PAPER

UTILIZATION OF JERUSALEM ARTICHOKE POWDER IN PRODUCTION OF LOW-FAT AND FAT-FREE FERMENTED SAUSAGE

C.O. ÖZER
Department of Food Engineering, Faculty of Engineering and Architecture, Nevsehir Hacı Bektaş Veli University, 50300, Nevsehir, Turkey
*Corresponding author: Tel.: +90 3842281000-15077; Fax: +90 3842281123
E-mail address: cemokanozer@nevsehir.edu.tr

ABSTRACT

The effects of Jerusalem artichoke powder (JAP) on the quality characteristics and storage stability of fermented sausage were investigated. The replacement of added beef fat with JAP were carried out during sausage manufacturing. Replacement of beef fat with JAP resulted in a significant decrease in TBARS and pH values and an increase in moisture and protein content in sausages during fermentation and storage ($p<0.05$). L* values decreased and a* values increased by adding JAP ($p<0.05$). JAP addition decreased hardness values and increased adhesiveness ($p<0.05$). The use of JAP encourages the development of lactic acid bacteria and positively affected their counts during the fermentation ($p<0.05$).

Keywords: sausage, Jerusalem artichoke powder, functional food, storage stability

1. INTRODUCTION

In recent years, functional meat products have attracted the attention of the consumer and their demands are rapidly increasing. Researchers and producers have tried to meet these demands with different strategies they have developed such as low fat, cholesterol, sodium chloride and nitrite and improved composition of meat products with incorporated health enhancing specific natural food ingredients (DEMEYER and ASTIASARÁN, 2007).
Natural additives have been more preferred than synthetic additives in food products because of their low toxicity, safety and cost efficiency (SIROCCHI *et al*., 2017; VAN HAUTE *et al*., 2016). Several natural and functional components mainly from plant origins have been introduced to meet consumer preferences and technological requirements. Therefore, improvement of meat products with some natural vegetable source compounds has been studied extensively over the past decades (HYGREEVA *et al*., 2014; OLMEDILLA-ALONSO *et al*., 2013). Vegetable sources with functional properties can be allowing many strategies to be carried out together in meat products and so many effects can be shown together such as reduction of beef fat, cholesterol and energy, enrichment with antioxidants, plant protein and dietary fiber and some technological improvements (GRASSO *et al*., 2014; OLMEDILLA-ALONSO *et al*., 2013). Jerusalem artichoke (*Helianthus tuberosus L.*) powder also may be a versatile alternative functional additive in dry fermented sausage to both reduction of beef fat and a consequent reduction of cholesterol, saturated fatty acid and energy value and increasing nutritional value and textural properties without adversely affecting quality characteristics.
Jerusalem artichoke contains high amounts of dietary fiber and most of it is inulin. Additionally, it contains some antioxidant compounds such as polyacetylenic derivatives, sesquiterpenes and coumarins (FURLAN *et al*., 2014). There are many studies about using of inulin and Jerusalem artichoke (GEDROVICA and KARKLINA, 2013) in many food products such as sausages, frankfurters, cookies, pasta and some dairy products and also successful results about technological and nutritional improvements have been reported in the literature (AFOAKWAH *et al*., 2015, FURLAN *et al*., 2014; PRAZNIK *et al*., 2002). However, study about the effects of Jerusalem artichoke powder in meat fermentation is limited in the literature. Therefore, the present study is aimed to assess the effect of Jerusalem artichoke powder as beef fat replacers on the quality characteristics and storage stability of dry fermented sausage, including physicochemical composition, lipid oxidation, color, textural and microbiological properties.

2. MATERIAL AND METHODS

2.1. Ingredients

A 24 h post-mortem *Longissimus thoracis et lumborum* cuts and beef fat (beef back fat) was purchased from a local butcher (Birlik Market, Nevsehir, Turkey) for each of 3 replications on separate production days. All meat cuts were trimmed from all subcutaneous and intermuscular fats. The lean beef and fat sources were separately ground in a 2 mm and 3 mm plate meat grinder, respectively (Arı Makine A.Ş, İstanbul). The freeze-dried culture mix, which contains *Lactobacillus curvatus, Staphylococcus xylosus, Staphylococcus carnosus* and *Pediococcus pentosaceus*, was used as starter culture mix.
Jerusalem artichoke (*Helianthus tuberosus L.)* tubers were obtained from a local producer (Nevsehir, Turkey) during harvest season. Jerusalem artichoke was washed, peeled and then dried using freeze dryer at −80°C and 0.01 mbar (Operon, OPR-FDU-8612, Korea).

Dried samples were ground to a fine powder using laboratory grinder (Yucebas Makine, Izmir, Turkey). Physicochemical properties, which are moisture, fat, ash, protein, carbohydrate and dietary fiber contents of Jerusalem artichoke powder was determined.

2.2. Sausage Preparation

The production and ripening of sausages were carried out as described in OZER and KILIC (2014). Five batches were prepared from ground beef. The control group incorporated with %72 lean beef and 20% beef fat was prepared without Jerusalem artichoke powder. The other experiment groups were given codes as JAP25, JAP50, JAP75 and JAP 100 in relation to the ratio of JAP powder used replacement of beef fat. JAP25, JAP50, JAP75 and JAP100 groups were produced with 15% beef fat and 5% JAP, 10% beef fat and 10% JAP, 5% beef fat and 15% JAP and 0% beef fat and 20% JAP, respectively. The other ingredients were added into sausages as follows: 2.5 % NaCl, 1.5 % garlic, 1.5 % red pepper, 0.8 % cumin, 0.5 % sucrose, 0.5 % black pepper, 0.5 % allspice and 150 ppm NaNO2. During the mixing, the starter culture mixture was added at a dose of 4-5 log cfu/g of sausage dough. After the filling up to cases of sausages samples, sausages were ripened at 95-70 % relative humidity (RH) at 25-18 ºC during 7 days; 24 h at 95 % RH at 24 ºC; 24 h at 90 % RH at 22 ºC; 12 h at 85 % RH at 20 ºC; 12 h at 80 % RH at 20 ºC; 48 h at 75 % RH at 18 ºC; and 48 h at 70 % RH at 18 ºC. Sausages were vacuum-packaged and then stored at 4 ºC for 30 days. The entire experiment was replicated three times on separate processing days.

2.3. Physicochemical composition

Fat, protein, ash and moisture content of sausages were measured at manufacturing and after fermentation day (AOAC 2005). pH of sausages were measured at manufacturing day, after fermentation and during storage period (7, 15, 30d) (AOAC 2005). Also, moisture, fat, ash, protein and total dietary fiber content of JAP according to AOAC (2005). Additionally, the total carbohydrate content of JAP was calculated by difference. Furthermore, total phenolic compounds were determined as described by TAKEUCHI and NAGASHIMA (2011) and total phenol concentration was quantified against a gallic acid (Sigma-Aldrich, St. Louis MO) standard curve. Finally, the water holding capacity of JAP was determined and expressed as g water per g of JAP (TAKEUCHI and NAGASHIMA 2011).

2.4. TBARS analysis

Thiobarbituric acid reactive substances (TBARS) values of samples were determined as described by KILIC and RICHARDS (2003) to evaluate of oxidation stability during fermentation and storage period (7, 15, 30 d) and TBARS values were expressed as μmol TBARS per kg of meat.

2.5. Color measurement

Color measurement was conducted by a Minolta Chroma Meter CR-200 (Minolta, Osaka, Japan) colorimeter using D65 as a standard daylight illuminant and a standard observer position of 10°. 8-mm-diameter circle and the specular component included (SCI) mode was used to measure. The colorimeter was standardized against a white calibration plate (D65, CIE L*=97.79, a*=−0.11, b*=2.69). Three readings were taken and averaged for each

of the three replications. Color values were determined at manufacturing day, after fermentation and during storage period (7, 15, 30 d).

2.6. Texture profile analysis

Samples were cut into slices (10±0.5 mm thick), wrapped with plastic film, and then held for equilibration to room temperature (20 ºC) for texture profile analysis (TPA). TPA tests and conditions were carried out as described in KıLıÇ and ÖZER (2017), using a texture analyzer (TA-XT2Í, Stable Micro Systems, UK). Test conditions were briefly as follows: rectangular probe (5 cm · 4 cm); pre-test speed 2 mm/s, test speed 5 mm/s, post-test speed 2 mm/s, 70 % compression and 50 kg load cell. Hardness (N), adhesiveness (Ns), springiness, cohesiveness, chewiness index, and resilience value of sausages were determined using 6 sausage slices per treatment.

2.7. Microbiological analysis

Sausage samples (10 g) were homogenized with sterile buffered peptone water (90 ml) in a stomacher at room temperature. Decimal dilutions in buffered peptone water were prepared and duplicate 0.1 ml samples of appropriate dilutions were spread. The following groups were investigated: total viable aerobic (TVAC) on Plate Count Agar (Merck, Darmstadt, Germany), incubated at 30°C for 48 h; lactic acid bacteria on De Man, Rogosa and Sharpe Agar (Merck, Darmstadt, Germany), incubated in anaerobic jar at 37°C for 48 h; yeast and molds on Potato Dextrose Agar (Merck, Darmstadt, Germany), incubated at 25°C for 72 h; coliform on Violet Red Bile Agar (Merck, Darmstadt, Germany), incubated at 37°C for 24 h.

2.8. Statistical analysis

The results were expressed as mean values with standard errors from the three replications. The statistical evaluation of the results was performed using the SPSS 22.0.0 (SPSS Inc., Chicago, USA). Data collected for physicochemical properties of sausages were analyzed by one-way analysis of variance (ANOVA). A completely randomized design was used with 5 treatment groups and 3 replications on separate production days. The treatments were one control group and four groups, which were assigned, and the data were analyzed using general linear model (GLM) procedure, in which treatment groups and storage time were assigned as fixed effects and replications as a random effect. Duncan multiple comparison test was used to compare means values and differences among mean values were considered significant when $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Microbiological analysis

Replacement of beef fat by JAP showed no significant effect on mold and yeast, total viable and coliform bacteria count during fermentation and storage periods (data is not presented) ($p<0.05$). The microbiological counts of sausage groups at the end of the fermentation ranged from 8.71 to 9.37 log cfu/g for total viable, from 5.61 to 5.82 log cfu/g for mold and yeast, and from 0.42 to 1.28 log cfu/g for total coliform bacteria, respectively. However, results of lactic acid bacteria count showed that the use of 50% and a higher rate

of JAP significantly increased lactic acid bacteria count during the fermentation period ($p<0.05$) (Fig. 1).

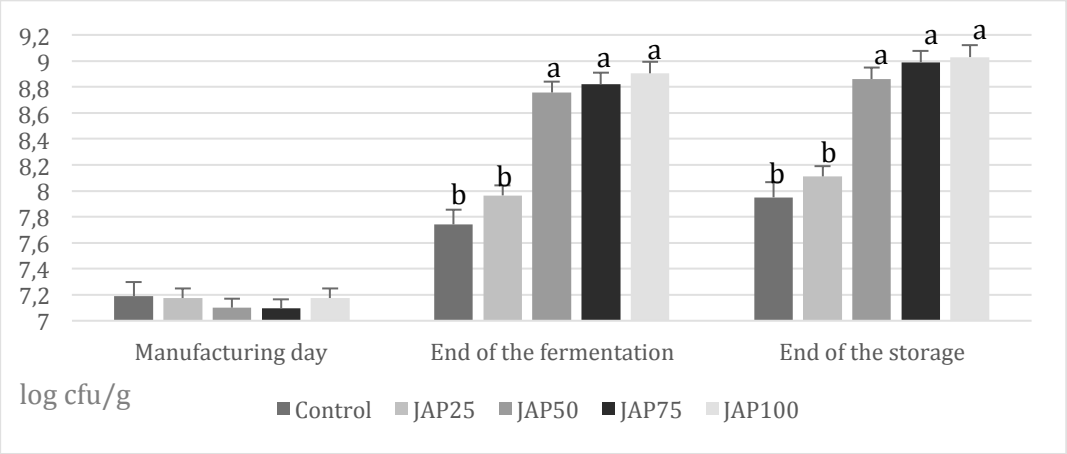

Figure 1. Lactic acid bacteria count in sucuk during the fermentation and storage periods.
a, b; Different letters in same day are significantly different ($P<0.05$).

This may be associated with the prebiotic effect of dietary fiber especially inulin and nutritional value of Jerusalem artichoke for lactic acid bacteria. It has reported that certain species of lactobacilli can ferment fructo-oligosaccharides and degrade even long-chain inulin-type fructans (CHOI *et al*., 2012). Additionally, CHOI *et al.* (2012) indicated that some *L. paracasei* strains could convert carbohydrates in Jerusalem artichoke to lactic acid without any pretreatment. There is numerous study about the prebiotic effect of added inulin to food products in literature and they indicated that inulin promotes the growth and activities of probiotic microorganisms in some dairy products such as yogurt, ice-cream and cheese (CARDARELLI *et al*., 2008).

3.2. Physicochemical composition analysis

Physicochemical properties of used JAP were determined and results showed that it contained 70.43%±0.68 carbohydrates, 8.18%±0.21 moisture, 9.46%±0.11 protein, 4.19%±0.18 ash and 7.13%±0.14 total dietary fiber. The determined mean proximate compositions for JAP are consistent with the literature (AFOAKWAH *et al*., 2015; PRAZNIK *et al*., 2002). Furthermore, JAP contained 103.41±21.6 mg GAE/kg total phenolic compounds. TAKEUCHI and NAGASHIMA (2011) have reported that peels of Jerusalem artichoke tuber were the main source of polyphenols and peels contains 10 times more polyphenols than peeled tubers and our result is similar to theirs. JAP revealed having the capacity to absorb at least 4.57±0.11 g of water/g at 20°C.
The proximate compositions of sausages formulated with different levels of JAP are given in Table 1. The use of JAP had shown significant differences in protein, ash, moisture and fat content of sausage dough. In addition, replacement of beef fat by JAP had shown significant differences on all components except ash values after fermentation. JAP75 and JAP100 had the highest protein content ($p<0.05$). Additionally, as expected, there were significant differences in the fat content of sausage dough ($p<0.05$) due to variation in the amount of beef fat used in sausage manufacture. Similar differences were also determined after fermentation ($p<0.05$) and control samples no containing JAP had the highest fat content after fermentation and storage ($p<0.05$). The moisture content for sausages after

fermentation was lower in the control group than other treatment groups ($p<0.05$). These results may be related to protein and carbohydrate content and water holding ability of JAP. It was also previously reported that compounds having water holding ability decelerate water loss and the drying rate during the ripening period in dry fermented meat products (CHOI *et al*., 2009). Additionally, Garcia *et al*. have reported that dietary fibers or additives containing rich carbohydrate and protein may cause a lower degree of water loss during ripening of fermented meat products such as dry sausage (GARCIA *et al*., 2002). As a result, the protein content proportionally increased by approximately 13% due to the drying process during the fermentation period, and fat content decreased by approximately 36% due to replacing beef fat with JAP in the final product.
pH of all sausage samples decreased during fermentation period ($p<0.05$) and were found to be at the same level for all sausage groups during the storage period (Table 2).

Table 1. Chemical composition* of sausage treatment groups.

Groups	Manufacturing Day	End of the Fermentation	Manufacturing Day	End of the Fermentation
	Protein (%)		Fat (%)	
Control	18.64±0.24 ^{cB}	25.91±0.24 ^{cA}	21.51±0.10 ^{aB}	31.35±0.18 ^{aA}
JAP25	18.98±0.10 ^{cB}	26.64±0.39 ^{cA}	19.39±0.27 ^{bB}	29.88±0.26 ^{bA}
JAP50	19.25±0.13 ^{bB}	27.83±0.14 ^{bA}	16.11±0.16 ^{cB}	25.71±0.13 ^{cA}
JAP75	19.70±0.16 ^{aB}	28.77±0.28 ^{aA}	12.91±0.20 ^{dB}	23.12±0.27 ^{dA}
JAP100	20.11±0.25 ^{aB}	29.41±0.43 ^{aA}	10.52±0.19 ^{eB}	19.91±0.19 ^{eA}
Groups	**Ash (%)**		**Moisture (%)**	
Control	1.91±0.04 ^{dB}	4.06±0.09 ^{bA}	56.94±0.28 ^{eA}	36.68±0.61 ^{eB}
JAP25	2.08±0.04 ^{cB}	4.28±0.14 ^{abA}	59.54±0.67 ^{dA}	39.20±0.39 ^{dB}
JAP50	2.19±0.16 ^{bcB}	4.52±0.21 ^{aA}	62.45±0.41 ^{cA}	41.94±0.27 ^{cB}
JAP75	2.40±0.13 ^{bB}	4.12±0.19 ^{abA}	64.99±0. 87 ^{bA}	43.99±0.74 ^{bB}
JAP100	2.76±0.08 ^{aB}	4.50±0.24 ^{aA}	66.60±0.48 ^{aA}	46.18±0.62 ^{aB}

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

Table 2. pH values* of sausage during the manufacturing, fermentation and storage periods.

Groups	Manufacturing Day	End of the Fermentation	Storage Days (d)		
			7d	15d	30d
Control	5.84±0.00 ^{bA}	5.11±0.00 ^{aB}	5.08±0.00 ^{aB}	5.07±0.00 ^{aB}	5.06±0.01 ^{aB}
JAP25	5.85±0.00 ^{abA}	5.06±0.02 ^{bB}	5.04±0.02 ^{bB}	5.02±0.03 ^{bB}	5.01±0.02 ^{bB}
JAP50	5.86±0.01 ^{abA}	5.02±0.01 ^{cB}	4.99±0.01 ^{cB}	4.98±0.02 ^{bB}	4.96±0.01 ^{cB}
JAP75	5.85±0.00 ^{abA}	4.94±0.00 ^{dB}	4.94±0.00 ^{dB}	4.93±0.00 ^{cB}	4.92±0.01 ^{dB}
JAP100	5.87±0.00 ^{aA}	4.90±0.00 ^{eB}	4.88±0.00 ^{eB}	4.84±0.00 ^{dB}	4.84±0.00 ^{eB}

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

Replacement of beef fat by JAP had shown no significant differences in sausage dough at manufacturing day. However, replacement of beef fat by JAP in sausage production affected the pH of sausages during the fermentation period. pH values of sausages decreased depending on the amount of replacement of beef fat by JAP in the sausage formulation and significant differences were determined among the treatment groups at the end of fermentation day and storage period ($p<0.05$).
MENDOZA *et al.* (2001) have reported a conflicting result with us that the use of inulin as a fat substitute in low fat-dry fermented sausages did not affect the pH during the fermentation period. However, the reason for decreases in pH of sausages in the present study is may be related to protein, carbohydrates and dietary fiber content of JAP. These components in JAP could be used as a nutrient by lactic acid bacteria and produced more lactic acid. Additionally, JAP may have created a suitable environment with high moisture content for development of starter culture by decelerating water loss and the drying rate during the fermentation period. Despite the effects of replacement of beef fat by JAP on the physicochemical properties of sausages produced in the present study were in accordance with the values reported by previous studies and Turkish standards for sausage (BOZKURT and BAYRAM, 2006; TSE, 2002).

3.3. TBARS analysis

TBARS values of sausages were measured throughout fermentation and the storage period shown in Table 3. The TBARS values of all sausage samples increased during fermentation and storage periods ($p<0.05$).

Table 3. TBARS values* of sausage (μmol/kg) during the manufacturing, fermentation and storage periods.

Groups	Manufacturing Day	End of the Fermentation	Storage Days (d)		
			7d	15d	30d
Control	0.74±0.02 ^{bE}	2.19±0.04 ^{aD}	2.82±0.02 ^{aC}	3.49±0.02 ^{aB}	4.88±0.02 ^{aA}
JAP25	0.78±0.07 ^{abE}	1.81±0.01 ^{bD}	2.46±0.10 ^{bC}	3.12±0.02 ^{bB}	4.26±0.10 ^{bA}
JAP50	0.78±0.02 ^{abE}	1.59±0.01 ^{cD}	2.22±0.02 ^{cC}	2.73±0.05 ^{cB}	3.82±0.06 ^{cA}
JAP75	0.82±0.03 ^{abE}	1.47±0.02 ^{dD}	2.01±0.09 ^{dC}	2.43±0.06 ^{dB}	3.47±0.03 ^{dA}
JAP100	0.85±0.01 ^{aE}	1.35±0.02 ^{eD}	1.89±0.02 ^{dC}	2.24±0.02 ^{eB}	2.92±0.02 ^{eA}

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

There were no differences among TBARS values among all treatment groups for sausage dough. However, highest TBARS values in control group and lowest TBARS values in JAP100 group were determined compared with other treatments at the end of fermentation and storage period ($p<0.05$). According to TBARS results, it can be said that the replacement of beef fat by JAP in sausage production significantly decreased TBARS values ($p<0.05$). The decrease in TBARS levels may be a result of both reducing the beef fat and increasing the JAP content. Additionally, it is conceivable that bioactive components such as flavonoids and phenolic compounds such as polyacetylenic derivatives, sesquiterpenes and coumarins in Jerusalem artichoke exhibiting antioxidative activities and contributing to decrease in TBARS values (FURLAN *et al.* 2014).

3.4. Color analysis

The color properties of used JAP were determined and results showed that L* value is 81.18±0.51, a* value are 2.32±0.11 and b* value is 8.71±0.23. Replacement of beef fat by JAP influenced CIE L* and CIE a* values in sausage dough, at the end of fermentation and during storage period ($p<0.05$) (Table 4). However, non-significant differences on CIE b* values were determined during fermentation and storage period ($p<0.05$).

Table 4. Color values* of sausages during the manufacturing fermentation and storage periods.

	Groups	Manufacturing Day	End of the Fermentation	Storage Days (d) 7d	15d	30d
L* values	Control	58.02±2.70 ^{aA}	50.07±2.46 ^{aB}	49.35±2.42 ^{aB}	49.91±2.45 ^{aB}	50.40±2.48 ^{aAB}
	JAP25	46.89±1.42 ^{bA}	42.67±1.30 ^{bcB}	42.06±1.28 ^{bcB}	42.53±1.30 ^{bcB}	42.96±1.30 ^{bcB}
	JAP50	47.44±1.44 ^{bA}	43.99±0.42 ^{bB}	43.36±1.40 ^{bB}	43.85±1.42 ^{bB}	44.29±1.43 ^{bB}
	JAP75	43.50±0.67 ^{cA}	40.09±0.66 ^{cB}	39.51±0.65 ^{cB}	39.96±0.65 ^{cB}	40.36±0.66 ^{cB}
	JAP100	41.21±1.06 ^{cA}	37.08±1.20 ^{dB}	36.55±2.17 ^{dB}	36.96±2.19 ^{dB}	37.33±2.22 ^{dB}
a* values	Control	12.33±1.37 ^{cA}	11.22±1.24 ^{cB}	11.11±1.23 ^{cB}	11.38±1.26 ^{cB}	11.50±1.28 ^{cAB}
	JAP25	14.85±0.49 ^{bA}	13.51±0.44 ^{bB}	13.37±0.44 ^{bB}	13.70±0.45 ^{bB}	13.84±0.46 ^{bB}
	JAP50	15.72±0.15 ^{bA}	14.31±0.13 ^{bB}	14.16±0.13 ^{bB}	14.51±0.13 ^{bAB}	14.65±0.14 ^{bAB}
	JAP75	15.91±0.30 ^{bA}	14.48±0.28 ^{bB}	14.33±0.36 ^{bB}	14.68±0.32 ^{bB}	14.83±0.01 ^{bAB}
	JAP100	17.34±0.22 ^{aA}	16.78±0.20 ^{aAB}	15.62±0.20 ^{aB}	16.00±0.20 ^{aAB}	16.16±0.80 ^{aAB}
b* values	Control	10.65±0.71 ^{aA}	10.86±0.72 ^{aA}	10.80±0.72 ^{aA}	10.75±0.72 ^{aA}	10.86±0.73 ^{aA}
	JAP25	12.32±2.76 ^{aA}	12.56±2.82 ^{aA}	12.50±2.80 ^{aA}	12.43±2.79 ^{aA}	12.56±2.82 ^{aA}
	JAP50	12.95±1.04 ^{aA}	13.21±1.06 ^{aA}	13.14±1.06 ^{aA}	13.08±1.05 ^{aA}	13.21±1.06 ^{aA}
	JAP75	11.63±1.04 ^{aA}	11.86±1.06 ^{aA}	11.80±1.05 ^{aA}	11.74±1.05 ^{aA}	11.86±1.06 ^{aA}
	JAP100	10.89±1.49 ^{aA}	11.11±1.57 ^{aA}	11.05±1.55 ^{aA}	11.00±1.53 ^{aA}	11.11±1.57 ^{aA}

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

When the replaced of beef fat by JAP, CIE L* values decreased and CIE a* values increased in sausage samples. It was determined that the control group had the highest CIE L* and lowest CIE a* values at all manufacturing period ($p<0.05$). Additionally, CIE L* values for all treatment groups decreased during fermentation period ($p<0.05$). Some researchers have reported that non-meat ingredients may affect the color properties of minced meat products because of the dilution of meat pigments rather than the color of the additives (SARTESHNIZI *et al*., 2015; TRESPALACIOS and PLA, 2007). These results in the present study were similar to some previous studies about the use of some vegetable source ingredient in meat products (ALAKALI *et al*., 2010; ERGEZER *et al*., 2014).

3.5. Texture profile analysis

Table 5 shows the TPA results of the sausages. Replacement of beef fat by JAP in sausage had shown a significant effect on hardness and adhesiveness. However, there were no significant changes in resilience, cohesiveness, chewiness index and springiness index among all sausage treatment groups. Results revealed that replacement of beef fat by JAP

resulted in an increase in adhesiveness values of sausages and a decreased in the hardness values compared control group ($p<0.05$). It is reported in many studies that fat reduction in comminuted meat products results in significant changes in textural properties and generally, hardness values of products increased (COLMENERO, 1996; KEETON, 1994; STEHLE, 2009). However, results of the present study showed that 50%, 75% and 100% replacement of beef fat by JAP in sausage resulted in a decrease in hardness values of sausages. JAP25 group, which contains 25% JAP and 75% beef fat, and the control group had the same level of hardness values.

Table 5. Texture profile analysis* of sausage at the end of the fermentation period.

Groups	Hardness (N)	Adhesiveness (mj)	Resilience	Cohesiveness	Springiness Index	Chewiness Index (N)
Control	61.69±2.39 ^{a}	0.43±0.05 ^{c}	0.02±0.00 ^{a}	0.40±0.07 ^{a}	0.60±0.09 ^{c}	0.90±0.25 ^{a}
JAP25	60.92±1.07 ^{a}	0.64±0.07 ^{b}	0.03±0.00 ^{a}	0.36±0.02 ^{a}	0.75±0.03 ^{bc}	0.88±0.26 ^{a}
JAP50	52.40±0.88 ^{b}	0.76±0.04 ^{a}	0.03±0.01 ^{a}	0.44±0.02 ^{a}	0.81±0.02 ^{b}	1.28±0.42 ^{a}
JAP75	35.20±0.63 ^{c}	0.80±0.00 ^{a}	0.05±0.01 ^{a}	0.44±0.07 ^{a}	0.88±0.02 ^{b}	1.35±0.33 ^{a}
JAP100	27.94±1.13 ^{d}	0.83±0.03 ^{a}	0.04±0.02 ^{a}	0.36±0.07 ^{a}	1.07±1.16 ^{a}	1.22±0.24 ^{a}

*All values are the mean ± standard error of three replicates
a, b, c (↓) Different letters within a column are significantly different ($p<0.05$)

The decrease in hardness values may be a result of increasing the proteins, carbohydrates and dietary fiber that have functional properties such as water binding and retention properties. Researchers have reported that fat replacer containing proteins, carbohydrates and dietary fiber may interact with water and fat of meat products and therefore lead to a change in textural properties (ERGEZER *et al*., 2014). The effects of using JAP on the moisture content of sausage also support this idea.

4. CONCLUSIONS

Regarding to results of lipid oxidation analysis, this study proved that improved lipid oxidation stability in fermented sausages during fermentation and storage can be achieved by replacing beef fat with Jerusalem artichoke powder. However, some textural differences, which can be undesirable by the consumer, can occur. Nevertheless, it can be concluded that meat products manufacturers should consider replacing beef fat with up to 25% Jerusalem artichoke powder in low-fat fermented sausage production to enhance positive nutritional effects such as lower beef fat and energy value and rich dietary fiber and improve the shelf life of sausage.

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