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Fatty acids profile and physicochemical properties of various shortenings formulated with palm oil

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A B S T R A C T

Shortenings are a mixture of one or more vegetable edible oil with partial hydrogenation in mixed with or without animal fat. In this study, three formulations of shortenings, with the best commercial and technological properties were prepared. Increasing consumption of shortenings at the human daily diet, with low adverse coronary effects in human daily diet, three formulations prepared using a mixture of different oils and Palm fat (as the basis) followed by the evaluation the fatty acid profile and chemical properties. All formulations were studied in terms of suitability in food applications. The obtained results indicated that there were no significant differences between physicochemical properties, peroxide value, refractive index and acidity of samples. Only the melting point had a significant difference ($p < 0.05$). Apart from trans fatty acids and oleic acid contents, there were no differences between fatty acids pattern, and the palmitic, stearic, linoleic and linolenic acids. The results indicated that between total saturated fatty acids, total unsaturated fatty acids and MUFA/PUFA there were great differences that must be noticed due to nutritional attributes. Peroxide value of samples indicated that the percent of oleic, linolenic and linoleic acids have a detrimental role on the peroxidative stability of analyzed formulations. Due to the results, all of the formulations can be used as a replacement for traditional hydrogenated fats in the bakery industry, only their trans fatty acids must be lowered.

Keywords: Fatty acids, Palm, Shortening, Trans fatty acids

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1. Introduction

Nowadays, with population growth and the extending of nutritional needs, besides of food healthy, the diversity at food production is an essential matter (Codex Alimentarius Commission, 2001). Fats and oils are valuable materials in calorie providing and have a critical role for healthiness. These are categorized as necessary utilized goods (Tiemann et al., 2018). Most vegetable oils, after purification and necessary processing, are consumed at human diet (Fu et al., 2018). Some traditional fats and oils may cause some dietetic disorders such as obesity and cardiovascular diseases, because of their unhealthy fatty acids (Xu et al., 2018).

Shortening, is a viscoelastic semisolid food product containing both liquid and solid fats (Habi Mat Dian, 2018). Shortenings are commonly produced by instant cooling of oil and fat blends. In such conditions, liquid oil is entrapped with solid fat and yields a homogenous solid product. Some factors including temperature, processing history and storage can change shortenings physicochemical and sensory properties (Gharaei et al., 2019). They are used in bakery products, such as pastries, pie crusts, and bread, to form desirable texture and extending the shelf life (Li et al., 2010). Shortenings are produced by super-chilling of a mixture of oils and fats to form homogenous and smooth product (Kanagaratnam et al., 2013). These are a mixture of one or more partially hydrogenated vegetable edible oils with or without adding animal fat. The reason for using solid fats is to gain plastic texture. Urbanity, low consumption of fibers, increasing use of purified sugars, salt and saturated animal fats are common factors which leads to coronary and heart diseases (Ascherio & Willett, 1997; Ascherio et al., 1996). There have been abundant researches about the harmful effects of trans fatty acids on human health. Trans fatty acids have an important role on increasing of LDL-C and triglycerides (TG), decreasing HDL-C and enhancing coronary diseases (Christiansen et al., 1997; Oh et al., 2005; Xu et al., 2018). Recently, some manufacturers and state institutions promote the lower consumption of hydrogenated oils consumption. There is a decreasing interest in the use of some foods such as confectionary goods mainly due to having large amounts of trans fatty acids. For example, cookies are of mostly used confectionary that some solid

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shortenings are used on their production (Pourmohammadi et al., 2009). Trans fatty acids are produced during hydrogenation of vegetable oils. Palm oil is free from trans fatty acids and can be used at shortening formulation.

There are many types of shortenings as: All-purpose, fluid, cake, icing, filler fat, bread, frying, pie crust, pastry, confectionary, and dry shortenings (Ghotra et al., 2002). As it comes from their name, they are used in confectionary products, instant mixes and in frying oils. The quality of a baked product is mostly related to the choice of desired shortening (Goh et al., 2019). Plastic shortenings are manufactured by hydrogenation of oils, that some fatty acids change to trans ones with higher melting point and the probable role in heart disease risks. One of the best methods to avoid shortening health risks, is blending palm olein with other oils to make a stable plastic fat (Jeyarani et al., 2009). Alternatives of hydrogenated oils are one of the effective ways of eliminating the trans fatty acid in fat products, such as margarine, shortening and cream (Liu et al., 2019). Fractionation is one of the reliable methods to produce the shortenings, but it is not possible to obtain satisfactory plastic fat with this method (Hu et al., 2017). Despite the fractionation, blending is a practical and economical method and can modify oils for specific applications (Hashempour-Baltork et al., 2016). To manufacture of some fatty dairy-like product, blending has been applied based on vegetable oils (Al-Neshawy, 2000). Shortenings application in some foods such as breads, cakes, biscuits, creams, and pastries are greatly dependent on their physical stability (Kanangaratnam et al., 2013). Also, their application depends on the chemical and physical properties such as the length of the fatty acids chain, number and position of double bonds (da Silva et al., 2010). Fu et al. (2018) reported that the structure of shortenings (monoacylglycerols) can affect the density and firmness of battles. Also, Lee et al. (2014) indicated that monoacylglycerol with high monostearin (C18) improve the batter aeration and reduce cake crumb firmness.

The most used oil for the shortenings production is palm oil. It accounts for 32% of global supply of oils and fats (Tiemann et al., 2018). This oil has acceptable amount of vitamin E, that can prevent heart attacks and dietary supplementation with palm tocotrienols lower lipid associated coronary heart risk factors (Al-saqer et al., 2004). Palm oil and its derivatives palm olein are extensively used in plastic fats (Xu et al., 2016). Al-saqer et al. (2004) argued that palm olein is one of the best sources of tocotrienols and vitamin E and cookies containing high palm oil content, had higher levels of these desirable phytochemicals and antioxidant vitamins.

There is not a comprehensive study about the fatty acid profile and its relationship of fatty acids with texture and physicochemical properties of commercial shortenings used in Iran. Nowadays, the lowering of trans fatty acids consumption is recommended, however, compared to daily intake, lower studies have been performed on the relation of shortenings with the level of trans fatty acids utilization. Because of the harmful effects of trans fatty acids in human health, palm oil is used at the formulation of most shortenings, but few studies have been performed on the substitution of palm oil with other oils and fats and its effect on the shortening physicochemical properties. The current study was performed to determine fatty acids profile and physicochemical properties of three commercial shortening formulations and consequently, to suggest a shortening with lower risk factors, determining the effective elements on the texture of shortening and propose suitable formula with desirable quality attributes.

2. Material and Methods

2.1. *Shortening production*

About the following formulations, the shortening samples were produced. *Note that all of the formulations are real formulation of the commercial shortenings of Nazgol edible oil refinery company (Kermanshah, Iran).*

The formulations were:

- Formula 1: Hydrogenated palm oil (with 37 °C melting point) 45% + hydrogenated palm oil (with 45 °C melting point) 45% + Soybean oil 10%.
- Formula 2: Hydrogenated Palm oil (with 37 °C melting point) 100%.
- Formula 3: Hydrogenated Palm oil (with 37 °C melting point) 50% + Hydrogenated Palm oil (with 45 °C melting point) 50%.

First, all the semi-solid fats and oils were heated to above melting temperature; then the shortenings were formulated and transported to a cooling section for further processing.

By a chilling process, texturizing of a shortening is achieved to improve plasticity. On a chilling unit, the melted fat is rapidly cooled. Under shear crystallization, improves the plasticity and texture of the shortening and removes heat of crystallization from the shortening (Ahmadi & Marangoni, 2009). The crystallization or texturizing were carried out in a prefector pilot plant (Gerstenberg and Agger, Copenhagen, Denmark) with a previously described method by kanagaratnam et al. (2013). The blend was placed in a feed tank and heated to 65 ºC for an hour to ensure total melt. The blend was then maintained at 65 ºC and processed through the first chilling unit (scraped surface heat exchanger: Unit A). The main function of this unit was to instantaneously cool the blend by reducing the temperature of the blend from 65 ºC to 45 ºC. The blend was further chilled by passing it through the second chilling unit to instantaneously reduce the temperature from 45 ºC to 25 ºC. The rotation speed of both the scraped surface heat exchanger shaft was set at 450 rpm. The blend was then homogenized by further processing through a pin worker (Unit B), with the rotation speed of the shaft set at 150 rpm. This experimental shortening was collected in 1000 g containers and stored at room temperature.

2.2. *Shortening production*

2.2.1. *Acidic value*

The acidic value was analyzed with the standard method (AOCS, 1998).

2.2.2. *Peroxide value*

Peroxide value of samples was determined using AOCS standard method for oils (AOCS, 1998).

2.2.3. *Fatty acids profile*

- Extraction method: Fatty acid composition was determined as fatty acid methyl esters (FAME). The samples (0.05 g) were weighed and dissolved in 1 ml hexane. The mixture was then added to sodium methoxide solution (0.2 mL of $NaOCH_3$ (2 M) in anhydrous methanol) and then mixed for 1 min with a vortex mixer. After sedimentation of sodium glycerolate, 1 µL of clear supernatant was injected (Kanagaratnam et al., 2013).

- Fatty acids profile: A gas chromatograph (GC 6890N, Agilent, USA) was used to determine fatty acids profile of the samples. The column was BP*70 with the inner diameter of 0.25 mm and 60 m length (SGE, Australia), the oven temperature of 182 °C as isothermal, the carrier gas pure N2, with steady flow of 1 ml/min. FID detector was used with 300 °C, N2 flow 40 mL/min, air flow 250 mL/min and the injected sample volume was 1 µL as the split method with the ratio of 1/100 (AOCS, 1998).

2.3. Physical tests

2.3.1. Color

The samples color was tested using a Lovibond Tintometer (PEX880) with a 5.25-inch cell (AOCS, 1998).

2.3.2. Refractive index

An Atago refractometer (model RX-5000α) was used at 40 °C to measure the refractive index of the samples (AOAC, 1998; 921/08).

2.3.3. Oxidative stability

A rancimeter (Metrohm 679) was used at 110 °C with the air flow of 20 L/h to measure the stability of samples to oxidation (AOCS, 1998; Cd 12-57).

2.3.4. Melting point

The melting point of the samples was determined with capillary tube method (AOAC, 1998; 920/157).

2.3.5. Viscosity

The viscosity of the samples was measured by a Brookfield viscometer (DVII-RV, Brookfield) using spindle 03 at 150 RPM for 5 minutes.

2.4. Statistical analysis

The obtained data were analyzed using SPSS (version 24, IBM Corporation) software at $p < 0.05$. Statistical analyses were performed to detect any significant differences between the treatments using a one-way ANOVA test ($p < 0.05$), and multiple comparisons of the means were according to Duncan's multiple range test.

Table 1. Changes of physico-chemical attributes of formulations*

The parameters**	The quantity at formula		
	Formula 1	Formula 2	Formula 3
Peroxide index (meq/kg)	0.06 ± 0.167^a	0.06 ± 0.167^a	0.05 ± 0.200^a
Melting point (°C)	42.83 ± 0.29^a	40.00 ± 0.87^b	42.50 ± 0.50^a
Acidity (%w/w)	0.040 ± 0.005^a	0.037 ± 0.002^a	0.036 ± 0.001^a
Oxidative stability index (OSI)	47 ± 0.98^a	45 ± 0.90^a	45 ± 0.88^a
Yellow hue	70.03 ± 1.85^a	57.04 ± 1.45^b	46.01 ± 1.98^c
Red hue	5.3 ± 0.3^a	3.5 ± 0.5^b	3.0 ± 0.2^b
Refractive index (°C)	1.458 ± 0.005^a	1.458 ± 0.002^a	1.458 ± 0.001^a

*The data have been reported as mean of three replications ± Standard deviation.
** In each row, the similar letters indicate no significant difference between results.
Formula 1: Hydrogenated palm oil (with 37 °C melting point) 45% + hydrogenated palm oil (with 45 °C melting point) 45% + Soybean oil 10%.
Formula 2: Hydrogenated Palm oil (with 37 °C melting point) 100%.
Formula 3: Hydrogenated Palm oil (with 37 °C melting point) 50 % + Hydrogenated Palm oil (with 45 °C melting point) 50%.

3. Results and Discussion

3.1. The changes of physicochemical attributes of different formulations

Table 1 indicates the result of physicochemical attributes of different shortening formulations. Data analysis showed that only in the case of melting point, it was significant differences between different formulas were present ($p < 0.05$). The melting point of the studied formulas was between 40 - 42.83 °C. The highest melting point was for formula 1, with relatively higher stearic and lower oleic acids. Whereas stearic acid has high melting point and oleic acid, as a predominant mono-unsaturated fatty acid, has low melting point. The different and multitude arrangements of fatty acids on the glycerol backbone depend on the diversity of triacylglycerols, as a result, this pattern influences the melting and crystallization behavior of the fat. Also, the melting point is as a function of crystal type and diversity (Liu et al., 2019). Also, Mattice and Marangoni (2018) evaluated the effect of hydrogenated and non-hydrogenated shortening on the crystalline wheat starch, gelatinized wheat starch, gluten, and formed gluten network and concluded that the rate of crystallization was greater in croissant matrixes containing gelatinized wheat starch, indicating that the gelatinized starch could act as a nucleation site to speed crystallization and variation of fats melting point. Bakery products needs to wide melting point ranges, and this achieves with heterogenous type triglycerides (Jeyrani et al., 2009). Melting points of the samples indicated that these values are higher than human body temperature, i.e., these shortenings are not liquified at the mouth. Thus, the shortenings crystallization pattern must be adjusted to lower melting point to human body temperature (37 °C).

There was not any significant difference between oxidative stability of samples, but the yellow and red attributes of samples differed significantly ($p < 0.01$). Jeyrani et al. (2009) indicated that blending of coconut stearin with hard fraction from palm oil lead to increase iodine value. Oils with a high iodine value are very sensitive and susceptible to oxidation and have less stability.

Table 2. Fatty acids changes at different formulations of shortenings*

Fatty acid	Percent at formulations		
	Formula 1	Formula 2	Formula 3
Palmitic acid ($C_{16:0}$)	36.65 ± 0.87^{b}	38.11 ± 1.02^{ab}	39.43 ± 0.40^{a}
Stearic acid ($C_{18:0}$)	10.99 ± 0.16^{a}	8.75 ± 0.14^{b}	10.20 ± 1.19^{a}
Elaidic acid ($C_{18:1t}$)	8.14 ± 1.12^{a}	8.75 ± 0.14^{a}	7.15 ± 1.42^{a}
Oleic acid ($C_{18:1}$)	33.11 ± 0.87^{b}	36.95 ± 1.01^{a}	35.57 ± 2.57^{ab}
Linoleic acid ($C_{18:2}$)	7.87 ± 1.53^{a}	6.94 ± 0.86^{ab}	5.05 ± 0.51^{b}
Linolenic acid ($C_{18:3}$)	0.97 ± 0.25^{a}	0.67 ± 0.82^{ab}	0.42 ± 0.08^{b}

* In each row, different letters show significant differences at $p < 0.05$.
Formula 1: Hydrogenated palm oil (with 37 °C melting point) 45% + hydrogenated palm oil (with 45 °C melting point) 45% + Soybean oil 10%.
Formula 2: Hydrogenated Palm oil (with 37 °C melting point) 100%.
Formula 3: Hydrogenated Palm oil (with 37 °C melting point) 50 % + Hydrogenated Palm oil (with 45 °C melting point) 50%.

Table 3. The fatty acids composition of different formulas of shortenings*

Fatty acid	The formulas**		
	Formula 1	Formula 2	Formula 3
SFA (w/w)	47.64 ± 0.99^{ab}	46.86 ± 1.11^{b}	49.62 ± 0.93^{a}
USFA (w/w)	41.94 ± 2.61^{a}	44.55 ± 1.90^{a}	41.04 ± 2.75^{a}
MUFA (w/w)	33.10 ± 0.87^{b}	36.94 ± 1.00^{a}	35.57 ± 2.56^{ab}
PUFA (w/w)	8.84 ± 1.76^{a}	8.84 ± 1.76^{a}	5.47 ± 0.52^{b}
TFA (w/w)	8.14 ± 1.17^{a}	8.75 ± 0.13^{a}	8.15 ± 1.42^{a}
USFA/SFA	0.88 ± 0.07^{a}	0.95 ± 0.06^{a}	0.82 ± 0.06^{a}
PUFA/SFA	0.19 ± 0.04^{a}	0.19 ± 0.07^{a}	0.11 ± 0.06^{a}
MUFA/PUFA	3.83 ± 0.67^{b}	4.30 ± 0.96^{b}	6.53 ± 0.63^{a}
USFA/SFA+TFA	0.75 ± 0.05^{a}	0.80 ± 0.05^{a}	0.73 ± 0.07^{a}
SFA (w/w)	47.64 ± 0.99^{ab}	46.86 ± 1.11^{b}	49.62 ± 0.93^{a}

* The results have been reported as mean ± SD
** In each row, different letters indicate that there is significant difference between formulas.
Formula 1: Hydrogenated palm oil (with 37 °C melting point) 45% + hydrogenated palm oil (with 45 °C melting point) 45% + Soybean oil 10%.
Formula 2: Hydrogenated Palm oil (with 37 °C melting point) 100%.
Formula 3: Hydrogenated Palm oil (with 37 °C melting point) 50 % + Hydrogenated Palm oil (with 45 °C melting point) 50%.

3.2. Fatty acid changes at evaluated formulas

Physiochemical properties of fats depend to lipids composition (Liu et al., 2019). Fatty acids changes and their mean amounts have been reported in Table 2. Other than trans fatty acids, there were significant differences between other fatty acids amount (Table 3).

Major fatty acids were palmitic, stearic, oleic, linoleic and linolenic that comprised about 98% of total fatty acids. Total saturated fatty acids (SFA) and unsaturated fatty acids (USFA) at different shortenings formula are shown in Table 3. Also, the ratio of polyunsaturated fatty acids to saturated ones (PUFA/SFA) and total unsaturated fatty acids to the whole of saturated fatty acids and trans fatty acids (USFA/SFA+TFA) have been reported. There were significant differences between SFA, PUFA and the ratio of monounsaturated fatty acids to PUFA (MUFA/PUFA) ($p < 0.05$).

The major saturated fatty acids in the evaluated shortenings were palmitic acid and stearic acid (36.65 - 39.43% and 8.75 - 10.99%, respectively). Palmitic acid was the major fatty acid (46%) of palm oil fatty acids (Ghotra et al., 2002). In comparison with formula 2 and 3 that were comprised of 100% hydrogenated palm oil, Formula 1 had about 10% Soybean oil and the lowest content of palmitic acid. Palmitic acid of palm oil is about 46% and 11% for soya oil (Ghotra et al., 2002). The world health organization recommends unsaturated fats consumption and removing saturated-fats and trans-fats from diet (WHO, 2004). Trans fatty acids were identified in all the samples (8.14 - 8.75%) (Table 3). The presence of trans fatty acid proved that the samples, that were commercial formulations of the shortening, contained partially hydrogenated fat. The main part of trans fatty acids were elaidic acid (18:1t). Normally hydrogenation is done under less selective conditions, while there is not trans fatty acid at palm oil, the resultant trans fatty acids have been arisen from hydrogenation process of oil. Recently, Sanz et al. (2015) indicated that substituting conventional shortenings with cellulose ether emulsions in biscuit dough is a healthier choice by lower fat content, lower saturated fatty acids content without trans fatty acids.

All the formulated shortenings contained high amounts of unsaturated fatty acids (41.04 - 44.55%) in which the major fatty acid was oleic acid (33.11 - 36.95%). The shortenings have nutritional roles and are used for special goods such as cooked, fried and confectionary foods. In the case of hypoglycemia, the oleic acid and essential fatty acids contents are considered as beneficial (Ahmadi & Margoni, 2009). Palm oil contains 51.7% Palmitic acid, while sufficient dietary intake of essential fatty acids exists, Palmitic acid has not harmful role on serum lipoprotein profiles (Jeyrani et al., 2009). The PUFA of the samples were between 5.47 to 8.84%, most of them was linoleic acid (5.05 - 7.87%), Due to the high oxidative susceptibility, replacing linoleic with oleic acid can improve the oxidative stability of the shortenings. Hence linoleic acid is major fatty acid of soya oil (54% of all fatty acids) (Ghotra et al., 2002), Formula 1 with combination of palm (90%) and soybean oil (10%) had highest level of linoleic acid (7.87%). Although the PUFA content of the elevated samples was not very high, fat sources higher in unsaturated fatty acids lack structure at room temperature. As a result, they can produce adverse effects in food products and often results in a reduction of product quality when used instead of solid fats (Hughes et al., 2009; Youssef & Barbut, 2009).

These differences between fatty acids have an important role on nutritional aspects of the shortenings. In recent years, there have been many researches about the detrimental effect of trans fatty acids on human health. It has been proved that trans fatty acids can increase LDL-C and TG, decrease HDL-C and result in coronary heart diseases (Oh et al., 2005; Aro et al., 1995). Mert and Demirkesen (2016) argued that substitution of trans and solid fats with palm and other oleogels is the best way to increase confectionary goods quality. Foods prepared with hydrogenated fats are the main source of trans fatty acids. Some confectionary goods that have been manufactured with these fats have the highest amount of trans fatty acids (Mozaffarian et al., 2006). Recently, to lower trans fatty acids consumption, the production of hydrogenated fats has been confined, but the effect of confectionary goods on the consumed trans fatty acids has not been studied enough (Haratian et al., 2013). As indicated in Table 3, there is not any significant difference between trans fatty acids of the evaluated shortening formulations. As a result, the addition of soybean and palm oil with 45 °C melting point has not any effect on trans fatty acids amount. The ratio of USFA to SFA is as an index for autoxidation of lipids (Melton et al., 1994), but there was not any significant difference for this index in the evaluated different formulas. Most of the fatty acids in the studied shortenings were saturated (~ 47%) and unsaturated (~ 42%) long chain fatty acids. Formulas with both medium and long-chain fatty acids, because of their fairly complex packing and smaller crystals at the molecular level, make more suitable shortenings (Floter & Van Duijin, 2006). As dedicated on the materials section, the evaluated formulas were the commercial formulation of Nazgol edible oil refinery factory (Kermanshah, Iran).

With regard to fatty acids analysis of all samples, it was revealed that all formulations had high amount of saturated and trans fatty acids that concerns are about their health problems and possibility of their heart related diseases (Li et al., 2010). So, the researchers of this paper suggest using healthier formulation of shortenings or fat content reduction by replacing shortening or butter in bakery products with healthier fat substitutes. Recently, Gharaie et al. (2019) introduced the gum tragacanth oil/gels as an alternative to shortening in cookies and resulted that replacement of shortenings by oil/gels reduced the fat content by about 27 - 30% in cookies. Also, they reported that cookies containing oil/gels, produced sensory scores similar to those of the shortening sample and replacement of up to 50 g/100 g of shortening with oil/gels containing 1.5 g/100g of the gum tragacanth could be a possible alternative to produce healthier food products. Other researchers (Giarnetti et al., 2015) replaced 50 and 100 g/100 g of butter in cookies with gels containing inulin and olive oil as fat replacers. They showed that the fat content decreased by 19 and 46% compared to the control sample and Tarancon et al. (2013) also replaced shortening with oil/gel systems containing Hydroxypropyl methyl cellulose (HPMC) or xanthan gum and olive oil or sunflower oil that this replacement led to 10.6 and 15.6% reduction of fat content compared to a shortening sample. Zhou et al. (2011) concluded that the high levels of trans or saturated fats in some plastic shortenings may have healthy concerns and liquid shortenings significantly reduce the dependence on fats and the emulsifiers in this type of shortenings enhance the functionality of shortenings.

3.3. *Oxidative stability of the evaluated formulas*

On determining the oxidative stability of one fat or oil, it is not possible to rely only on one fatty acid (e.g., linolenic) and, the total and structure of all fatty acids must be noticed. Thus, for determining oxidative stability of samples, all oleic, linoleic, linolenic, SFA and USFA were analyzed. The oxidative instability showed a negative correlation with oleic acid R^2 0.87) indicating that the increase in oleic acid content increases the oxidative stability (Fig. 1).

As expected, the oxidative instability was positively correlated with the amount of linoleic (R^2 0.56) and linolenic (R^2 0.79) acids indicating that an increase in the amount of polyunsaturated fatty acids decreases the oxidative stability of shortenings. Increasing total amount of saturated fatty acids improved the oxidative stability (i.e., a negative correlation with oxidative instability in Fig. 1).

3.4. *The viscosity of the shortenings*

Fig. 2, indicate the apparent viscosity of shortening formulations during the time. As shown, the number 3 formulation had the highest viscosity in comparison with the two other ones that can be related to its fatty acid profile and more 45 °C fraction of palm oil. Thus formula 3 had more plasticity than other two formulas. All of the samples showed Newtonian behavior, normally, oils are Newtonian. As fat has a lubricant role in the food texture, its texture and viscosity can be detrimental for food texture. Higher viscosity shortenings can produce bulker products. Goh et al. (2019) indicated that the volume, hardness, chewiness and springiness of the finished baked products were significantly affected by the choice of the shortening, its plasticity and viscosity.

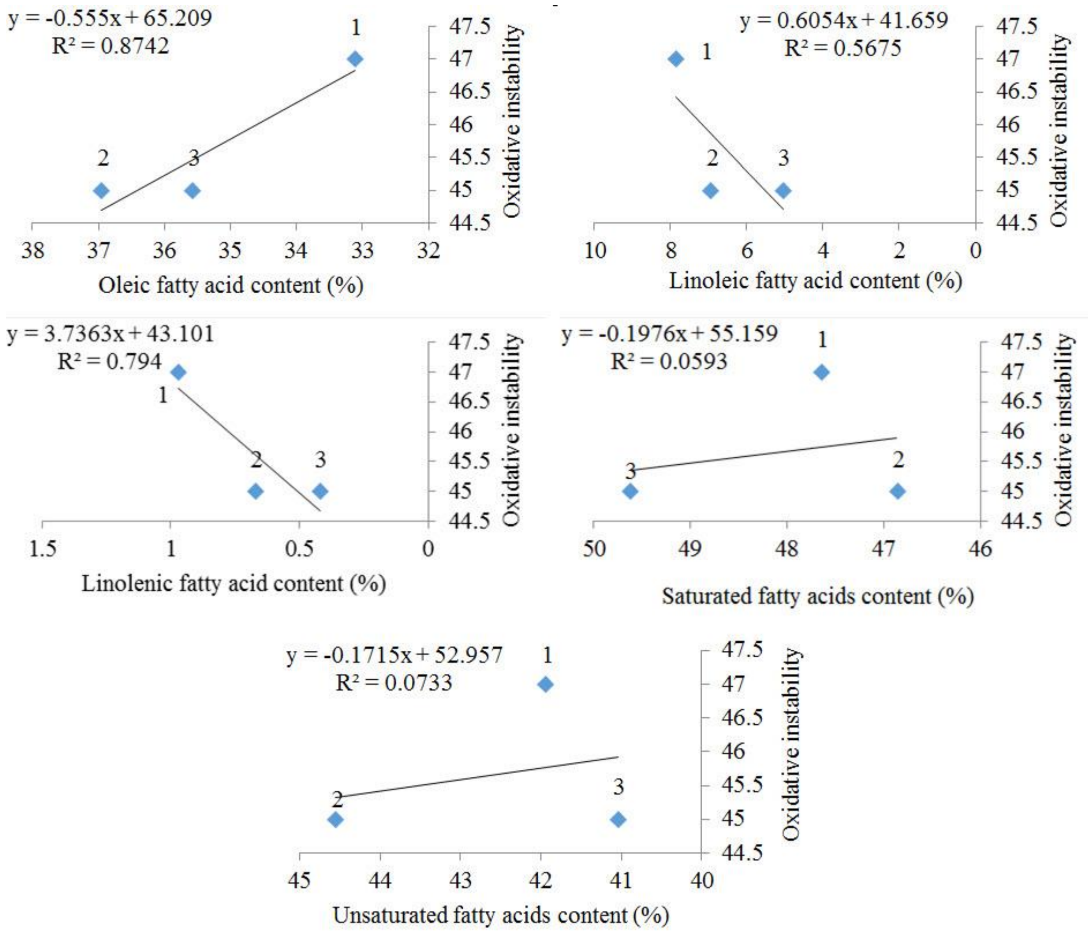

Fig. 1. Oxidative instability of the evaluated formulas with regard to their fatty acids content.

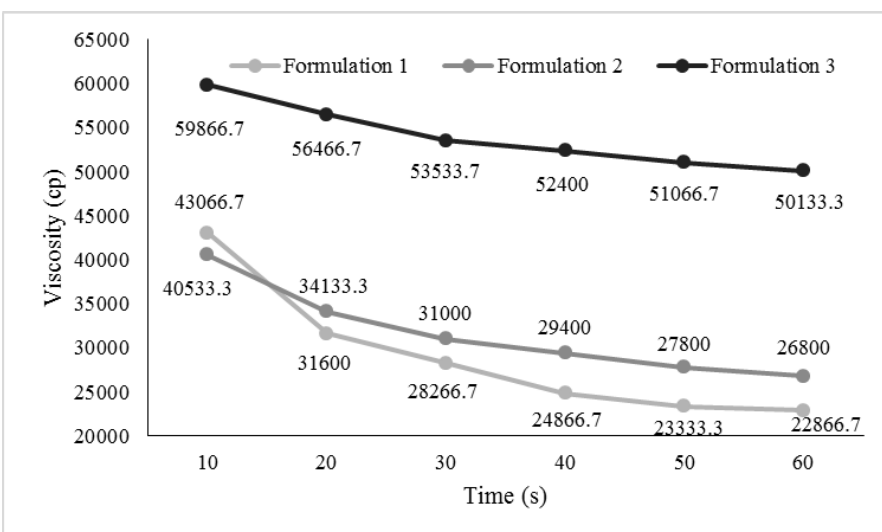

Fig. 2. Apparent viscosity of the evaluated samples
(Formula 1: Hydrogenated palm oil (with 37 °C melting point) 45% + hydrogenated palm oil (with 45 °C melting point) 45% + Soybean oil 10%; Formula 2: Hydrogenated Palm oil (with 37 °C melting point) 100%; Formula 3: Hydrogenated Palm oil (with 37 °C melting point) 50 % + Hydrogenated Palm oil (with 45 °C melting point) 50%.)

4. Conclusion

Results indicated that in shorteninig with different fatty acids composition, there were not any significant differences between physicochemical properties of the analyzed formulas, and only melting point of them and some physicochemical properties were different. Harmfulness of shortenings belongs to their trans fatty acids content. Unfortunately, the trans fatty acids content of the evaluated formulations were high that must to be corrected or substituted with other healthier shortenings, although there were not significant differences between trans fatty acids of the samples. Regard to oxidative instability, oleic, linoleic, and linolenic acid contents were the main effective factors on oxidative instability of the evaluated samples. Suggestions for future work of this project include baking tests with a greater range of shortenings and shortenings substitute and the effect of the proposed formulations on the properties of baked products. Also, lowering the trans fatty acids of shortenings or a suitable substitute for them may be an important case study.

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