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ORIGINAL RESEARCH PAPER

THE EFFECT OF THE PARTIAL SUBSTITUTION OF PORK BACK FAT WITH VEGETABLE OILS AND WALNUTS ON THE CHEMICAL COMPOSITION, TEXTURE PROFILE AND SENSORIAL PROPERTIES OF MEATLOAF

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The present study investigates the effects of the partial substitution of the pork back fat with different vegetable oils (sea buckthorn, walnut and sunflower) and walnuts on the chemical composition, texture profile and sensory characteristics of meatloaves. The dry matter and ash content of meatloaf with vegetable oils and walnuts were higher than the control sample ($P < 0.05$). The cooking loss, energy values and lipid oxidation for the samples with walnuts and vegetable oils were lower than the control sample. The meatloaf sample containing walnuts and sea buckthorn oil had the highest total antioxidant capacity. The partial substitution of pork back fat showed a positive effect on textural and sensorial characteristics. Results reveal that the incorporation of vegetable oils and walnuts has successfully reduced the animal fat content in the finite products while improving the quality characteristics.
Keywords: meatloaf, vegetable oils, walnuts, chemical composition, texture, sensory analysis

Introduction

Meat and meat products are important sources of proteins, fats, essential amino acids, minerals, vitamins and other nutrients in human nutrition. In processed food products, animal fat is a significant component because it provides flavor, texture and juiciness, improves water holding capacity and decreases cooking loss (Vural *et al*., 2004; Choi *et al*., 2010; Choi *et al*., 2010; Choi *et al*., 2013).

Fat is also a good source of essential fatty acids, precursors of prostaglandins, essential cell membrane components (Chin *et al*., 2004; Choi *et al*., 2013). However, recent studies have established a relationship between animal fats consumption (especially saturated fatty acids) and an increased risk of suffering from serious health disorders such as cardiovascular diseases, hypertension, coronary heart diseases (Luruena-Martinez *et al*., 2004; Moon *et al*., 2008; Ozvural and Vural, 2008; Weiss *et al*., 2010; Ferguson, 2010; Rodríguez-Carpena *et al*., 2012).

In recent years, the partial substitution and reduction of fat content in meat products with vegetable oils and non-meat ingredients such as walnuts has been found to be an efficient strategy to obtain healthy products (Choi *et al*., 2009; Rodríguez-Carpena *et al*., 2012). Several vegetable oils have already been used as fat substitutes, such as cottonseed, avocado, olive, corn, soybean, flaxseed and canola oil (Park *et al*., 2005; Choi *et al*., 2009; Choi *et al*., 2010; Rodríguez-Carpena *et al*., 2012).

Walnuts (*Juglans regia* L.) have a higher polyunsaturated fatty acids (linoleic and α-linolenic) content than typical vegetable oils and are also rich in monounsaturated fatty acids (oleic). It has been reported that walnuts may reduce the risk of coronary heart disease. This effect has been associated with the addition of nutrients and phytochemicals found in walnuts (Menegas *et al*., 2013).

The objective of this study was to evaluate the effect of partial substitution of animal fat with various vegetable oils and walnuts on the proximate composition, cooking loss, lipid oxidation, texture profile analysis and sensory properties of meatloaf.

Materials and methods

Chemicals

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

Meatloaf preparation

To obtain meatloaf, fresh pork meat (moisture 71.97%, fat 4.96%, protein 15.82%) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor at 48 h postmortem. Four different meatloaf formulations were prepared (Table 1). Control meatloaf (M_0) was made from fresh pork meat, pork back fat, sodium chloride and pepper, while M_1, M_2 and M_3 samples contained walnuts, vegetable oils and powder milk.

Table 1. Formulation (%) of experimental products

Sample*	Meat	Fat	Walnuts	Vegetable oil**			Powder milk	Salt	Pepper	Water
				SFO	SBO	WNO				
M_0	69.2	23.2	–	–	–	–	–	0.4	0.4	6.8
M_1	69.2	18	4.8	0.4	–	–	4.8	0.4	0.4	2
M_2	69.2	18	4.8	–	0.4	–	4.8	0.4	0.4	2
M_3	69.2	18	4.8	–	–	0.4	4.8	0.4	0.4	2

*M_0 – Control meatloaf; M_1 – meatloaf with walnuts and sunflower oil; M_2 – meatloaf with walnuts and sea buckthorn oil; M_3 – meatloaf with walnuts and walnut oil.
**Vegetable oil: SFO – sunflower oil; SBO – sea buckthorn oil; WNO – walnut oil.

Three types of vegetable oils were used to partially replace pork back fat: sea buckthorn oil, walnut oil and sunflower oil. Sunflower oil, walnut oil and all other additives (powder milk, sodium chloride and pepper) were purchased from a local supermarket in Galati (Romania). Sea buckthorn oil was obtained from S.C. Hofigal

Export Import S.A. Bucharest, Romania. Walnuts (S.C. Romtransilvan S.R.L, Oradea, Romania) were ground with a food processor (Philips Essence HR7766) for approximately 2 min to a particle size of approximately 12 μm.

For the manufacturing of meatloaf a meat paste was prepared and maintained for maturation at 4 °C for 30 min to obtain desirable consistency. The preform product was packed in aluminum foil container and cooked in an electric oven at 180 °C for 50 min. To ensure the optimal parameters of cooking process, the oven was preheated for 10 minutes (Akwetey *et al.*, 2014). All the samples were cooled at room temperature (25 °C) for 3 h, then stored at 4°C overnight before analysis.

Proximate analysis

The chemical composition of meatloaf was determined using procedures prescribed by the national standards. Dry matter was determined according to SR ISO 1442: 2010. Fat content by Soxhlet extraction (according to SR 9065-10:2007) and protein content (according to SR ISO 937:2007) was determined by the Kjeldahl method. Ash was determined according to the SR ISO 936: 2009. Carbohydrate contents were calculated. The analyses were performed in duplicate.

Calorific value

Total calories estimated (kcal) for meatloaf were calculated on the basis of 100 g portion using the Atwater system where fats account for 9 kcal/g, proteins for 4.02 kcal/g, and carbohydrates for 3.87 kcal/g (Mansour and Khalil, 1999; Choi *et al.*, 2010).

Cooking loss

After cooking at 180°C for 50 min, the samples were cooled at room temperature (25°C) for 3 h and the percentage of cooking loss was recorded as described by Franco *et al*. (2011) using the following equation:

$$Cooking\ loss\ (g/100g) = \frac{(W_0 - W_1)}{W_0} \times 100$$

where W_0 – weight of raw meatloaf (g), and W_1 – weight of cooked meatloaf (g)

TBAR$_S$ measurement

Lipid oxidation was assessed in duplicate by the 2-thiobarbituric acid (TBAR$_S$) assay following the method of Serrano *et al.* (2006). The results were expressed as mg of malondialdehyde (MDA) per kg of meatloaf.

Texture profile analysis

The texture profile of the meatloaf samples was determined at room temperature (25°C) using CT3 Texture Analyzer (Brookfield, UK). The samples (block with 10 mm length, 10 mm width and 14 mm depth) were compressed to 50% of their original height with a cylindrical probe (TA25/1000) 50.8 mm diameter, a 1000 g load cell and a cross-head speed of 2.0 mm/s. Values for hardness (N), springiness (mm), cohesiveness (dimensionless), chewiness index (N) and gumminess (N) were measured following the method of Bourne (1978). All analyses were performed in duplicate.

Sensory evaluation

The sensory evaluation of the meatloaf samples was performed in duplicate with 15 trained panelists. A hedonic test with a 9 points scale was used for the evaluation. This analysis was conducted following the method of Akwetey *et al*. (2014).

Statistical analysis

The data were statistically processed using the program STATGRAPHICS Centurion XVI Version 16.1.11. The differences among the samples were evaluated by means of the one-way analysis of variance (ANOVA). Differences were considered significant at $P < 0.05$. All results were presented as mean value ± standard error.

Results and discussion

Chemical analysis, energy value and cooking loss of meatloaf

The proximate composition and energy value of meatloaf formulated with various vegetable oils (sea buckthorn, walnut and sunflower) and with walnuts are shown in Table 2. The differences in dry matter, fat and ash content of the meatloaf were significant compared to the control sample ($P < 0.05$).

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

Parameters	*Meatloaf sample*			
	M_0	**M_1**	**M_2**	**M_3**
Dry matter (g/100g)	37.66 ± 0.38	43.17 ± 0.21	41.81 ± 0.26	42.95 ± 0.29
Protein (g/100g)	13.69 ± 0.16	18.11 ± 0.17	18.35 ± 0.18	18.24 ± 0.22
Fat (g/100g)	23.15 ± 0.25	21.22 ± 0.23	20.62 ± 0.19	20.89 ± 0.21
Carbohydrate (g/100g)	-	2.31 ± 0.08	2.29 ± 0.04	2.30 ± 0.06
Ash (g/100g)	1.13 ± 0.11	1.53 ± 0.12	1.54 ± 0.13	1.52 ± 0.13
Energy value (kcal/100g)	263.34 ± 0.21	272.72 ± 0.27	268.21 ± 0.23	270.23 ± 0.25

All values are mean ± standard deviation

The dry matter of the meatloaf sample containing sunflower oil and walnuts (M_1) was higher (43.17 ± 0.21 g/100g) than the control sample (37.66 ± 0.38 g/100g) due to the added walnuts and powder milk in this sample which had high water retention and improved emulsion stability (Serrano *et al*., 2006; Andiç *et al*., 2010). Similar trends were observed by Choi *et al*. (2013) when different amounts of sunflower seed oil and dietary fiber extracted from *makgeolli* lees were added to meat emulsions. The protein and carbohydrate content in meatloaf samples were not significantly different ($P > 0.05$).

The fat content decreased in the samples formulated with vegetable oil and walnuts compared with the control meatloaf containing only animal fat, ranging between 23.15 ± 0.25 g/100g and 20.62 ± 0.19 g/100g with the highest value in the control sample (M_0). The sample with sea buckthorn oil and walnuts (M_2) had the lowest fat content among the all samples (20.62 ± 0.19 g/100g). These results agree with Choi *et al*. (2009) who reported similar quality characteristics to reduced-fat emulsion systems when different amounts of vegetable oil and dietary fiber were added.

The addition of vegetable oils and walnuts increase the ash level of the meatloaf. The ash content was higher for meatloaf with walnuts and sea buckthorn oil (1.54 ± 0.13 g/100g) than the control sample (1.13 ± 0.11 g/100g), because these vegetal materials contain minerals. Ayo *et al*. (2007) reported that ash content significantly increased with the addition of walnut to low-fat meat products and Choi *et al*. (2008) obtained significantly increased values for the ash content with the addition of rice bran fiber to low-fat meat products.

Energy values (Table 2) of meatloaves ranged from 263.34 ± 0.21 kcal/100g (M_0) to 272.72 ± 0.27 kcal/100g (M_1). The effect of walnuts and vegetable oils on energy values of meatloaves was significant ($P < 0.05$). The control sample (meatloaf made with fresh pork meat and pork back fat) shows a decrease of energy value compared to samples with vegetable oils and walnuts. These results agree with Álvarez *et al.* (2011) who reported that canola-olive oil, rice bran and walnuts have influence on the energy values for low-fat meat products.

The cooking loss of meatloaf with vegetable oils and walnuts are shown in Figure 1. Cooking loss for all meatloaf samples ranged from 10.16% for M_1 sample to 12.97% for M_0 sample. For the obtained samples, the reduction of the cooking loss is perhaps dependent on the fat type. The decreasing values of the cooking loss could be associated to an increase of the binding capability between meat proteins and vegetal material proteins or pork back fat and vegetal material fat (from walnuts and oils).

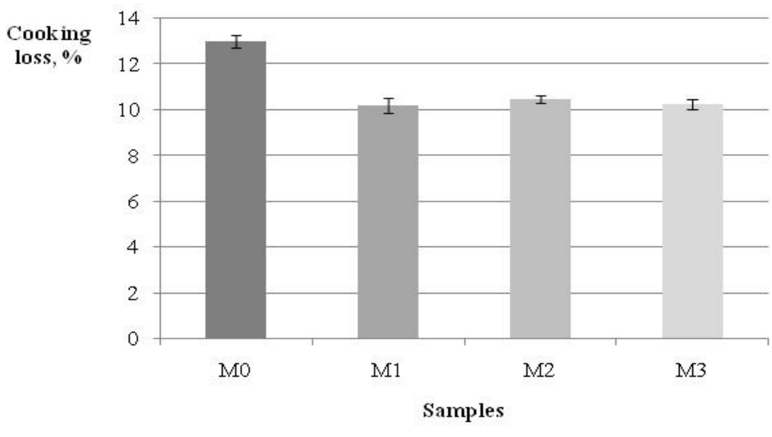


Figure 1. Effects of vegetable oils and walnuts on cooking loss of meatloaf

Choi *et al*. (2009) reported that cooking losses for low-fat meat emulsion systems were affected by the type of vegetable oil and dietary fiber used and Aktas and Genccelep (2006) observed that a reduction in cooking loss is associated with emulsion stability. Park *et al*. (2005) suggested that reducing the animal fat content in frankfurters decreased the cooking loss, and this may be due to the dependence on fat type.

TBAR$_S$ index

The results of the partial substitution of pork back fat with vegetable oils and walnuts on lipid oxidation of meatloaf are summarized in Figure 2. The TBAR$_S$ value decreased in the samples formulated with vegetable oil and walnuts compared with the control meatloaf and ranged from 0.42 ± 0.05 mg MDA/kg of sample to 1.42 ± 0.03 mg MDA/kg of sample. The vegetable oils and walnuts used in the present study as replacers of animal back-fat enhanced the oxidative stability of meatloaves.

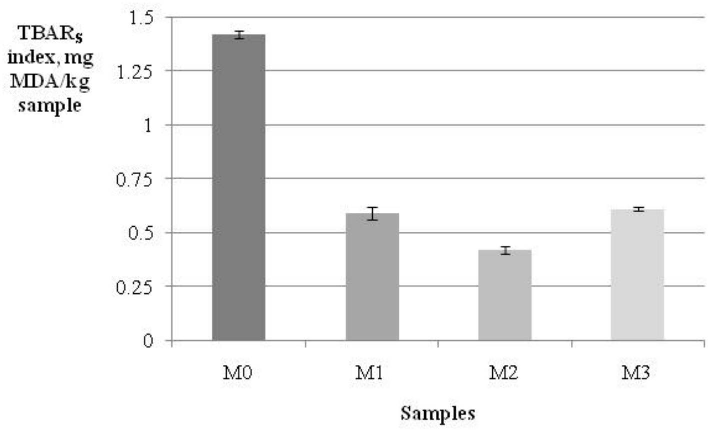


Figure 2. Effect of vegetable oils and walnuts on lipid oxidation of meatloaf

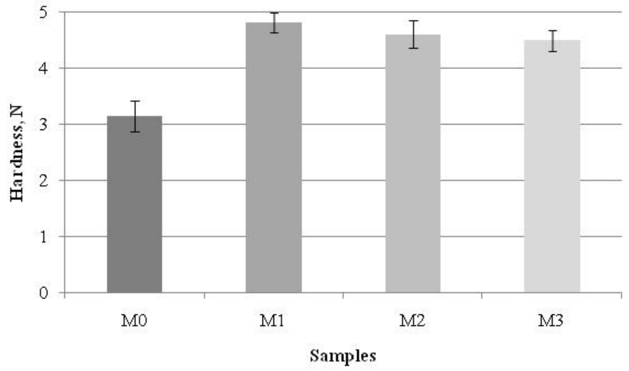
All samples with vegetable oils and walnuts had TBAR$_S$ values within acceptable limits (< 1.0). The obtained values of TBAR$_S$ were similar to those reported by Yildiz-Turp and Serdaroglu (2008) for Turkish fermented sausages where the beef fat was replaced with hazelnut oil.

Texture profile analysis

The vegetable oils and walnuts significantly affected the textural properties of meatloaf (Figure 3). The hardness (Figure 3a) was higher for all the samples with vegetable oil and walnuts compared to the control sample ($P < 0.05$). The values of hardness for these samples ranged from 3.14 ± 0.27 N for control sample (M_0) to 4.81 ± 0.17 N for meatloaf with walnuts and sunflower oil (M_1). These results agree with Woo *et al.* (1995) who reported that cottonseed oil increased the hardness of emulsion type sausages. The springiness (Figure 3b) value was highest for the control sample and lowest for all the samples with vegetable oil and walnuts.

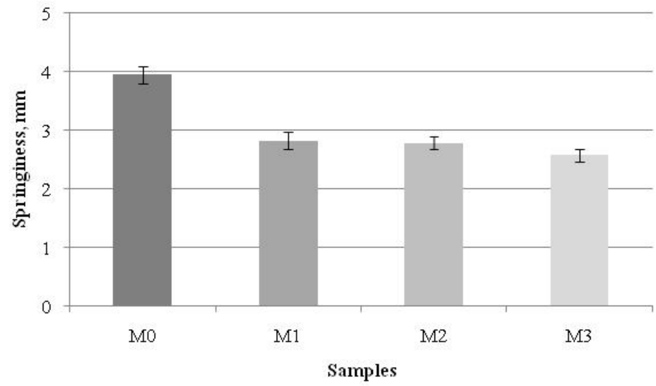
The cohesiveness (Figure 3c) of the control sample was lower than for those containing vegetable oils and walnuts and ranged from 0.30 ± 0.01 to 0.60 ± 0.05. Similar results were reported by Luruena-Martinez *et al.* (2004) for low-fat frankfurters with olive oil and locust bean/xanthan.

a)



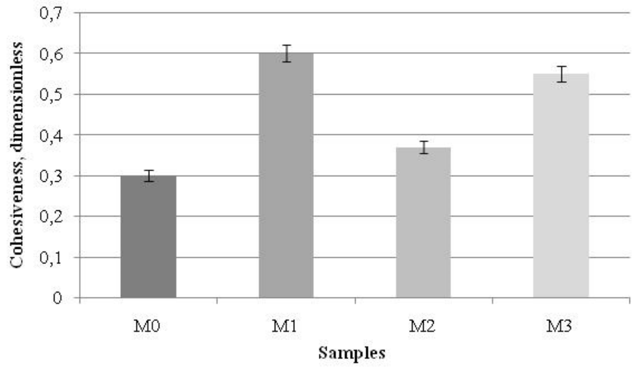
Hardness, N
0
1
2
3
4
5
M0
M1
M2
M3
Samples

b)



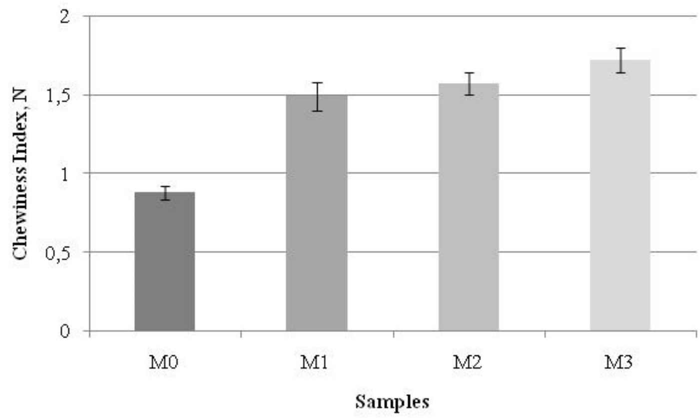
Springiness, mm
0
1
2
3
4
5
M0
M1
M2
M3
Samples

c)



Cohesiveness, dimensionless
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
M0
M1
M2
M3
Samples

d)



e)

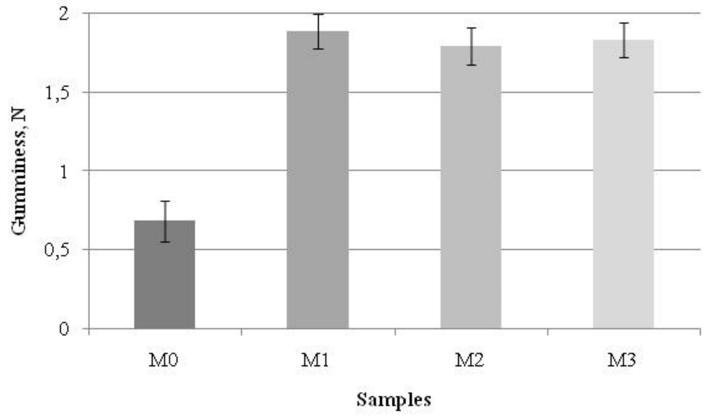


Figure 3. Effects of various vegetable oils and walnuts on the textural attributes of meatloaf

The values of gumminess and chewiness indexes (Figures 3d and 3e) for control sample were the lowest and increased for the samples with vegetable oils and walnuts. The mean values for gumminess ranged from 0.68 ± 0.14 N (M_0) to 1.88 ± 0.14 N (M_1) and chewiness index ranged from 0.88 ± 0.04 N (M_0) to 1.72 ± 0.08 N (M_3). The increasing of gumminess and chewiness indexes can be justified by the addition of powdered milk and walnuts, external sources of protein. This is in agreement with Claus *et al.* (1990) and Gregg *et al.* (1993) which analyzed the texture of meat based emulsion products.

The values of textural parameters: hardness, cohesiveness, gumminess and chewiness indexes were higher ($P < 0.05$) for all the samples where the pork back fat was partially substituted with vegetable oil and walnuts.

Sensory evaluation

The sensory evaluation of the meatloaves is shown in Figure 4. Each meatloaf sample was evaluated for aspect, colour, taste, overall acceptability, hardness, springiness, cohesiveness, gumminess and chewiness. The control sample has the lowest scores for taste, aspect and overall acceptability. The mean scores for taste ranged from 6.15 (M_0) to 8.52 (M_3), aspect scores ranged from 5.17 (M_0) to 8.81 (M_3) and overall acceptability scored 5.24 (M_0) to 8.86 (M_1). Similar results were reported by Muguerza *et al*. (2002) and Choi *et al*. (2010) for the effects of replacing pork back fat with vegetable oils.

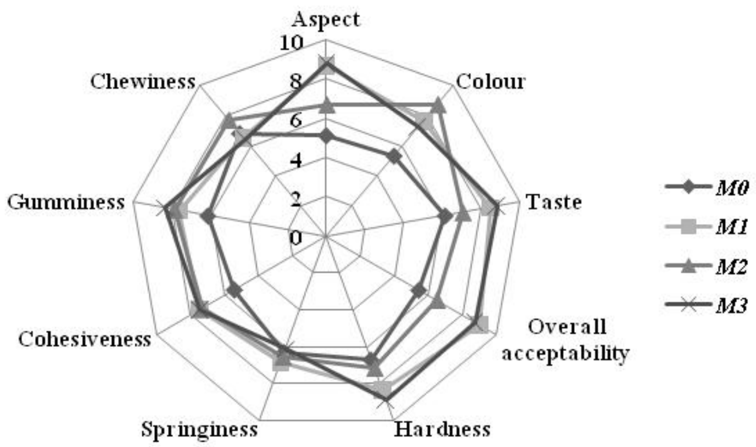


Figure 4. Sensory evaluation of meatloaf sample

The sample with sea buckthorn oil and walnuts (M_2) presents the highest color scores. The mean scores for color ranged from 5.17 (M_0) to 8.92 (M_2). These results may be due to the presence of sea buckthorn oil whose color is orange. The hardness, cohesiveness, gumminess and chewiness index were higher ($P < 0.05$) for all the samples with vegetable oils and walnuts compared to the control sample.

Compared with the control sample containing only animal fat, meatloaves in which pork back fat was partially replaced by vegetable oils and walnuts were generally found to have better taste, a compact consistency and less juicy.

In order to establish if the texture determined by instrumental analysis is relevant for the consumers, the scores obtained by sensorial analysis were correlated with the values of textural parameters determined by texture profile analysis (TPA). The R^2 values between instrumental and sensorial analysis are shown in Table 3. In this table it can be noticed the good correlation between all parameters.

Table 3. Correlation coefficients for textural parameters determined by texture profile analysis (TPA) and by sensorial analysis

Textural parameter	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness Index
R^2	0.9533	0.8649	0.8724	0.9207	0.9161

Conclusions

The partial substitution of pork back fat with vegetable oils (sea buckthorn, sunflower and walnut) and walnuts had an important effect on the quality of meatloaf. The addition of vegetable oils and walnuts are beneficial for meatloaf technology, because they improved chemical and textural properties. The use of vegetable oils and walnuts decreases the lipid oxidation in meatloaf samples. Meatloaf formulated with vegetable oils and walnuts samples had better sensory properties than the control one. The partial substitution of pork back fat with various vegetable oils and walnuts can contribute to the achievement of meatloaf with desirable quality characteristics.

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