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EFFECTS OF FAT TYPE ON THE TEXTURAL PROPERTIES OF CORN PUREE

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ABSTRACT
In this study, corn flour, milk powder, sugar, emulsifier, and fat (milk fat, palm stearin, sunflower oil and mixture of palm stearin and sunflower oil) were used to produce corn puree. After producing the corn puree, the textural properties of the samples were determined to prepare a formula for a viscoelastic corn puree as a new nutritious product for the food industry. The viscoelastic properties of corn puree samples prepared by various ratios of different fat sources and mix (milk fat, palm stearin, sunflower oil, and a mixture of palm stearin and sunflower oil) were evaluated in the temperature range of 25 to 50°C using a texture analyzer. As the amount of fat increased (40%), the corn puree produced became softer except the sample containing palm stearin, which was found to be harder. As the temperature was reduced, the firmness and work of shear values of purees produced using 10-40% of fat increased.
Keywords: corn, puree, fat, milk fat, palm stearin, sunflower, texture

YAĞ ÇEŞİDİNİN MISIR PÜRESİNİN TEKSTÜREL ÖZELLİKLERİ ÜZERİNE ETKİLERİ

ÖZ
Bu çalışmada, mısır unu, süt tozu, şeker, emülgatör ve yağ (süt yağı, palm stearin, ayçiçek yağı ve palm stearin ile ayçiçeği yağı karışımı) mısır püresi üretmek için kullanılmıştır. Gıda sanayi için besleyici değeri yüksek viskoelastik özellikte yeni bir ürün ortaya koyabilmek amacıyla mısır püresi üretildikten sonra ürünlerin tekstürel özellikleri belirlenmiştir. Farklı yağ kaynakları (süt yağı, palm stearin, ayçiçeği yağı ve palm stearin ile ayçiçeği yağı karışımı) ve farklı yağ oranları kullanılarak hazırlanan mısır püresi örneklerinin viskoelastik özellikleri 25 ila 50° C sıcaklık aralığında bir tekstür analiz cihazı ile belirlenmiştir. Yağ miktarı arttıkça, üretilen mısır püresinin sert olduğu tespit edilen palm stearin içeren örnekler haricinde diğer örneklerin daha yumuşak bir yapıya sahip olduğu belirlenmiştir. Sıcaklık düştükçe, %10-40 yağ kullanılarak üretilen pürelerin sıkılığı artmış ve işlenebilirliği zorlaşmıştır.
Anahtar kelimeler: mısır, püre, yağ, süt yağı, palm stearin, ayçiçeği, tekstür

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INTRODUCTION

In recent years, the functional and nutritional properties of foods have become important food quality parameters and requirements for the industry. Functional and nutritious foods are particularly important for the feeding of babies during the weaning period since at this critical phase of an infant's life, breast milk is mostly not adequate to meet nutritional requirements and support body growth. To compensate for this deficiency, infants need supplemental foods (Mitzner et al*.,* 1984). Furthermore, with the growing number of working mothers, the demand for easy-to-prepare food and infant food has significantly increased. The World Health Organization (WHO) recognizes that there is a legitimate market for infant formula when a mother cannot or chooses not to breastfeed her child. However, the nutrient composition of infant formulas is often very different from that of breast milk, and some important nutrients found in the latter may be missing in the former. Therefore, particularly in cases where breastfeeding is not possible or is not sufficient alone, there is an obvious need for nutritionally balanced, energy-dense, and easily digestible weaning foods. Presently, various preparations of weaning foods are available in the market for different age groups and nutritional needs. These foods are semi-solid in nature, which makes them easy to handle for feeding infants (Hansen et al*.,* 1981). Furthermore, considering consumer demand for natural and healthy food, it is necessary to produce foods with nutritious raw materials, rather than adding artificial ingredients.

In many developing countries, infant foods are prepared from locally available sources, mainly cereal grains, roots and tubers, which are served in a thick puree form (Sanni et al*.,* 1999). Sweet potato is an important staple food or base material for a variety of food and industrial applications (Ravi et al*.,* 1996). Pureeing of sweet potato (*Ipomoea batatas* L. Lam) is carried out on a large scale around the world (Maleki, 2001). Sweet potato is an economical and healthy food crop containing high β-carotene and carbohydrates, as well as substantial amounts of ascorbic acid and minerals (Woolfe, 1992); however, it lacks other nutrients, such as protein. Therefore, researchers have examined the ability of some additives to enhance the nutritional value of potato puree. For example, Álvarez et al. (2012) investigated the effect of soybean protein isolate on the physicochemical, functional and sensory characteristics of potato puree and found that the concentration of this isolate had a significant impact on the rheological properties of the samples. Similarly, Conforti et al. (2013) reported that whey protein concentrate, pectin, inulin, and extra virgin olive oil modified the rheological, thermal and structural properties and sensory quality of potato puree. Furthermore, in a very recent study, Miao et al. (2018) investigated the effect of the addition of soybean protein isolate, whey protein isolate, whole milk powder, and sodium caseinate on the rheological, sensory and microstructural properties of potato puree. They reported that these four proteins had a great impact on the investigated properties of potato puree.

Even though potato has certain advantages as infant food over other cereal-based foods, corn (*Zea mays* L.) contains more protein than potato and is cultivated in almost all countries of the world since it can grow in a wide range of climates, including tropical, sub-tropical and temperate regimes. Due to the wider use of corn compared to potato and other cereals (wheat, barley, rye), the demand for it has increased also depending on various factors, such as growing population, increased demand for processed products, growing tendency to eat healthy, increasing animal production, and development of industry. Corn has become a commonly grown agricultural product in many countries, with 90% of production being used as human food (20%) and animal feed (65-70%) due to the nutritional value of corn as a raw material. The remaining 8-10% is utilized in various branches of industry (Özcan, 2009; Babaoğlu, 2005).

Corn has an average of 71.7% starch, 9.5% protein, 9.5% fiber, and 26 mg / kg carotene. In addition, it contains B1 vitamins, pantothenic acid, folate, niacin, vitamin C, dietary fiber, phosphorus, and magnesium. In addition, the dietary fiber content of corn facilitates the digestive process, prevents constipation, and reduces the risk of coronary heart disease. Corn contains vitamin A, which strengthens the eyes and contributes to production of blood. Furthermore, the cholesterol-lowering, anti-vascular, and hypoallergenic effects of corn have been reported (White and Johnson, 2003; Özcan, 2009; Rose et al., 2010; Anon, 2018).

In the literature, it has been reported that corn puree exhibited a stronger elastic characteristic (Ahmed and Ramaswamy, 2006). This is not suitable for infant formula. Therefore, various ratios of different fat sources (milk fat, sunflower, palm stearin and mixture of sunflower-palm stearin) were used in the production of corn puree, and the textural properties of the samples were determined at different temperatures to generate a new nutritional formula in this study.

MATERIALS AND METHODS

Material

In the production of corn puree, corn flour, emulsifier [mixture of mono-diglyceride (MDG), palm stearin, sunflower oil (Sunar Group, Adana, Turkey), milk powder, and milk fat (Bakkalbaşıoğlu Dairy Products Inc., Niğde, Turkey) were used. A mix of 37 fatty acid methyl esters (FAMEs) (C4-C24) was purchased from Supelco (Bellefonte, PA, USA). All the reagents were of analytical grade.

Methods

Preparation of Corn Puree

Corn flour, sugar, milk powder, emulsifier (0.5% MDG), and different contents of palm stearin, sunflower oil and milk fat were mixed (Table 1). 100 g of this mixture was transferred to a 250 mL beaker, and 200 mL of pure water heated to 80°C was added to the beaker. The mixture was stirred in a bain-marie at 80°C for 10 minutes. The textural analysis of the puree samples was carried out at different temperatures (25-50°C). This allowed the determination of the effect of the components used in different amounts on the textural properties of the final product.

Table 1. Formulas used for the preparation of corn puree samples

	Flour (%)	Milk powder (%)	Sugar (%)	Emulsifier (%)	Sunflower oil (%)	Palm stearin (%)	Milk fat (%)	Mix oil (%)
10S*	60	25	4.5	0.5	10	-	-	-
20S	60	25	4.5	0.5	20	-	-	-
30S	60	25	4.5	0.5	30	-	-	-
40S	60	25	4.5	0.5	40	-	-	-
10Ps	60	25	4.5	0.5	-	10	-	-
20Ps	60	25	4.5	0.5	-	20	-	-
30Ps	60	25	4.5	0.5	-	30	-	-
40Ps	60	25	4.5	0.5	-	40	-	-
10MF	60	25	4.5	0.5	-	-	10	-
20MF	60	25	4.5	0.5	-	-	20	-
30MF	60	25	4.5	0.5	-	-	30	-
40MF	60	25	4.5	0.5	-	-	40	-
10M	60	25	4.5	0.5	-	-	-	10
20M	60	25	4.5	0.5	-	-	-	20
30M	60	25	4.5	0.5	-	-	-	30
40M	60	25	4.5	0.5	-	-	-	40

**10-40 %fat content, S: Sunflower oil, Ps: Palm stearin, MF: Milk fat and M: Mix oil*

Analyses of raw material

Moisture and ash content in corn flour were determined according to the International Chamber of Commerce Standard Methods No: 110/1 and 104/1 (Anon, 2002), respectively, and the protein content was determined according to the American Association for Clinical Chemistry Standard Method No. 46-12 (Anon, 2000). The corn flour was subjected to oil extraction using a Soxhlet apparatus (Gerhardt) according to the American Oil Chemist Society Official method Am 2-93 (Anon, 2003). The FAMEs of palm stearin, sunflower oil, mix oil, milk fat and emulsifier (MDG) were prepared following the method described by the International Union of Pure and Applied Chemistry (Anon, 1987). The fatty acid compositions were determined by Shimadzu GC-2010 (Japan) equipped with a DB-23 capillary column (60 m × 0.250 mm × 0.25 μm; J&W) and a flame ionization detector. Helium (1 mL/minutes) was used as the carrier gas. The split ratio was 1:80. The working temperatures of the injector, column and detector were 230, 190 and 240°C, respectively. The FAMEs were identified by the reference standard.

Analyses of puree

The color values (L*, a* and b*) of the corn puree samples were measured by a Minolta CR-400 colorimeter (Konica Minolta Sensing, Osaka, Japan). The flow resistance of the samples was determined in a texture analyzer (TA-XTplus, UK) using an apparatus (Figure 1) at room temperature (25°C) (test speed: 1.0 mm/sec and distance: 20 mm). In this analysis, the force required for flow of the product through a certain gap (6 mm) was determined, and the results of the analysis were given in gram. The spreadability properties of the samples were determined at different eating temperatures (25, 30, 40 and 50°C) by the 'measure force in compression' method (test speed: 3.0 mm/second and distance: 16 mm) using the TTC Spreadability Rig HDP/SR equipment in a texture analyzer (TA-XTplus, UK).

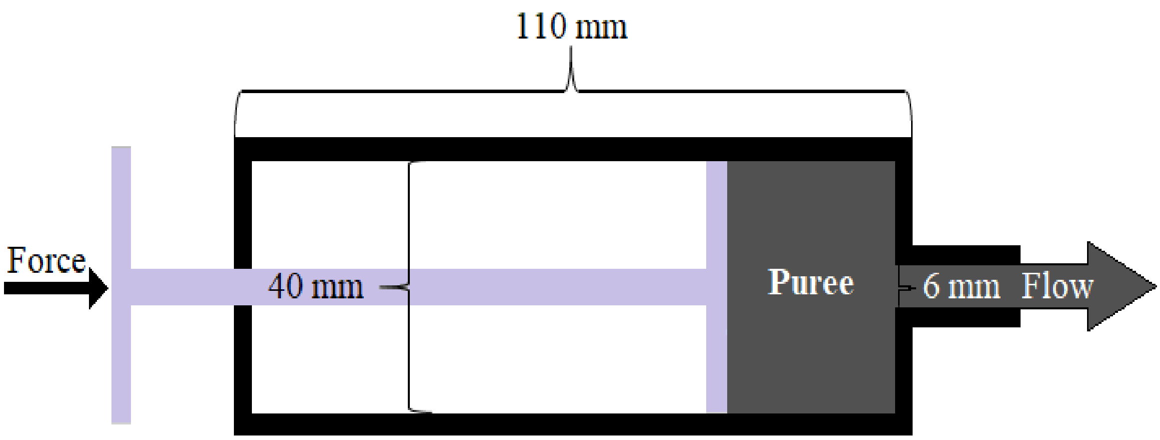

Figure 1. The apparatus used for the flow resistance analysis

Statistical Analysis

Duplicate measurements were performed for each replicate of puree production, and the results were obtained as mean values. The data was analyzed by ANOVA, and multiple comparisons of the means were undertaken using Duncan's test. Statistical analysis was performed with SPSS 15.0 for Windows Evaluation Version (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

The moisture, ash, oil and protein contents of the corn flour were determined as 3.50±0.035%, 0.54±0.012%, 3.18±0.048% and 7.71±0.002%, respectively. The results of the fatty acid composition analysis of the fat samples by gas chromatograph are given in Table 2. MDG used as the emulsifier contained high levels of palmitic acid (58.94±0.485%) and stearic acid

(39.93±0.252%). The predominant fatty acid was found to be palmitoleic acid (39.18±0.532%) in milk fat, palmitic acid (63.46±0.642%) in palm stearin, and linoleic acid (54.69±0.052%) in sunflower oil. Milk fat is usually used in puree production, but the polyunsaturated fatty acid (PUFA) content of milk fat was quite low (3.00±0.008%). Even though palmitic acid (34.64±0.222%) was identified as the dominant fatty acid in the mix of palm stearin + sunflower (50:50), high amounts of oleic acid (30.78±0.075%) and linoleic acid (29.82±0.062%) were also determined. The PUFA content of the mixed oil was quite high (29.85±0.062).

Table 2. The fatty acid composition of butter, palm stearin, sunflower oil, mix oil and emulsifier

Fatty acids (%)	Milk fat	Palm stearin	Sunflower oil	Mix oil	MDG
Butyric acid (4:0)	0.25±0.002	ND	ND	ND	ND
Caproic acid (6:0)	0.12±0.001	ND	ND	ND	ND
Caprylic acid (8:0)	1.37±0.008	ND	ND	ND	ND
Capric acid (10:0)	0.87±0.006	ND	ND	ND	ND
Lauric acid (12:0)	2.13±0.005	0.11±0.001	ND	0.06±0.001	ND
Myristic acid (14:0)	2.75±0.003	1.17±0.001	0.08±0.001	0.63±0.000	1.01±0.004
Palmitic acid (16:0)	12.56±0.009	63.46±0.642	5.81±0.012	34.64±0.222	58.94±0.485
Palmitoleic acid (16:1)	39.18±0.532	ND	0.12±0.022	0.06±0.001	ND
Stearic acid (18:0)	13.69±0.012	4.74±0.042	3.25±0.008	3.99±0.042	39.93±0.252
Oleic acid (18:1)	24.32±0.022	25.57±0.132	35.99±0.548	30.78±0.075	0.07±0.001
Linoleic acid (18:2, ω-6)	3.00±0.008	4.94±0.011	54.69±0.052	29.82±0.062	0.05±0.000
Linolenic acid (18:3, ω-3)	ND	ND	0.06±0.001	0.03±0.000	ND
SFA	33.74±0.046	69.48±0.686	9.14±0.021	39.32±0.265	99.88±0.741
MUFA	63.5±0.554	25.57±0.132	36.11±0.570	30.84±0.076	0.07±0.001
PUFA	3.00±0.008	4.94±0.011	54.75±0.053	29.85±0.062	0.05±0.000

ND: Not Detected
SFA: Saturated Fatty Acid, MUFA: Mono Unsaturated Fatty Acid, PUFA: Poly Unsaturated Fatty Acid

Color is considered an important parameter in the marketing of food. The results of the color analysis of puree samples are given in Table 3. Since fat is bright, with the increase in the fat content, the L* (brightness) values of samples increased, but b* (yellowness) values decreased (Table 3). On the other hand, a* (redness) values of samples increased with the increase in the fat content.

The composition of a food product along with its structure determines the rheology of that product (Ahmed and Ramaswamy, 2006). Fat interacts with other ingredients to develop and mold the texture, and gives feeling in the mouth, as well as an overall sensation of the lubricity of the product (Giese, 1996). The rheological and textural properties have been considered to be important analytical tools to provide a fundamental insight into the structural organization of food. Some foods, especially starches and proteins, undergo changes during processing, resulting in viscous dispersions, solutions or gels depending on temperature and concentration (Gunasekaran and Ak, 2000).

As shown in Figure 2, there was no change in the flow properties of the samples until the fat content reached 20%. This can be explained by the fat binding capacity of starch. It has been reported that one gram of corn starch can bind 0.4 milliliters of fat (Seguchi, 1984). In products containing 30% and 40% fat (except the sample with palm stearin), increasing the fat content in the puree formulation reduced the flow resistance, and more than 20% fat concentration affected the lubricity properties. However, when palm stearin was used, unlike the other fats, the flow resistance of the corn puree increased. On the other hand, increasing the mixed fat (1:1, sunflower oil + palm stearin) increased the fluidity and flow properties of the product similar to those produced with milk fat.

Table 3. The L*, a* and b* values of the corn puree samples

	Samples			
	10S**	20S	30S	40S
	77.03±0.150a	78.71±0.225b	78.91±0.090b,c	80.72±0.105c
	10P	20P	30P	40P
	76.22±0.315a	78.29±0.175b	78.76±0.040c,d	79.75±0.012d
L* values	10MF	20MF	30MF	40MF
	77.44±0.900a	78.61±0.275b	79.11±0.065b,c	79.57±0.355c
	10M	20M	30M	40M
	77.01±0.185a,b	77.67±0.025b,c	78.13±0.215c	79.31±0.225d
	10S	20S	30S	40S
	-4.06±0.010a	-3.81±0.075a,b	-3.97±0.040b,c	-3.71±0.010c
	10P	20P	30P	40P
	-3.81±0.030a	-3.75±0.035a,b	-3.76±0.045b,c	-3.65±0.015c
a* values	10MF	20MF	30MF	40MF
	-4.87±0.145a	-4.61±0.025a,b	-4.69±0.015a,b	-4.78±0.030b
	10M	20M	30M	40M
	-4.78±0.095a,b	-4.71±0.040a,b	-4.66±0.010a,b	-4.50±0.045b
	10S	20S	30S	40S
	24.31±0.065c	23.24±0.170b,c	22.53±0.370b,c	22.09±0.020a
	10P	20P	30P	40P
	23.92±0.180b	23.88±0.045b	22.84±0.025a	22.91±0.290a
b* values	10MF	20MF	30MF	40MF
	23.61±0.395b	23.49±0.260a,b	23.12±0.730a,b	23.08±0.050a
	10M	20M	30M	40M
	23.30±0.310b,c	23.66±0.005c	22.23±0.275a	22.20±0.020a

[a] *Different superscript letters in the same row indicate a significant difference between the values at the P <0.05 level*
***10-4 % fat content, S: Sunflower oil, Ps: Palm stearin, MF: Milk fat and M: Mix oil*Figure 2

Puree manufacturers recommend that the product should be served warm and consumed quickly. Since puree is semi-solid, its textural properties would alter significantly during consumption depending on temperature (Woolfe, 1992).

In this study, the firmness and work of shear values of the corn purees produced using 10-40% fat were determined at different temperatures (Table 4). As a result of the textural analysis, different properties were observed in the final product depending on the amount and type of fat used in the formulation. As the fat content increased (40%), the corn puree became softer, except for the product containing palm stearin. Although the puree was soft with a low amount of palm stearin, it became harder as the amount of this fat was increased. As the temperature decreased, the firmness and work of shear values of the purees produced using 10-40% of oil increased. Both the 40MF and 40M purees exhibited similar viscoelastic properties (P <0.05).

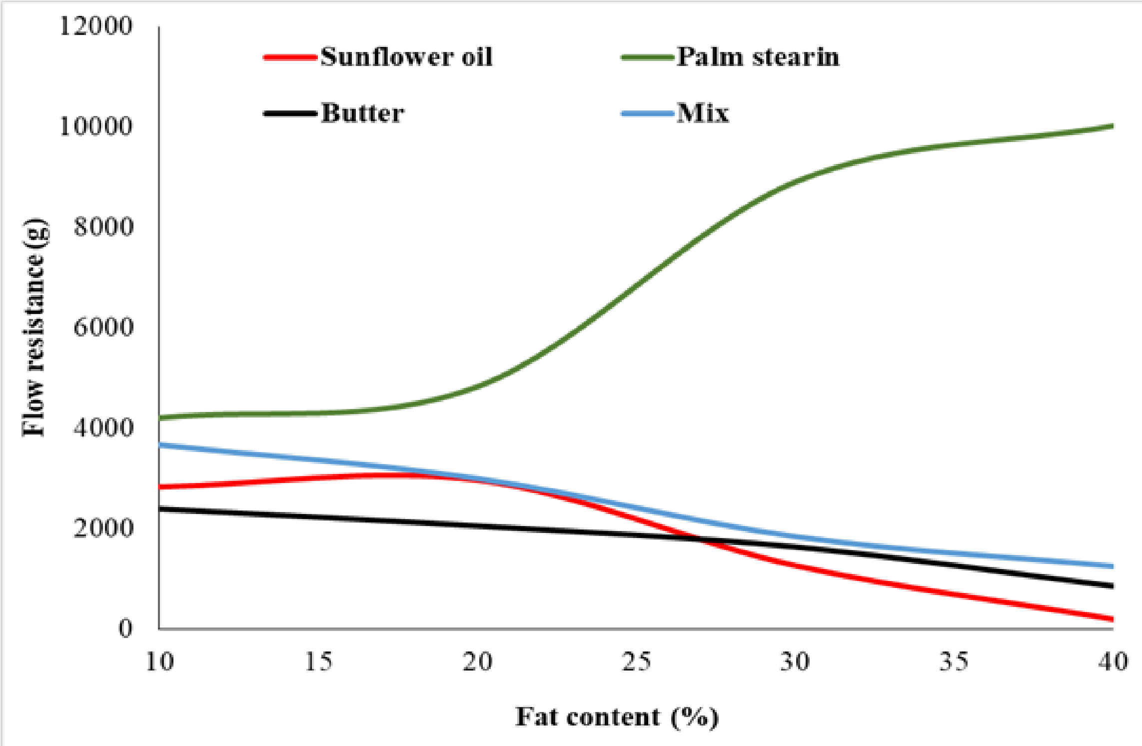

Figure 2. Flow resistance of corn puree samples

Table 4. The firmness and work of shear values of the corn puree samples

	Firmness (g)				Work of Shear (g.sec)			
	50°C	40°C	30°C	25°C	50°C	40°C	30°C	25°C
10S**	$1255^{e,f,g}$	1928^{g}	$2695^{g,h}$	4415^{g}	1958^{f}	2764^{g}	$3478^{d,e}$	$3767^{c,d}$
20S	$1099^{e,f}$	1816^{g}	$1968^{e,f}$	3267^{f}	$1647^{e,f}$	2238^{f}	2772^{c}	$3536^{c,d}$
30S	$630^{b,c}$	704^{b}	760^{b}	$801^{a,b}$	667^{b}	771^{b}	$885^{a,b}$	$976^{a,b}$
40S	140^{a}	198^{a}	229^{a}	354^{a}	251^{a}	310^{a}	489^{a}	505^{a}
10Ps	$1314^{f,g}$	$1467^{e,f}$	1710^{e}	2047^{d}	$1476^{d,e}$	$1723^{d,e}$	2530^{c}	2968^{c}
20Ps	1405^{g}	$1779^{f,g}$	2293^{g}	2574^{e}	$1786^{e,f}$	$1999^{e,f}$	$2917^{c,d}$	$3632^{c,d}$
30Ps	1794^{h}	2282^{h}	$2521^{g,h}$	2729^{e}	1873^{f}	2950^{g}	3753^{e}	4142^{d}
40Ps	2275^{j}	2566^{h}	2731^{h}	3365^{f}	3201^{g}	3852^{h}	4486^{f}	6731^{e}
10MF	$707^{b,c}$	$864^{b,c,d}$	$1117^{b,c}$	$1319^{b,c}$	$868^{b,c}$	$1257^{b,c,d}$	1351^{b}	1526^{b}
20MF	$705^{b,c}$	$844^{b,c,d}$	$937^{b,c}$	$1084^{b,c}$	$851^{b,c}$	$1240^{b,c,d}$	1351^{b}	1515^{b}
30MF	$653^{b,c}$	$767^{b,c}$	801^{b}	$919^{a,b}$	736^{b}	$102^{b,c}$	1267^{b}	1402^{b}
40MF	413^{b}	539^{b}	726^{b}	$865^{a,b}$	624^{b}	888^{b}	$1001^{a,b}$	$1143^{a,b}$
10M	$1062^{e,f}$	$1147^{d,e}$	$1566^{d,e}$	1889^{d}	$1129^{c,d}$	$1414^{c,d}$	2212^{c}	2704^{c}
20M	$1001^{d,e}$	$1124^{c,d,e}$	$1543^{d,e}$	1881^{d}	$1126^{c,d}$	$1412^{c,d}$	2162^{c}	2525^{c}
30M	$764^{c,d}$	$844^{b,c,d}$	$1279^{c,d}$	$1517^{c,d}$	$906^{b,c}$	$1230^{b,c,d}$	1514^{b}	1605^{b}
40M	460^{b}	553^{b}	756^{b}	$901^{a,b}$	657^{b}	$950^{b,c}$	$1104^{a,b}$	$1200^{a,b}$

** Different superscript letters in the same column indicate a significant difference between the values at the P <0.05 level*

***10-40 %fat content, S: Sunflower oil, Ps: Palm stearin, MF: Milk fat and M: Mix oil*

The fat concentration was directly related to the fatty acid composition, and the physical properties of the oil (solid-liquid) affected the fluidity of the final product. Thus, the results of the current study indicate that sunflower oil produces a softer corn puree than palm stearin and milk fat. Another important finding was that purees produced with a mixture of suitable oils result in similar textural properties similar to those of milk fat puree.

In the literature, it has been reported that when the fat concentration in biscuit dough formula is reduced, the resultant dough samples become harder (Erinç, 2011). In another study conducted by Ertaş and Karabaş (1996), sunflower oil was used in sausage production, and the sausages were found to be softer as the sunflower oil content increased. In a similar study by Jacob and Leelavathi (2007), who used different oils in biscuit formulas, biscuit dough produced with hydrogenated oil was harder than the dough prepared with sunflower oil. Babji et al. (1998) used different oils (palm stearin, commercial oils, and animal fat) in hamburger formulas and reported that with the increased fat content, the hamburger dough had a harder texture.

CONCLUSION

Different results were obtained from the final products depending on the amount and type of fat used in the corn puree formula. However, all corn purees exhibited viscoelastic behavior. The textural properties of the corn purees containing up to 20% fat were not greatly affected. In products with more than 20% fat content, the textural characteristics changed depending on the type of fat. When unsaturated fatty acid containing fats were used, softer corn puree production was achieved from all samples. On the other hand, as the fat content increased, the corn puree became softer, except for the palm stearin-containing product, which formed a rather rigid structure.

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