Meat Science*, **2010**, *84*(3), 557–563.
4. Luruena-Martinez M.A., A.M. Vivar-Quintana and I. Revilla, Effect of locust bean/xanthan gum addition and replacement of pork fat with olive oil on the quality characteristics of low-fat frankfurters. *Meat Science*, **2004**, *68*(3), 383–389.
5. Ozvural E.B. and H. Vural, Utilization of interesterified oil blends in the production of frankfurters. *Meat Science*, **2008**, *78*(3), 211–216.
6. Weiss J., M. Gibis, V. Schuh, and H. Salminen, Advances in ingredient and processing systems for meat and meat products. *Meat Science*, **2010**, *86*(1), 196–213.
7. Mun S., Y.L. Kim, and C.G. Kang, Development of reduced fat mayonnaise using 4αGTase-modified rice starch. *International Journal of Biological Macromolecules*, **2009**, *44*(5), 400–407.
8. Zhang W., S. Xiao, H. Samaraweera, E.J. Lee, and D.U. Ahn, Improving functional value of meat products. *Meat Science*, **2010**, *86*(1), 15–31.
9. Furlán L., T. Rodriguez, A. Padilla, C. Pérez, and E. Mercedes, Development of reduced fat minced meats using inulin and bovine plasma proteins as fat replacers. *Meat Science*, **2014**, *96*(2 Pt A), 762–768.
10. Rodríguez-Carpena J.G., D. Morcuende, and M. Estévez, Avocado, sunflower and olive oils as replacers of pork back-fat in burger patties: Effect on lipid composition, oxidative stability and quality traits. *Meat Science*, **2012**, *90*(1), 106–115.
11. Özcan M.M., Some Nutritional Characteristics of Fruit and Oil of Walnut (*Juglans regia* L.) Growing in Turkey. *Iranian Journal of Chemistry and Chemical Engineering – International English Edition*, **2009**, *28*(1), 57–62.
12. Ayo J., J. Carballo, J. Serrano, B. Olmedilla-Alonso, C. Ruiz-Capillas, and F. Jiménez-Colmenero, Effect of total replacement of pork backfat with walnut on the nutritional profile of frankfurters. *Meat Science*, **2007**, *77*(2), 173–181.
13. Akwetey W.Y., I.N. Oduro, and W.O. Ellis, Whole cowpea (Vigna unguiculata) flour (WCPF) as non-conventional extender in meatloaf. *Food Bioscience*, **2014**, *5*, 42–46.
14. A.O.A.C., Association of Official Analytical Chemists, Official Methods of Analysis. 17th Ed., (edited by W. Horwitz). Pub. By the A.O.A.C. 2000: Gaithersburg, USA.
15. Mansour E.H., and A.H. Khalil, Characteristics of low-fat beef burgers as influenced by various types of wheat fibers. *Food Research International*, **1999**, *30*(3-4), 199 – 205.
16. Franco D., E. Rodríguez, L. Purriños, S. Crecente, R. Bermúdez, and J.M. Lorenzo, Meat quality of "*Galician Mountain*" foals breed. Effect of sex, slaughter age and livestock production system. *Meat Science*, **2011**, *88*(2), 292–298.
17. SR CEN ISO/TS 17764-1:2008, Animal feeding stuffs – Determination ot the content of fatty acids – Part 1: Preparation of faffy acid methyl esters. Bucharest: Romanian Standards Association.

18. SR CEN ISO/TS 17764-1:2008, Animal feeding stuffs – Determination ot the content of fatty acids – Part 2: Gas chromatographic method. Bucharest: Romanian Standards Association.
19. Serrano A., S. Cofrades, and F. Jiménez-Colmenero, Characteristics of restructured beef steak with different proportions of walnut during frozen storage. *Meat Science*, **2006**, *72*(1), 108–115.
20. Miller N.J., J.D. Johnston, C.S. Collis, and C. Rice-Evans, Serum total antioxidant activity after myocardial infarction. *Annal of Clinical Biochemistry*, **1997**, *34*(Pt 1), 85–90.
21. Re R., N. Pellegrini, A. Proteggente, A. Pannala, M. Yang, and C. Rice-Evans, Antioxidant Activity Applying An Improved ABTS Radical Cation Decolorization Assay, *Free Radical Biology & Medicine*, **1999**, *26*(9/10), 1231–1237.
22. Bourne M.C., *Principles of Objective Texture Measurement*, *in*: Food Texture and Viscosity: Concept and Measurement, 2nd edition (ed. S.L. Taylor). 2002, London: Academic Press, p. 107 – 189.
23. Andiç S., Ö. Zorba, and Y. Tunçtürk, Effect of whey powder, skim milk powder and their combination on yield and textural properties of meat patties. *International Journal of Agriculture and Biology*, **2010**, *12*(6), 871–876.
24. Choi Y.S., J.H. Choi, D.J. Han, H.Y. Kim, M.A.L, Hyun-Wook, and K.J.Y. Jeong, Characteristics of low-fat meat emulsion systems with pork fat replaced by vegetable oils and rice bran fiber. *Meat Science*, **2009**, *82*(2), 266–271.
25. Choi Y.S., J.Y. Jeong, J.H. Choi, D.J. Han, H.Y. Kim, and M.A Lee, Effects of dietary fiber from rice bran on the quality characteristics of emulsion-type sausages. *Korean Journal for Food Scieince of Animal Resources*, **2008**, *28(1)*, 14–20.
26. Álvarez D., R.M. Delles, Y.L. Xiong, M. Castillo, F.A. Payne, and J. Laencina, Influence of canola-olive oils, rice bran and walnut on functionality and emulsion stability of frankfurters. *LWT-Food Science and Technology*, **2011**, *44*(6), 1435–1442.
27. Garcia-Garcia E., and A. Totosaus, Low-fat sodium-reduced sausages: Effect of the interaction between locust bean gum, potato starch and j-carrageenan by a mixture design approach. *Meat Science*, **2008**, *78*(4), 406–413.
28. Jiménez-Colmenero F., Healthier lipid formulation approaches in meat-based functional foods. Technological options for replacement of meat fats by non-meat fats. *Trends in Food Science & Technology*, **2007**, *18*(11), 567−578.
29. Shand P.J., Textural, water holding, and sensory properties of low-fat pork bologna with normal and waxy starch hull-less barley. *Journal of Food Science*, **2000**, *65*(1), 101–107.
30. Aktas N., and H. Genccelep, Effect of starch type and its modifications on physicochemical properties of bologna-type sausage produced with sheep tail fat. *Meat Science*, **2006**, *74*(2), 404–408.
31. Paneras E.D., and J.G. Bloukas, Vegetable oils replace pork backfat for low-fat frankfurters. *Journal of Food Science*, **1994**, *59*(4), 725−728.
32. Wood J.D., R.I. Richardson, G.R. Nute, A.V. Risher, M.M. Campo, and E. Kasapidou, Effects of fatty acids on meat quality: A review. *Meat Science*, **2003**, *66*(1), 21–32.
33. Yildiz-Turp G., and M. Serdaroglu, Effect of replacing beef fat with hazelnut oil on quality characteristics of sucuk – A Turkish fermented sausage. *Meat Science*, **2008**, *78*(4), 447–454.
34. Kayaardi S., and V. Gok, Effect of replacing beef fat with olive oil on quality characteristics of Turkish soudjouk (sucuk). *Meat Science*, **2004**, *66*(1), 249–257.
35. Ansorena D., and I. Astiasarán, Effect of storage and packaging on fatty acid composition and oxidation in dry fermented sausages made with added olive oiland antioxidants. *Meat Science*, **2004**, *67*(2), 237–244.
36. Claus J.R., M.C. Hunt, C.L. Kastner, and D.H. Kropf, Low-fat, high added water bologna: effects of massaging, preblending, and time of addition of water and fat on physical and sensory characteristics. *Journal of Food Science*, **1990**, *55*(2), 338–341.
37. Gregg L.L., J.R. Claus, C.R. Hackney, and N.G. Marriot, Low-fat, high added water bologna from massaged, minced batter. *Journal of Food Science*, **1993**, *58*(2), 259–264.
38. Muguerza E., G. Fista, D. Ansorena, I. Astiasaran, and J.G. Bloukas, Effect of fat level and partial replacement of pork backfat with olive oil on processing and quality characteristics of fermented sausages. *Meat Science*, **2002**, *61*(4), 397–404.
39. Paneras E.D., J.G. Bloukas, and D.G. Filis, Production of low-fat frankfurters with vegetable oils following the dietary guidelines for fatty acids. *Journal of Muscle Foods Banner*, **1998**, *9*(2), 111−126.