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Formulation of Trans Free Shortening Based on Canola, Palm Olein and Fully Hydrogenated Soybean Oils Blends; The Application on Biscuit

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ABSTRACT: The objective of this work is to study the changes in physicochemical properties of trans free shortenings and their efficacy on texture and sensory properties of biscuits since these days the researches show that trans fatty acids cause the risk of heart diseases, blood pressure and also cancer. Trans free shortenings were prepared by blending of canola, palm olein and fully hydrogenated soybean oils (FHSO) in the ratio of 45:45:10, 40:40:20, 35:35:30, 30:30:40, and 25:25:50 respectively followed by comparison of the physical properties each formulation. The products were evaluated and compared in respect of texture and sensory properties with biscuits that were made of commercial shortening (CS). The results showed that 40:40:20 mixture had low trans (2%) fatty acids in contrast to the commercial shortening (5%), lower peroxide value and free fatty acids with moderate amount of unsaturated and saturated fatty acids and more acceptability concerned with texture and sensory evaluation, therefore it might be a suitable substitute as shortenings.

Keywords: *Biscuit, Blending, Shortening.*

Introduction

Shortenings are usually a mixture of oils and fats that are hydrogenated to various degrees (i.e., partially or fully hydrogenated) with some additives such as emulsifiers. Shortenings without emulsifier are typically used for cookies, crackers and frying (Ahmadi *et al*., 2009). Soybean oil, palm oil and low-erucic acid rapeseed oil are the main vegetable oils used in industrial shortenings.

Shortenings as high calorie fats have been widely applied in baking foods, confectionary and some other products due to their physical and chemical characteristics they possess (Yilmaz *et al*., 2015). Shortenings induce a number of desirable functions in bakery products such as; tenderness and texture, mouth feel, structural integrity, lubrication, incorporation of air, heat transfer, and extended shelf life (Ghotra *et al*., 2002).

Biscuits are the most popular bakery items consumed by nearly all levels of society. They approximately contain 1-5% moisture and are made of wheat flour, sugar, and fat as the main ingredients. Fats play a major role in biscuit making, but are more expensive than flour or sugar. Besides being used in the doughs, fats or oils are used as

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surface sprays, in cream fillings and coatings (such as chocolate), and as releasing agents (Hazelton *et al*., 2003). Fats play a decisive role in baked product structure and sensory characteristics that strongly depend on the type of fat and content as fat imparts shortening, richness, and tenderness, and also improves mouthfeel and flavor delivery (Tarancon *et al*., 2013).

Quality, stability and nutritional features of oils are the most important factors in food technology. There is no pure oil with good functional and nutritional properties. Therefore, vegetable oils are modified using different methods to enhance their commercial applications and improve their nutritional value. Modification methods namely hydrogenation and interesterification and blending are sometimes applied. Trans isomers of fatty acids are formed during hydrogenation have negative effects on health. Interesterification needs special equipment and is more costly. Blending should not have any adverse effects on health attributes. Blending vegetable fats/oils with different compositions and properties is one of the simplest methods to create new special products with desired textural, oxidative and nutritional values which lead to improved industrial applications and also improved functional characteristics. (Hashempour *et al*., 2016).

As reported by Ab Latip *et al*. (2013) bakery shortening blends which were produced by mixing the stearin fraction of palm-based diacylglycerol (PDAGS) and palm mid fraction (PMF) at proportion of 50:50 and 60:60 (w/w) of PDAGS: PMF were the most suitable fat blends to be used as bakery shortenings because of their abilities to achieve the desired level of solid fats, especially melting and crystallization behavior of shortening system at body temperature.

The importance of blending oils and fats as a technological method that causes effective air entrapment to improve cake volumes and also crispness and good texture of biscuits and cookies, is choosing suitable oils and fats to achieve the best characteristics in final products. Canola, Palm olein and hydrogenated soybean oil has been employed to improve the nutritional value and functional characteristics of the product.

Materials and Methods

- *Materials*

Commercial sample of shortening and primary oils such as canola oil, palm olein and fully hydrogenated soy bean oil were obtained from Behshahr Factory (Tehran, Iran).

- *Methods*

- *Sample preparation*

Various binary blends were prepared at different percentages (Table 1). Oils and fats were first heated at 80°C to destroy crystal phases, blends were prepared by mixing them in a clean, dry glass vessel at the appropriate proportion. Total weight of each blend was 300gr. The mixtures were kept in liquid form at the temperature of 50°C. Shortenings were produced by crystallizing the blends in a freezer at -20°C for half an hour followed by storing at 15°C for 7 days to be sure that shortening's phase didn't change.

Table 1. Percentage of primary oils to make the mixtures

Samples	Mixtures	Canola oil (%)	Palm olein (%)	Fully Hydrogenated Soybean Oil (%)	Total (%)
Shortening 1	45:45:10	45	45	10	100
Shortening 2	40:40:20	40	40	20	100
Shortening 3	35:35:30	35	35	30	100
Shortening 4	30:30:40	30	30	40	100
Shortening 5	25:25:50	25	25	50	100

- ***Shortening samples analysis***

Fatty acid profile was determined by gas chromatograph (GC) (model AGLENT) equipped with flame ionization detector and Epsill 88 capillary column after preparation of fatty acid methyl esters according to AOCS Ce 2-66 and AOCS 1Ce -91methods.

Iodine value was determined from fatty acid composition according to AOCS Cd 1c-85 method.

Slip melting point (SPM) was measured according to AOCS Cc 3-25 method.

Solid fat content (SFC) was determined at 20, 30, 35°C by nuclear magnetic resonance (NMR) model MINISPEC20 (AOCS, 16b-93).

Induction period of the samples were measured by Metrohm Rancimat apparatus based on secondary oxidation product (AOCS, Cd 12b-92 at 110°C).

Free fatty acids and peroxide values were determined according to AOCS Ca 5a-40 and AOCS Cd 8-23 by titration with sodium-hydroxide and sodium thiosulfate respectively.

- ***Preparation of biscuits***

Shortening (33.3%) and sugar powder (13.3%) were mixed in a kitchen aid mixer, beaten eggs (3.4%) was added on low speed for about 2 min until the mixture is just combined. Flour (46.6%) was added to the mixture and was combined perfectly to set uniform dough. Chocolate chips (10%) were added to the dough and mixed. Final dough was kept in refrigerator for about 30 min, to be ready to shape. Biscuits were placed on a baking sheet and baked at 180°C for about 10-20 min (Ahmadi *et al*., 2009).

The formulation of all biscuits was the same except variations in shortening ratios (such as; 45:45:10, 40:40:20, 35:35:30, 30:30:40, 25:25:50). In all formulas there isn’t any flavoring agent such as vanilla and cocoa powder due to the perceiving the original taste of shortenings.

- ***Sensory and physical evaluation of biscuits***

The sensory analysis of biscuits was carried out by 40 untrained customer panelists and ask them to specify the sample which like more and recognize which two samples are more similar. The sensory evaluation test and analysis of biscuits were carried out a day after preparation (Ahmadi *et al*., 2009).

The texture of biscuits was studied by texture profile analysis (TPA) (model BROOKFIELD). The shape of all samples was the same (Block: 20mm× 20mm× 20mm). According to this test some parameters of samples such as hardness, cohesiveness, springiness, fracturability, adhesiveness, stringiness, gumminess and chewiness were measured.

- ***Statistical analysis***

Analysis of variance (ANOVA) with Duncan`s multiple range tests were performed to determine significant of difference at $p<0.05$. For statistical analysis all the 5 made shortenings were put in one group and then we compared their physical characteristics with commercial shortening, canola, palm olein and fully hydrogenated soy bean oils as three other groups.

Results and Discussion

Fatty acid composition and trans fatty acid content of 5 made shortenings, commercial shortening and primary oils are presented in Table 2. There is a significant difference concerned with trans fatty acids, palmitic, stearic and linoleic acids among the 5 made shortenings, commercial shortening and also primary oils, whereas, there is not any significant differences related to linolenic and oleic acids. Careful blending of oils might change and improve the overall fatty acid composition; therefore, there is no need to saturate fatty acids by hydrogenation (Padmavathy *et al*., 2001).

Table 2. Fatty acid composition of primary oils, commercial shortening and shortening`s mixtures (%)

Samples	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0	trans	others
Shortening 1	21.5	0.1	11.3	44.2	13.9	2.6	0.5	0.6	0.2	2.0	2.5
Shortening 2	21.3	0.1	17.7	39.2	12.7	2.3	0.5	0.1	0.1	2.0	3.4
Shortening 3	19.9	0.1	26.8	36.9	11.4	2.1	0.5	0.5	0.3	0.6	0.4
Shortening 4	17.5	0.1	34.9	28.9	11.7	1.8	0.5	0.4	0.3	1.4	2.1
Shortening 5	18.1	0.1	43.6	24.7	7.8	1.4	0.6	0.3	0.3	1.2	1.5
CS	38.2	----	10.6	35.4	2.2	0.1	0.4	----	0.1	5.0	6.9
Canola oil	5.0	0.2	2.0	60.6	22.8	0.5	0.1	1.2	0.3	0.9	6.3
Palm olein	39.6	0.2	5.7	39.1	8.4	0.2	0.4	0.1	0.1	2.4	2.6
FHSO	11.2	0.0	82.7	1.9	1.2	0.6	0.4	0.0	0.1	0.6	1.2

* Shortening 1 (45:45:10), Shortening 2 (40:40:20), Shortening 3 (35:35:30), Shortening 4: (30:30:40), Shortening 5 (25:25:50), Commercial Shortening (CS), Fully Hydrogenated Soybean Oil (FHSO)

According to the analytical results, the high concentration of palmitic (39.6%) and stearic acids (82.7%) that are saturated were found in palm olein and FHSO respectively. Due to the hydrogenation, FHSO has less content of saturated fatty acids. High quantities of oleic (44.2%), linoleic (13.9%) and linolenic (2.6%) acids were found in shortening 1 as compared to the other shortenings. Shortenings 1, 2 & 3 that included more proportion of canola oil and palm olein, had higher unsaturation, whereas, shortenings 4 & high content of FHSO had more saturated fatty acids.

The highest content of trans fatty acids was found in the commercial shortening (totally 5%), while shortening 3 had lower (totally 0.6%). According to the chemical analysis all the 5 shortenings that were made had lower concentration of trans fatty acids as compared to the commercial shortening. Therefore the results indicated that blending can be an effective method to reduce trans fatty acid content in the final product.

Table 3 presents iodine value (IV) slip melting point (SMP) free fatty acid contents, peroxide values (PV) and induction period (IP) of the samples. Iodine value of the made shortenings, commercial shortening and primary oils had significant differences. Iodine values are often used to indicate the amount of unsaturation in oils and fats and the higher iodine value indicate the higher unsaturation that means the more sensibility to oxidation chain reaction. The range of iodine value for 5 made shortenings was about 40-75 that is quite desirable. Shortenings 1, 2 & 3 (with high amount of canola oil and palm olein and more unsaturated fatty acids) had higher iodine value (75.4, 70.8 & 69.4) than shortenings 4 & 5 (46.1 & 41.2) (with high content of FHSO and saturation).

Significant differences concerned with Slip Melting Point (SMP) were found between 5 made shortenings, commercial sample and primary oils. The results showed that by decreasing the proportion of canola oil and palm olein (unsaturated fatty acids) and increasing the amount of FHSO (saturation) in the formulas, the SMP is increased. Canola oil due to its unsaturation had less SMP according to the standard range for SMP (43.3-54.4°C), shortening 2 had the closest SMP (54.7°C) as compared to the other samples.

The free fatty acid (FFA) is a common parameter in the specification of fats and oils. An increment in the amount of FFA in a sample of oil or fat indicates hydrolysis of triglycerides. Such reaction occurs by the action of lipase enzyme or exposure to high temperature in the presence of water. According to the results the major content of FFA value was related to the shortening 3 (0.14%) and shortening 1 had the least concentration (0.09%).

Table 3. Analysis prepared and commercial shortenings

Samples	Iodine value	Slip melting point (°C)	Free fatty acids (oleic acid %)	Peroxide value (meq/kg)	Induction period (h) (at 110°C)
Shortening 1	75.4	28.5	0.09±0.01	0.3±0.01	28.5
Shortening 2	70.8	54.7	0.13±0.01	0.3±0.01	26.8
Shortening 3	69.4	60.1	0.14±0.01	0.2±0.01	24.7
Shortening 4	46.1	63.1	0.1±0.02	0.4±0.01	44.5
Shortening 5	41.2	63.6	0.1±0.02	0.6±0.02	48
CS	34.5	41	0.03±0.02	0.3±0.02	40
Canola oil	110.7	0	0.1±0.02	0.6±0.01	20.1
Palm olein	55.6	47.2	0.06±0.02	0.3±0.01	40.5
FHSO	2.392	61.5	0.11±0.01	0.2±0.03	>40

* Shortening 1 (45:45:10), Shortening 2 (40:40:20), Shortening

Detection of peroxide gives an initial evidence of rancidity in unsaturated fats and oils. Other methods are available, but peroxide value is the most widely used. It gives a measure of the extent to which an oil sample has undergone primary oxidation. The double bonds found in fats and oils play a role in autoxidation. Oils with a high degree of unsaturation are most susceptible to autoxidation.

Induction period (IP) indicates the stabilizing of the oil towards oxidation. The substitutes containing higher quantities of saturated fatty acid and antioxidants provide higher induction period or stability in respect of oxidation. All of the primary oils had TBHQ as antioxidant therefore canola oil with high unsaturated fatty acids had acceptable induction period (approximately 20 h) also FHSO with high amount of saturated fatty acids had the highest induction period (approximately 40 h). This item for shortening 1 & 2 was about 28.5 h and 26.8h respectively, because of the high proportion of unsaturated fatty acids. Shortening 5 had the highest induction period among all the samples examined and it was about 48 h.

Solid fat content (SFC) is important in food development and production in respect of oils and fats and blends need to be characterized and controlled according to their melting profiles. Solid fat content (SFC) strongly influences the mechanical behavior of fats, although relying on SFC alone to predict hardness has shown to be unreliable (Narine & Marangoni, 1999a, 1999b). The mechanical properties of edible fats can be influenced by a series of factors, including the amount of solids (SFC), the polymorphism of the solid state as well as the microstructure of the network of crystalline particles (Marangoni & Narine, 2002). SFC will decrease at high temperature and also, high content of unsaturated fatty acids has opposite effect on SFC, therefore by increasing the proportion of FHSO (saturated fatty acids) in the formulas the SFC is increased. According to the results shortening 5 with 50% FHSO had the highest SFC (61.4, 53.4 & 48.2 at 20, 30 & 35°C respectively) amongst all the made shortenings (Table 4).

Color is the main characteristic for bakery products because, together with texture and aroma, it contributes the preference to the consumer. Color is one of the important attributes which has an effect on consumer acceptability. Pure oils have individual colors and some of them have strong or very weak colors that can have undesired effects on their acceptance. Blending appropriate oils and fats can moderate the color (Wang *et al*., 2016; Serjouie *et al*., 2010). Oil blending might also change odor profiles (Ravi *et al*., 2005).

Table 4. The amount of SFC for shortenings and primary oils

Samples	SFC 20 (°C)	SFC 30 (°C)	SFC 35 (°C)
Shortening 1	19.8	12.7	10.8
Shortening 2	30.3	22.3	19.3
Shortening 3	42.0	33.8	29.6
Shortening 4	51.9	43.3	37.6
Shortening 5	61.4	53.4	48.2
CS	52.9	23.7	15.1
Canola oil	0	0	0
Palm olein	22.2	5.2	2.0
FHSO	94	92	89

* Shortening 1 (45:45:10), Shortening 2 (40:40:20), Shortening 3 (35:35:30), Shortening 4: (30:30:40), Shortening 5 (25:25:50), Commercial Shortening (CS), Fully Hydrogenated Soybean Oil (FHSO)

Biscuit were made of shortening 2 & 3 and also commercial shortening had the same color (yellow), but the biscuits made of shortening 4 & 5 were quite white. Shortening 1 contributed a sharp yellow to the biscuits. The source and amount of fat in the shortening's formula can affect biscuit's color, therefore biscuits with high amount of saturation in the fat source had white color, but the others with high amount of unsaturation in the shortening had yellow and more acceptable color.

Texture profile analysis (TPA) is a popular double compression test for determining the textural properties of foods. During TPA test samples are compressed twice using a texture analyzer to provide insight in to how samples behave when chewed. The TPA test was often called the "two bite test" because the texture analyzer mimics the mouth's biting action and can quantify multiple textural parameters in just one experiment. The textural identity of any food is rarely a simple matter of understanding a singular attribute such as hardness or cohesiveness. The texture of any food is milt-faceted and tied to consumer's sensory expectations. TPA test press all the samples twice. For each press the device gave one diagram that called hardness 1 and hardness 2 diagrams. The hardness of a fat (shortening) is an important property that strongly influences the perceived texture of a food product (Brunello *et al*., 2003). Surely, the compressing pressure which is used for pressing the samples at the first time is much more than the second time because at the second time the partial consistency of samples had lost by pressure. All the above facts have been shown in Table 5 and Figures 1-6. According to the results biscuit 1 had the least hardness (10.689 N) and also its consistency was lower than the other samples that means it was quite brittle, and the force for chewing (0.34N) less which caused less cohesiveness and fracturability (10.689N) because the shortening's formula of this biscuit had least the amount of saturated fatty acids, which is an important element for biscuit's texture. Another reason is the high amount of palm olein (45%), and the presence β' crystals in the shortening's structure and is the main reason of soft, smooth and brittle texture in fat resource and also biscuits.

Palm olein is β' tending fat and rapid cooling of palm oil results in the formation of β' crystals and slow cooling tends to favor β crystals formation (Wiedermann, 1972), therefore adding more of this oil to the formulation of shortenings gave a brittle biscuits.β'polymorphs are desirable in shortening's structure and give smooth mouth feel and their effect on final product is a brittle and fragile biscuits. It should be considered that hardness was the term used by all the consumers. in shortening 1 to 3 by increasing the proportion of FHSO and saturated fatty acids and decreasing the content of palm olein and β’, the hardness of biscuits has increased (the hardness of biscuit 3 was 30.724 N) and the force for chewing will be increased (chewiness for biscuit 3 was 9.783 N) that affect the on amplification and the consistency (biscuit s 3 had similar textural range with commercial one). This means that biscuits had great cohesiveness and fracturability. The hardness and consistency of biscuits 4 & 5 decreased. There is a direct connection between the amount of added water and dough’s consistency. Moreover, the addition of water has caused l the ingredients to be mixed properly. That is the reason for reduction of hardness, consistency, cohesiveness, fracturability.

Biscuits 4 & 5 needed more chewing (5.628 N & 9.14 N respectively), that means that they are quite hard and the number of their hardness (22.899 N & 28.947 N) and cohesiveness (0.44 &0.49) showed the fact that they did not have good acceptability among all the panelists and if water was not added to the doughs, the product would be hard more.

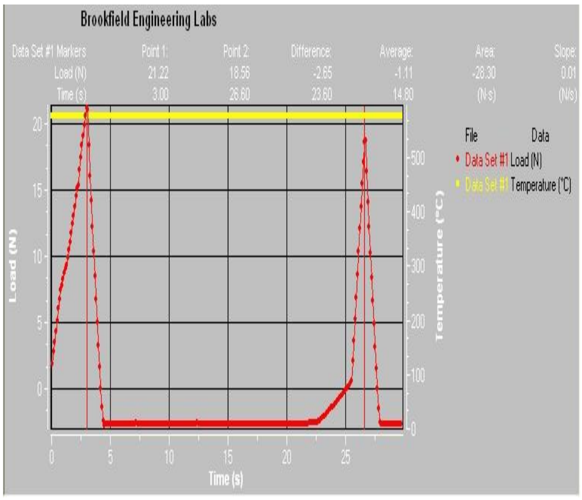

Fig.1. TPA for biscuit 1

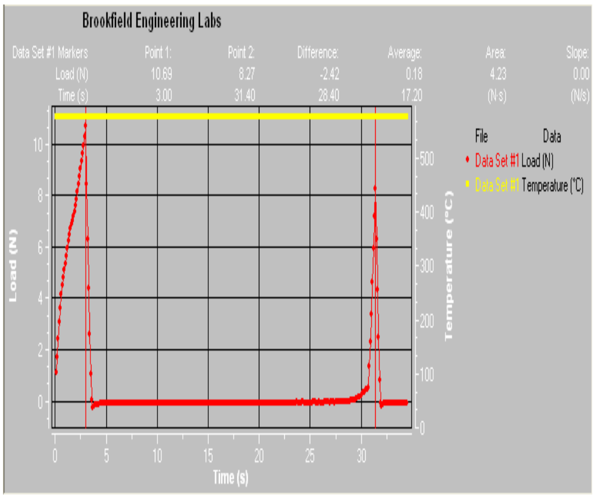

Fig. 2. TPA for biscuit 2

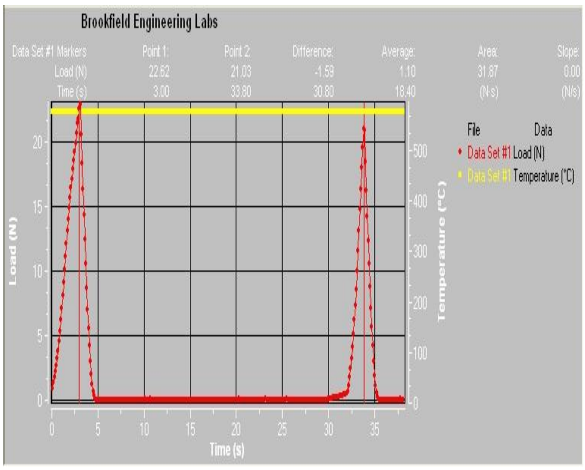

Fig.3. TPA for biscuit 3

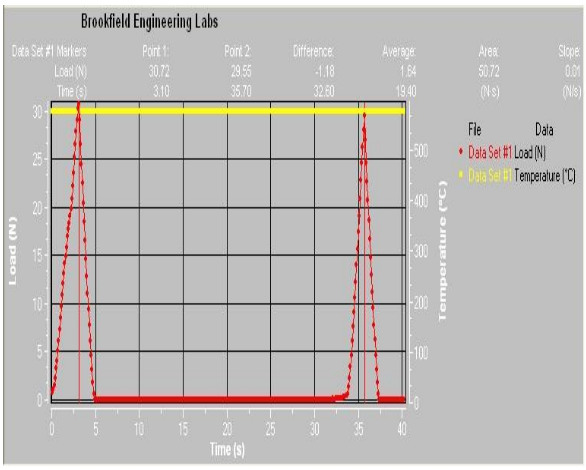

Fig. 4. TPA for biscuit 4

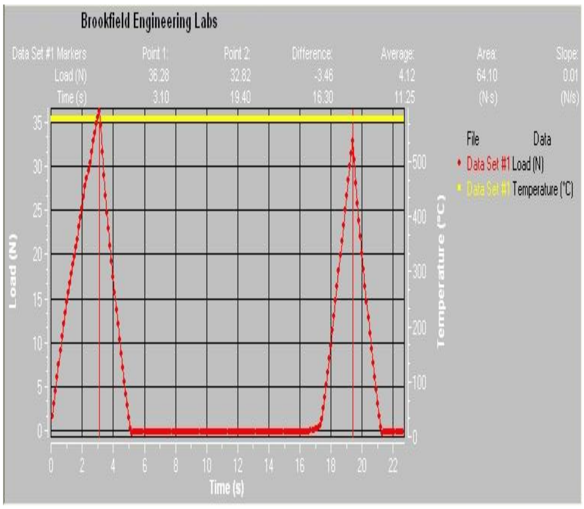

Fig. 5. TPA for biscuit 5

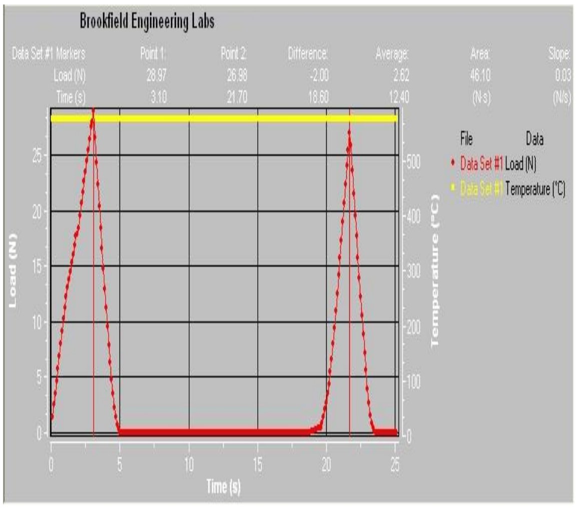

Fig. 6. TPA for commercial biscuit 6

Table 5. The results of TPA for biscuits

Samples	Hardnes 1 (N)	Hardness 2 (N)	Cohesiveness	Springiness (%)	Fracturability (N)	Adhesiveness (mm)	Gumminess (N)	Chewiness (N)
Biscuit 1	10.689	8.272	0.14	0.22	10.689	0	1.544	0.340
Biscuit 2	21.217	18.765	0.31	0.36	21.217	0.20	6.639	2.390
Biscuit 3	30.724	29.547	0.57	0.56	30.724	0.31	17.470	9.783
Biscuit 4	22.899	21.025	0.44	0.56	22.899	0	10.050	5.628
Biscuit 5	28.947	26.978	0.49	0.64	28.974	0	14.281	9.140
Commercial biscuit	36.280	32.823	0.53	0.63	36.280	0	19.235	12.118

[a] Biscuit 1 was made of shortening 1, biscuit 2 was made of shortening 2, biscuit 3 was made of shortening 3, biscuit 4 was made of shortening 4, biscuit 5 was made of shortening 5 and commercial biscuit was made of commercial shortening.

All the factors that were measured by TPA test had relevance with each other. The more hardness caused high cohesiveness and also high force for chewing and breaking samples.

Biscuits 2 had better texture and acceptable properties than the other samples. This sample had more harness than sample 1 and less hardness than samples 3, 4 & 5 (biscuit's 1 hardness was 21.217 N). This result also was shown for cohesiveness (0.31N), fracturability (21.217 N) and chewiness (2.39 N).

Sensory evaluation and quality might be considered more important than nutritional value for most consumers (Bakhtiary *et al.*, 2014). Oil blending has an important role in the sensory attributes of the final product (Sadoudi *et al.*, 2014). The consumers use different textural descriptors related to the behavior of a material when crushed and moistened in mouth such as; crunchy, hard and crispy characteristics and also the first flavor sensations that are noticed during eating. They described the main flavors of biscuits like buttery, sweetness and roasted flavor. About 72% of panelists liked the color, texture, aroma and the flavor of biscuit 2. Shortening 5 received the lower score. Most of the panelist didn't like the taste and flavor of commercial biscuit. Biscuit 2 that was formulated by shortening 2 was more acceptable than others. The definition of textural properties such as hardness, chewiness and cohesiveness in opinion of panelists is different from TPA test. The results of TPA showed that biscuit 3 and commercial biscuit was similar but in opinion of most (70%) panelists indicated that biscuit 2 is more similar to commercial one and just 7.5 % believe the similarity of biscuit 3 and commercial sample.

Conclusion

Inorder to choose the best shortening sample different physical tests were carried out on the samples followed by their applications in the formulas. All the 5 shortenings had less trans fatty acids than the commercial shortening but according to the results and evaluation, shortening 2 with the mixture of 40:40:20 canola oil, palm olein, FHSO had better properties such as; 2% trans fatty acids with iodine value of 70.8 and moderate amount of saturated and unsaturated fatty acids, SMP of 54.7°C, FFA content of 0.13% (oleic acid), peroxide value of 0.3meq/kg, induction period of 26.8 h at 110°C, SFC of 30.3 at 20°C , 22.3 at 30°C and 19.3 at 35°C (all the results was in the standard range). The acceptability of biscuits 2 by panelists was better than the other samples and most of the panelist voted that biscuit 2 and commercial biscuit had similar properties.

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