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Effect of replacing beef fat with safflower oil on physicochemical, nutritional and oxidative stability characteristics of wieners

Emel KAYNAKCI[1*], Birol KILIÇ[2]

Abstract

Five treatments of wieners were prepared with replacing 0, 25, 50, 75 and 100% of added beef back fat with safflower oil (SO). Changes in pH, thiobarbuturic acid reactive substances (TBARS) and color (L*, a*, b*) values of wieners were determined during manufacturing day and refrigerated storage (5, 10, 15, 20 and 30 d). Fatty acid profile, cholesterol content, cooking loss, proximate composition and textural properties of wieners were also determined on manufacturing day. Results revealed that SO incorporation in wiener formulation resulted in a higher unsaturated fatty acid contents ($P < 0.05$). Wieners manufactured with a 50% or higher fat replacement with SO resulted in lower cholesterol content compared to other treatments ($P < 0.05$). Increasing the amount of SO used for beef back fat replacement in wieners created higher TBARS formation during the storage period ($P < 0.05$). Incorporation of SO increased CIE L* and b* values, whereas it caused a decrease in CIE a* values of wieners ($P < 0.05$). On the other hand, replacing beef back fat with SO did not affect sensory attributes of wieners. Study results indicated that replacement rate of beef back fat with SO up to 50% can be good strategy for the meat industry to produce desirable and healthy weiners.

Keywords: plant oil; meat products; cholesterol; fatty acids.

Practical Application: Using safflower oil instead of beef fat in wieners.

1 Introduction

Wieners are emulsified meat products with 20-30% animal fat content and have high consumption in many countries (Ospina-E et al., 2015). Wieners are usually manufactured with animal based fats such as beef and pork back fats (Henck et al., 2019; Novakovic et al., 2019). Animal fat plays a key role in many quality traits of meat products, including nutritional value and sensory properties, as well as the technological aspects (Gómez & Lorenzo, 2013). Furthermore, it also has an important role in stabilizing emulsion, reducing cooking loss and improving juiciness and textural properties (Lorenzo et al., 2014). Hovewer, fat present in meat and meat products are mostly composed of saturated fatty acids (SFA) which have been associated with elevated blood cholesterol level and an increased risk of cancers, hypertension and obesity (Câmara & Pollonio 2015). The high level of blood LDL-cholesterol has been reported to be one of the major causes for cardiovascular diseases (Reddy et al., 2015). In response, consumers are demanding from their food to be not only safe and nutritious, but also healthy and natural (Tahmasebi et al., 2016). These demands force manufacturers and researchers to develop healthier meat products (Lorenzo et al., 2016; Heck et al., 2017, 2019).

Most authorities such as the U.S. Department of Agriculture (USDA) and the World Health Organization (WHO) recommend intake of oils because of their polyunsaturated fatty acids (PUFA) such as linoleic and linolenic fatty acids which cannot be synthesized by human body (Reddy et al., 2015). Therefore, several vegetable oils have been utilized as an animal fat replacer in the production of various meat products for enrichment of the products with unsaturated fatty acids, improvement of unsaturated and saturated fatty acid ratio (Barros et al., 2020; Vargas-Ramella et al., 2020; de Carvalho et al., 2019; Ospina-E et al., 2015) and reducing cholesterol content (Delgado-Pando et al., 2010). Some vegetable oils such as n-3 PUFA enriched oil (López-López et al., 2009), canola oil (Selani et al., 2016), palm oil (Tan et al., 2006), fish oil (Marchetti et al., 2014), linseed oil (Carvalho et al., 2020; Franco et al., 2020), grapeseed oil (Choi at al., 2010), sesame oil (Zhuang et al., 2016), camellia oil (Wang et al., 2018), olive oil, sunflower oil and avocado oil (Rodríguez-Carpena et al., 2012) have been studied previously to replace animal fat in various meat products.

Safflower oil is obtained from *Carthamus tinctorius L.*. plant seeds that have a fat content of 35-37% (La Bella et al., 2019). As far as the health benefits of safflower oil are concerned, safflower oil contains about 73.7% oleic acid (La Bella et al., 2019) and American Hearth Association (2016) reported that safflower oil is high in MUFA. The main components of safflower oil (SO) are linoleic acids (cis-9, cis-12 18:2) and cis-9, trans-11 conjugated linoleic acid (CLA). These unsaturated fatty acids such as cis-9, trans-11 CLA are potential antioxidant, antiatherogenic, hypolipidemic and anti-hypertensive (Ebadia et al., 2014). Therefore, incorporation of safflower oil in wiener formulation

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[1] *Department of Cooking, Göynük Gastronomy and Culinary Art Vocational School, Akdeniz University, Antalya, Turkey*
[2] *Department of Food Engineering, Faculty of Engineering, Suleyman Demirel University, Isparta, Turkey*
*Corresponding author: ekaynakci@akdeniz.edu.tr

may improve the potential of the meat products to enhance consumer health benefits.

The aim of present study was to investigate the effect of safflower oil incorporation as a beef fat replacer on physicochemical, sensorial and shelf life characteristics of wieners.

2 Materials and methods

2.1 Materials

A 24 h post mortem fresh lean chicken breast meat (*Musculus pectoralis*) and beef fat were supplied from Gülköy Meat Integrated Plant (Isparta, Turkey). Before the production, the meat was ground with the grinder with 3 mm plate (Model PKM 22/32, Arı Makine, Istanbul, Turkey). pH of the meat used in our study ranged from 6.02 to 6.36. Safflower oil was obtained from Sungur Co. (Sivas, Turkey). Whey powder, sodium erithorbate, sodium chloride, sodium nitrite, liquid smoke and wiener spices mix were provided by Gülköy Meat Integrated Plant (Isparta, Turkey).

2.2 Wiener manufacturing

Wiener treatments are presented in Table 1. Wiener batter was prepared with ice, sodium nitrite, whey powder, beef fat, spices mix, and liquid smoke in a cutter (Cutter A-20, Ramon, Spain). Safflower oil was also incorporated into meat batter during this process according to formulation of each treatment. Wiener batter was stuffed into cellulose casing with 15 mm diameter by using a stuffer (Model SC-13, Ramon, Spain). Wiener batters were then subjected to cooking in smokehouse (Model FPK 100, Arı Makina, Turkey). The cooked wieners were then vacuum packaged in a polyethylene polyamide plastic bags and stored at 4^{o}C. TBARS, color and pH analysis were performed on manufacturing day and storage period (5, 10, 15, 20, and 30 d). Physicochemical analysis, cooking loss, cholesterol, fatty acid profile, texture and sensory analysis were also carried out once on processing day.

2.3 Cooking loss and proximate composition

Cooking loss of wieners were determined according to the method described by Kılıç et al. (2018). The moisture (Association of Official Analytical Chemists, 1997), ash (Association of Official Analytical Chemists, 2000), protein (Association of Official Analytical Chemists, 1997) and fat (Association of Official Analytical Chemists, 1997) levels of wiener samples were determined according to the AOAC (Association of Official Analytical Chemists, 1997) method.

2.4 Cholesterol determination

Lipids of wiener samples were extracted, and the cholesterol content was determined according to the method described by Intarasirisawat et al. (2011). Lipids were methylated with tetramethylammonium hydroxide and subjected to gas chromatograhpy analysis. The analysis of cholesterol was conducted using an HP-Innowax capillary column (10 m × 0.10 mm I.D., Agilent Technologies Inc., Santa Clara, CA, USA) connected to a Agilent 7820A gas chromatography (Agilent Technologies, USA) with a flame ionization detector. High purity helium was used as the carrier gas set at 1.0 mL/ min, and the sample (1 µL) was injected into the GC. The temperature of the injector port was set at 275 °C. Split injection mode (10:1 for each injection) was used. Oven temperature was set at 250°C and held for 15 min, and the detector temperature was set at 300 °C. The cholesterol standard (C8667-56, Sigma-Aldrich) was used for the GC analysis. The content of cholesterol for each sample was calculated from peak area and expressed as mg/100 g.

2.5 Measurement of fatty acid profile

Lipids were extracted from wieners according to Folch et al. (1957). Following the extraction of lipids, analysis of fatty acid profile was performed with gas chromotography (7820A, Agilent Technologies, USA) equipped with an electron impact (EI) ionisation detector. A column, Cp WAX 52 CB 50 m*0,32 mm, 1,2 µm was used. The operating conditions were as follows: column temperature, 240 °C; injector temperature, 250°C; detector temperature, 250°C. The carrier gas used was helium, at a flow pressure of 10 psi. The column was operated at 60°C for 4 min, then the temperature was increased gradualy to 240 °C at a rate of 4 °C/min. Fatty acids were identified by comparison of their retention time with appropriate standards (Supelco 18919-1AMP, Sigma-Aldrich). The results were expressed in weight percent of the total amount of fatty acids (Khoddami et al., 2009).

2.6 Texture profile analysis

Texture profile analysis was performed using a TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, UK) as described by

Table 1. Formulations of wiener treatments.

Ingredients (%)	Treatments				
	Control	25SO	50SO	75SO	100SO
Ground meat	69.2	69.2	69.2	69.2	69.2
Ice	13.84	13.84	13.84	13.84	13.84
Beef fat	13.84	10.38	6.92	3.46	-
Safflower oil	-	3.46	6.92	10.38	13.84
Whey powder	0.69	0.69	0.69	0.69	0.69
Spice mix	1.04	1.04	1.04	1.04	1.04
Curing salt	1.38	1.38	1.38	1.38	1.38
Liquid smoke	0.003	0.003	0.003	0.003	0.003

Control: 100% beef fat; 25SO: 25% safflower oil + 75% beef fat; 50SO: 50% safflower oil + 50% beef fat; 75SO: 75% safflower oil + 25% beef fat; 100SO: 100% safflower oil.

Kılıç et al. (2018). Before the analysis, wiener samples were stored at room temperature for 30 min to provide homogeneity and cut into 2-cm thick sections. The analysis was performed using a 5 mm cylindrical stainless steel plunger attached to a 50 N cell connected to the crosshead (crosshead speed of 50 mm/min) and compressed by 70%. Analysis of force-times curves led to the identification of measured textural parameters. Measurements were taken in ten replicates from different locations of samples and hardness values were calculated by the software program. Hardness was the maximum peak force during compression.

2.7 pH analysis

The pH measurements were taken with spear tip electrode (Hanna Instruments HI 9024, Italy) on homogenates of 10 g of wiener sample and 90 ml of distilled water (Chouliara et al., 2007).

2.8 Color analysis

CIE Color values (L, a*, b*) of wiener batter and wiener samples were measured by a Minolta Chroma Meter CR-200, Minolta Camera Co., Japan (Luo, 2006). The colorimeter was calibrated using a standard white ceramic plate. The color measurements were replicated ten times using different parts of wiener samples.

2.9 Thiobarbituric acid reactive substances (TBARS) analysis

TBARS were determined using the muscle extraction procedure of Lemon (1975) with some modifications (Kilic & Richards 2003). This method requires addition of EDTA and propyl gallate to the trichloroacetic acid (TCA) extraction solution to prevent the development of TBARS during the analytic procedure. The TBARS values were expressed as μmol TBARS per kg of sample. A standard curve was prepared using 1,1,3,3-tetraethoxypropane.

2.10 Sensory analysis

The degree of difference and descriptive sensory analysis were performed at the Department of Food Sciences at the Suleyman Demirel University. Sensory analysis was performed by a total of 25 panelists (13 males and 12 females), who were between 17 and 25 years old, non-smoker, and experienced in the sensory evaluation of foods. The procedures described in the IFT Guideline (Institute of Food Technologists, 1981) were applied in sensory analysis. Sensorial attributes of wieners samples were evaluated for color, odor, flavor, taste, juiciness, texture and the overall acceptability. Samples were sliced to 1 cm thickness and chosen randomly from each treatment. Wieners were served hot (approximately 50 °C) after heated 40 s at microwave oven.

2.11 Statistical analysis

The entire experiment was replicated three times on separate production days. Data collected for chemical composition, physicochemical properties and sensory attributes were analyzed. Statistical analysis was performed using SPSS 17.0 (Version 17.0. Chicago, IL, USA). The generated data were analyzed by analysis of variance (ANOVA). Differences among mean values were established using the Tukey multiple range test and were considered significant when $P< 0.05$. pH, TBARS, color (L*, a*, b*) data were also analyzed by Repeated Measures (GLM). Significance level of $P \leq 0.05$ was used for all evaluations.

3 Results and discussion

3.1 Cooking loss, proximate composition and textural properties

Cooking loss values of wieners are shown in Table 2. Cooking loss values of all wiener treatments varied between 6.06-7.69%. There was no difference among treatments in terms of cooking loss ($P > 0.05$). Jiménez-Colmenero et al. (2010) reported that replacement of pork backfat by oil-in-water emulsion had no effect on cooking loss of frankfurters. Ospina-E et al. (2015) also stated that there was no difference between the cooking losses of the frankfurters produced by replacing the animal fat with the chemicaly modified vegetable oils.

Moisture, ash, protein, fat and hardness values are presented in Table 2. There were no significant differences in ash, protein and hardness values among wiener treatments. Protein levels of the wiener samples produced in this study ranged from 12.53% to 13.52%. Similar protein values were reported for chicken frankfurters (Ospina-E et al., 2015). Results revealed that moisture content significantly decreased when the increasing the safflower oil incorporation rate in the wiener formulation ($P < 0.05$). Yılmaz et al., (2002) reported similar results for frankfurters made with the sunflower oil. According to Turkish Sausage Standards (Turkish Standards Institute, 2016), the moisture value of sausages should not exceed 65%. In this regard, the moisture values of all wiener treatments were in accordance with

Table 2. Physico-chemical composition* of wiener treatments.

	Treatments				
	Control	25SO	50SO	75SO	100SO
Moisture (%)	54.24 ± 2.71^{a}	54.64 ± 1.31^{a}	52.69 ± 1.03^{ab}	51.15 ± 1.69^{b}	52.75 ± 2.21^{b}
Ash (%)	2.39 ± 0.03^{a}	2.42 ± 0.17^{a}	2.31 ± 0.04^{a}	2.25 ± 0.08^{a}	2.35 ± 0.03^{a}
Protein (%)	13.52 ± 0.47^{a}	13.20 ± 1.19^{a}	13.20 ± 0.79^{a}	12.53 ± 0.27^{a}	12.91 ± 0.03^{a}
Fat (%)	30.53 ± 1.25^{b}	30.95 ± 0.30^{b}	30.95 ± 0.30^{b}	32.67 ± 0.30^{a}	31.84 ± 0.52^{ab}
Hardness (N)	254.9 ± 68.4^{a}	252.6 ± 55.4^{a}	257.6 ± 44.3^{a}	262.9 ± 18.8^{a}	247.9 ± 47.5^{a}
Cooking loss (%)	7.69 ± 0.21^{a}	7.03 ± 0.86^{a}	6.55 ± 1.00^{a}	6.76 ± 0.22^{a}	6.06 ± 0.77^{a}

Control: 100% beef fat; 25SO: 25% safflower oil + 75% beef fat; 50SO: 50% safflower oil + 50% beef fat; 75SO: 75% safflower oil + 25% beef fat; 100SO: 100% safflower oil; *All values are the mean ± standard error of three replicates; a, b (→) Different letters within a row are significantly different ($p < 0.05$).

TS 980 Turkish Sausage Standards. Previous studies indicated that adding vegetable oils causes softening problem in meat products (Yıldız-Turp & Serdaroğlu, 2008). The present study results revealed that addition of safflower oil did not cause any change in hardness values of wieners.

Replacement of animal fats with vegetable oils was expected to increase the amount of total fat in the final product (Rodríguez-Carpena et al., 2012). Our study results also indicated that increasing the ratio of safflower oil in wiener formulation to replace beef fat resulted in an increased amount of total fat level in the final product ($P<0.05$).

3.2 Cholesterol content and fatty acid profile

The fatty acid composition of wieners are shown in Table 3. There were significant differences among treatments for cholesterol content ($P < 0.05$). However, there was no difference between the control and 25SO treatment regarding cholesterol level. 2.00, 18.64, 22.92, 23.70% reduction in cholesterol content were obtained in 25SO, 50SO, 75SO and 100SO, respectively, compared to control ($P < 0.05$). Muguerza et al., (2002) found that the cholesterol value of sausage produced by replacing 25% added animal fat with soybean oil was 5.98% lower than control. Another study showed that replacement of animal fat with vegetable oil caused cholesterol reduction in emulsion-type pork sausages (Lee et al., 2015).

The fatty acid composition has a great impact on the nutritional value, oxidative stability and sensory properties of muscle foods (Rodríguez-Carpena et al., 2012). In the present study, the most abundant fatty acids in control wiener samples were SFA, followed by MUFA and PUFA (Table 3). As compared with control, safflower replaced wieners had higher PUFA and MUFA levels. Addition of safflower oil also reduced myrictic, palmitic and stearic acids ($P < 0.05$). It is well demonstrated that while stearic acis is neutral, palmitic and myristic acids produce the greatest atherogenic effect (Delgado-Pando et al., 2010). In our study palmitic and myristic acid decrased from 24.9 and 3.19% to 16.84 and 0.75%, respectively when the beef fat was replaced by safflower oil. Results indicated that PUFA levels gradually increased with increasing the amount of added safflower oil ($P < 0.05$). PUFA contents in 25SO, 50SO, 75SO and 100SO treatments increased 30.8, 35.2, 41.8 and 44.72% respectively compare to control.

Asuming-Bediako et al. (2014) reported that replacing the pork backfat emulsion with rapeseed emulsion created an increase in MUFA and PUFA compositions from 45% to 59% and from 15% to 25% in sausage, respectively. From the nutritional point of view, PUFA/SFA ratio is one of the most important parameters and this ratio should be above 0.4 (Kasprzyk et al., 2015). The importance of the PUFA/SFA ratio in diets with reduced cholesterol level has been demonstrated by Marangoni et al., (2020). Research has been continuously undertaken to increase this ratio in the meat products (Paglarini et al., 2018, 2019, 2020). In this regard, the results showed that wieners manufactured in this study may be a good source for consumers with hyperlipidaemia, high cholesterol and heart diseases since PUFA/SFA ratios of wieners produced with SO were higher than 0.4 (Table 3).

3.3 pH, color and TBARS

Effect of safflower incorporation on pH, TBARS, color (L*, a* and b*) values of wieners stored at 4 °C during 30 days of storage are presented in Table 4. There was difference in

Table 3. Fatty acid profile and cholesterol content of wieners

Fatty acid	Control	25SO	50SO	75SO	100SO
C10:0	0.045 ± 0.06	-	-	-	-
C12:0	0.09 ± 0.09	-	1.39 ± 0.00	-	1.36 ± 0.01
C14:0	3.19 ± 2.13	1.28 ± 0.01	1.26 ± 0.49	0.33 ± 0.18	0.75 ± 0.07
C16:0	24.9 ± 2.11	22.38 ± 2.14	20.68 ± 1.94	21.56 ± 6.14	16.84 ± 2.39
C17:0	0.66 ± 0.00	0.30 ± 0.28	0.28 ± 0.00	-	0.39 ± 0.54
18:0	11.52 ± 5.86	14.41 ± 2.16	11.00 ± 1.06	7.93 ± 1.53	6.33 ± 0.95
ΣSFA[A]	40.41	38.38	33.82	29.92	25.7
C16:1	3.46 ± 2.23	1.92 ± 0.28	1.69 ± 0.01	0.99 ± 0.69	1.42 ± 0.14
C18:1	29.65 ± 3.01	27.18 ± 0.22	26.83 ± 0.99	25.91 ± 2.26	26.44 ± 0.80
C18:1 (n-7)	3.32 ± 1.67	1.05 ± 1.27	1.78 ± 0.01	1.03 ± 0.90	1.43 ± 0.25
ΣMUFA[B]	36.43	30.15	30.03	27.93	29.29
C18:2 (*n-6*)	17.65 ± 7.92	28.81 ± 1.47	33.09 ± 2.89	40.59 ± 0.13	42.88 ± 4.14
α-Linolenic C18:3 (n_3)	3.06 ± 1.19	1.89 ± 0.54	2.29 ± 0.16	1.28 ± 1.03	1.84 ± 0.27
Σn-3	3.06 ± 1.19	1.89 ± 0.54	2.29 ± 0.16	1.28 ± 1.03	1.84 ± 0.27
Σn-6	20.71 ± 1.24	28.96 ± 1.62	33.09 ± 2.89	40.59 ± 0.13	42.88 ± 4.14
ΣPUFA[C]	23.77	30.85	35.29	41.87	44.72
PUFA/SFA	0.59	0.8	1.04	1.4	1.74
MUFA+PUFA/SFA	1.49	1.58	1.93	2.33	2.88
n-6/n-3	6.76	15.32	14.45	31.71	23.3
Cholesterol mg/100 g	43.20 ± 2.18[a]	42.39 ± 2.68[a]	35.15 ± 1.45[b]	33.30 ± 1.92[b]	32.96 ± 2.47[b]

All values are the mean ± standard error; a, b (→) Different letters within a row are significantly different ($p<0.05$); [A] Saturated fatty acids (SFA); [B] Monosaturated fatty acids (MUFA); [C] Polyunsaturated fatty acids (PUFA).

Table 4. pH, TBARS and color (CIE L*, a*, b*) results of wieners during storage at 4 °C.

		Storage time (day)						Repeated measures
		0	5	10	15	20	30	
pH	Control	6.21 ± 0.01^{d}	6.44 ± 0.06^{ab}	6.47 ± 0.08^{a}	6.35 ± 0.0^{bc}	6.36 ± 0.00^{abc}	6.27 ± 0.0^{cd}	6.35 ± 0.01^{A}
	25SO	6.22 ± 0.02^{c}	6.56 ± 0.2^{a}	6.48 ± 0.05^{ab}	6.35 ± 0.0^{bc}	6.33 ± 0.0^{bc}	6.17 ± 0.1^{c}	6.35 ± 0.18^{A}
	50SO	6.20 ± 0.06^{b}	6.45 ± 0.2^{a}	6.48 ± 0.0^{a}	6.38 ± 0.0^{ab}	6.40 ± 0.0^{ab}	6.31 ± 0.0^{ab}	6.37 ± 0.13^{A}
	75SO	6.20 ± 0.06^{c}	6.33 ± 0.0^{b}	6.62 ± 0.0^{a}	6.36 ± 0.00^{b}	6.39 ± 0.0^{b}	6.31 ± 0.0^{b}	6.37 ± 0.14^{A}
	100SO	6.18 ± 0.07^{d}	6.30 ± 0.0^{bcd}	6.51 ± 0.0^{a}	6.37 ± 0.0^{abc}	6.42 ± 0.0^{ab}	6.25 ± 0.0^{cd}	6.33 ± 0.12^{A}
TBARS	Control	1.32 ± 0.15^{c}	1.82 ± 0.40^{ab}	1.90 ± 0.8^{ab}	1.75 ± 0.5^{ab}	1.84 ± 0.3^{ab}	1.41 ± 0.23^{a}	1.84 ± 0.53^{C}
	25SO	3.09 ± 0.50^{b}	3.61 ± 0.40^{a}	3.66 ± 0.39^{a}	3.87 ± 1.06^{a}	3.22 ± 0.45^{a}	3.00 ± 0.19^{a}	3.74 ± 0.62^{B}
	50SO	3.54 ± 0.45^{b}	3.95 ± 0.69 ^{ab}	3.95 ± 0.7^{ab}	3.19 ± 0.2^{ab}	3.85 ± 0.29^{a}	3.24 ± 0.71^{ab}	4.12 ± 0.64^{B}
	75SO	4.92 ± 0.22^{a}	4.55 ± 0.47^{b}	4.62 ± 0.30^{b}	5.06 ± 0.3^{ab}	5.56 ± 0.10^{a}	5.97 ± 0.59^{ab}	4.95 ± 0.48^{A}
	100SO	5.45 ± 0.23^{a}	4.94 ± 0.73^{b}	4.99 ± 0.52^{b}	5.64 ± 0.3^{ab}	6.13 ± 0.34^{a}	6.07 ± 0.15^{a}	5.54 ± 0.61^{A}
L*	Control	77.85 ± 1.85^{a}	77.05 ± 1.86^{ab}	75.76 ± 1.59^{b}	76.58 ± 1.43^{ab}	76.84 ± 1.12^{ab}	77.25 ± 0.83^{a}	76.89 ± 1.60^{C}
	25SO	78.56 ± 1.08^{a}	77.25 ± 1.19^{b}	76.98 ± 1.45^{b}	78.00 ± 1.16^{ab}	77.03 ± 1.55^{b}	77.32 ± 1.65^{ab}	77.52 ± 1.45^{C}
	50SO	79.62 ± 1.34^{a}	78.85 ± 0.86^{ab}	78.23 ± 1.11^{b}	78.76 ± 1.56^{ab}	77.88 ± 1.82^{b}	78.44 ± 0.89^{ab}	78.63 ± 1.40^{B}
	75SO	80.23 ± 0.97^{a}	79.00 ± 1.12^{b}	79.19 ± 0.77^{b}	79.81 ± 1.68^{ab}	79.12 ± 0.92^{b}	79.21 ± 0.78^{b}	79.43 ± 1.15^{A}
	100SO	80.53 ± 1.41^{a}	80.14 ± 1.37^{a}	79.62 ± 1.98^{a}	80.29 ± 1.85^{a}	80.05 ± 1.81^{a}	79.92 ± 1.27^{a}	80.09 ± 1.63^{A}
a*	Control	6.47 ± 0.72	6.34 ± 0.64	6.21 ± 0.60	5.99 ± 0.95	6.11 ± 0.75	6.47 ± 0.81	6.27 ± 0.76 ^{A}
	25SO	6.03 ± 0.62^{b}	6.07 ± 0.46^{b}	5.93 ± 0.39^{b}	5.81 ± 0.35^{b}	5.81 ± 0.39^{b}	6.71 ± 0.39^{a}	6.06 ± 0.53^{A}
	50SO	5.58 ± 0.51^{a}	5.53 ± 0.25^{a}	5.50 ± 0.24^{a}	5.35 ± 0.51^{a}	5.54 ± 0.29^{a}	5.06 ± 1.21^{a}	5.43 ± 0.62^{B}
	75SO	5.36 ± 0.34^{ab}	5.47 ± 0.28^{ab}	5.35 ± 0.24^{ab}	4.93 ± 0.30^{c}	5.20 ± 0.33^{bc}	5.54 ± 0.42^{a}	5.31 ± 0.37^{B}
	100SO	5.33 ± 0.78^{a}	5.00 ± 0.45^{a}	5.36 ± 0.56^{a}	5.24 ± 0.69^{a}	5.40 ± 0.53^{a}	5.11 ± 0.32^{a}	5.24 ± 0.58^{B}
b*	Control	16.99 ± 0.32^{c}	17.27 ± 0.61^{bc}	17.43 ± 0.87^{bc}	17.57 ± 0.57^{b}	17.65 ± 0.69^{b}	18.37 ± 0.63^{a}	17.46 ± 0.83^{C}
	25SO	17.30 ± 0.60^{c}	17.44 ± 0.95^{b}	17.58 ± 0.34^{b}	17.73 ± 0.33^{b}	17.72 ± 0.65^{b}	18.78 ± 0.70^{a}	17.76 ± 0.81^{BC}
	50SO	17.55 ± 0.25^{c}	17.58 ± 0.34^{bc}	17.64 ± 0.28^{bc}	17.81 ± 0.49^{bc}	17.94 ± 0.56^{b}	18.99 ± 0.39^{a}	17.92 ± 0.63^{B}
	75SO	17.62 ± 0.46^{c}	17.64 ± 0.38^{c}	17.73 ± 0.55^{bc}	18.00 ± 0.81^{bc}	18.15 ± 0.34^{b}	19.14 ± 0.40^{a}	18.05 ± 0.73^{AB}
	100SO	17.93 ± 0.10^{bc}	17.74 ± 0.48^{c}	18.09 ± 0.87^{bc}	18.22 ± 0.79^{bc}	18.66 ± 1.10^{ab}	19.40 ± 0.61^{a}	18.34 ± 0.99^{A}

All values are the mean ± standard error of three replicates; a, b, c, d (→) Different letters within a column are significantly different ($p < 0.05$); A,B,C (↓) Different letters within a row are significantly different (the last column) ($p < 0.05$).

the pH values of wieners during the storage days ($P < 0.05$). Ospina-E et al. (2015) reported that there were no significant differences in pH values of frankfurter during storage time. In contrast, Pereira et al. (2020) reported that adding vegetable oil decreased the pH values in frankfurters. Sisik et al. (2012) have also observed a reduction in pH values during the cold storage in bologna type sausages.

TBARS values of wieners manufactured in this study ranged from 1.32-5.45 μmol TBARS per kg on manufacturing day. In general, lipid oxidation in all wiener samples increased during the storage ($P < 0.05$). Pereira et al., (2020) determined that there was a general increase in TBARS values during storage time in fat-reduced frankfurters. Based on the results of repeated measurements in the present study, it was found that TBARS values of 100SO and 75SO treatmens were higher than those of 25SO, 50SO and control ($P < 0.01$). There were no significant differences among TBARS values of control, 25SO and 50SO treatmens ($P < 0.05$). It was previously suggested that the extracts of safflower are potent radical scavengers and primary chain-breaking antioxidants (Ebadia et al., 2014).

Substitution of safflower oil had significant effects on the color parameters of wieners ($P < 0.01$). The presence of safflower oil caused an increase in L* and b* values, in contrast, the presence of safflower oil reduced a* values of the wiener samples compared to control. High b* values obtained in this study was thougt to be associated with color of added safflower oil. It was also previously reported that addition of vegetable oils (without interesterification) caused a decrease in L* and a* values and an increase in b* values of meat products (Ospina-E et al., 2015). Özvural & Vural (2008) also found that the addition of interesterified vegetable oil and oil blends increased the L∗ and b∗ values of frankfurters. On the other hand, Vural (2003) stated that animal fat replacement with ineresterified oils has no effect on L*color values. Sisik et al., (2012) reported that presence of corn oil caused an increase in L* values of Bologna type sausages. In another study, there was no change in L* or b* of the sausages manufactured with corn oil; meanwhile, a* values were reported to be increased during 30 d storage and remained stable until day 45, indicating that the products became redder during storage (Menegas et al., 2013).

3.4 Sensory analysis

Variance analyses for wieners are shown in Table 5. Results indicated that addition of safflower oil did not affect color, odor, flavor, taste, juiciness, texture and the overall acceptability of wieners compared to control. Zlatko et al. (2009) reported that chicken frankfurters made with plant oils are acceptable in terms of sensorial features. Yıldız-Turp & Serdaroğlu (2008)

Table 5. Sensory evaluation results of wieners.

Treatments	Color	Color Intensity	Integrity	Hardness	Fragmentation	Juiciness
Control	5.69 ± 2.39[a]	6.07 ± 2.40[a]	7.54 ± 1.76[a]	4.69 ± 1.89[a]	5.15 ± 2.61[a]	5.31 ± 1.65[a]
25SO	6.62 ± 1.98[a]	5.00 ± 2.23[a]	7.54 ± 2.18[a]	5.31 ± 1.84[a]	5.00 ± 2.16[a]	4.69 ± 1.44[a]
50SO	6.69 ± 1.97[a]	4.15 ± 2.51[a]	7.08 ± 2.43[a]	5.31 ± 1.37[a]	5.85 ± 2.19[a]	5.31 ± 1.38[a]
75SO	6.54 ± 1.81[a]	4.38 ± 2.87[a]	7.77 ± 1.79[a]	5.08 ± 1.32[a]	5.31 ± 2.02[a]	5.54 ± 1.45[a]
100SO	6.38 ± 2.40[a]	3.77 ± 2.98[a]	7.31 ± 1.93[a]	5.08 ± 1.71[a]	5.31 ± 1.89[a]	5.00 ± 1.58[a]
	Oiliness	Flavor	Off-Flavor	Flavor Intensity	Odor	Overall Acceptability
Control	4.85 ± 2.44[a]	5.69 ± 1.93[a]	2.31 ± 3.09[a]	5.23 ± 1.96[a]	6.84 ± 1.62[a]	7.62 ± 1.80[a]
25SO	4.31 ± 1.75[a]	6.46 ± 1.94[a]	1.38 ± 1.98[a]	5.46 ± 2.37[a]	6.15 ± 2.44[a]	7.77 ± 1.48[a]
50SO	4.62 ± 1.26[a]	6.15 ± 2.07[a]	1.46 ± 1.51[a]	5.31 ± 1.93[a]	6.08 ± 2.29[a]	8.00 ± 1.53[a]
75SO	4.38 ± 1.19[a]	6.38 ± 2.43[a]	1.54 ± 1.98[a]	5.23 ± 2.08[a]	7.00 ± 1.47[a]	7.30 ± 1.65[a]
100SO	3.85 ± 1.63[a]	6.08 ± 2.60[a]	1.77 ± 1.64[a]	5.08 ± 2.72[a]	6.69 ± 1.80[a]	7.15 ± 1.95[a]

All values are the mean ± standard error of three replicates; a (→) Different letters within a column are significantly different ($p < 0.05$).

indicated that sausages produced with 15% emulsified nut oil received the highest taste and the overall acceptability scores compared to sausages produced with animal fat. On the other hand, Pappa et al. (2000) have reported that using vegetable oil in meat products is not a suitable strategy because of undesirable color formation.

4 Conclusion

The results of the present study suggested that use of safflower oil instead of animal fat may be good strategy to improve fatty acid profile and reduce cholesterol content of wieners without any negative effect on chemical composition and sensory properties. It is also suggested that the replacement rate up to 50% can be good strategy for the meat industry to avoid possible shelf life problems in weiner processing.

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