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Processo simplificado para produzir margarinas reduzida em ácidos graxos saturados usando organogéis de cera vegetal

Simplified process to produce margarines with reduced saturated fatty acids using vegetable wax organogels

Proceso simplificado para producir margarinas reducido en ácidos grasos saturados utilizando organogeles de cera vegetal

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Kamila Ferreira Chaves
ORCID: https://orcid.org/0000-0001-9865-9011
University of Campinas, Brazil
E-mail: chaves_kamila@yahoo.com.br
Júlio Cesar Barbosa Rocha
ORCID: https://orcid.org/0000-0003-3507-0220
University of Ceara, Brazil
E-mail: julio.rocha@ufc.br
Daniel Barrera Arellano
ORCID: https://orcid.org/0000-0002-8217-8392
University of Campinas, Brazil
E-mail: danbramex@gmail.com

Resumo

A necessidade de reduzir a quantidade de ácidos graxos saturados na dieta (AGS) fez da busca de substitutos para essas gorduras um campo muito importante para a pesquisa. Na busca por tais substituições, a tecnologia de organogel mostrou grande potencial. Este estudo teve como objetivo produzir margarinas SFA reduzidas usando a tecnologia de organogel para estruturar óleos vegetais. Foi realizado um processo em escala laboratorial (lote de 1kg), as margarinas foram produzidas utilizando 80% da fase lipídica (LP) e sua composição de ácidos graxos, capacidade de espalhamento, dureza e estabilidade térmica foram avaliadas e comparadas com amostras comerciais de margarinas na faixa de 70 a 82% (LP). Um projeto experimental foi utilizado para obter um produto semelhante ao produto comercial. Utilizando a análise das superfícies de resposta, foi possível observar que a espalhabilidade medida variou de 0,44 a 11,12 kg.s para as margarinas testadas e de 2,46 a 3,63 kg.s para as amostras comerciais,

respectivamente. 0,35 a 7,37 kg para a consistência (1,89 - 2,78 kg para amostras comerciais) e 1,23 a 35,97 N para dureza (5,78 - 7,84 N para amostras comerciais), com base nesses resultados, uma formulação otimizada foi produzida com óleo de soja e alta óleo de girassol oleico para obter as mesmas propriedades que os produtos comerciais. Em conclusão, foi possível produzir margarinas, utilizando organogéis para a estruturação do óleo.

Palavras-chave: Margarina; Emulsão; Cera de candelilla; Ácidos graxos saturados.

Abstract

The need to reduce the amount of dietary saturated fatty acids (SFA), made the search for replacements for these fats a very important field for research. At the search for such replacements the organogel technology has shown great potential. This study had the objective of produce reduced SFA margarines using organogel technology to structure vegetable oils. A laboratory scale process (1kg batch) were performed the margarines were produced using 80% of lipid phase (LP) and their fatty acid composition, spreadability, hardness and thermal stability were evaluated and compared to commercial samples of margarines ranging from 70 to 82% (LP). A experimental design were used to achieve a product similar to the commercial product. Using the analysis of the response surfaces it was possible to observe that the measured spreadability ranged from 0.44 up to 11.12 kg.s for the tested margarines, and from 2.46 to 3.63 kg.s for the commercial samples respectively. 0.35 up to 7.37 kg from for the consistency (1.89 – 2.78 kg for commercial samples) and 1.23 up to 35.97 N for hardness (5.78 – 7.84 N for commercial samples), based on such results a optimized formulation were produced using soybean oil and high oleic sunflower oil to achieve the same properties as the commercial products. In conclusion, it was possible to produce margarines, using organogels for oil structuring.

Keywords: Margarine; Emulsion; Candelilla wax; Saturated fatty acids.

Resumen

La necesidad de reducir la cantidad de ácidos grasos saturados en la dieta (SFA) hizo que la búsqueda de reemplazos para estas grasas fuera un campo muy importante para la investigación. En la búsqueda de tales reemplazos, la tecnología de organogel ha demostrado un gran potencial. Este estudio tuvo el objetivo de producir margarinas SFA reducidas utilizando tecnología de organogel para estructurar aceites vegetales. Se realizó un proceso a escala de laboratorio (lote de 1 kg), las margarinas se produjeron utilizando el 80% de la fase lipídica (LP) y su composición de ácidos grasos, capacidad de extensión, dureza y estabilidad

térmica se evaluaron y compararon con muestras comerciales de margarinas que van del 70 al 82% (LP). Se utilizó un diseño experimental para lograr un producto similar al producto comercial. Utilizando el análisis de las superficies de respuesta, fue posible observar que la capacidad de esparcimiento medida varió de 0,44 a 11,12 kg.s para las margarinas analizadas, y de 2,46 a 3,63 kg.s para las muestras comerciales, respectivamente. 0.35 hasta 7.37 kg desde la consistencia (1.89 - 2.78 kg para muestras comerciales) y 1.23 hasta 35.97 N para dureza (5.78 - 7.84 N para muestras comerciales), basado en tales resultados, se produjo una formulación optimizada utilizando aceite de soja y alto aceite de girasol oleico para lograr las mismas propiedades que los productos comerciales. En conclusión, fue posible producir margarinas, utilizando organogeles para la estructuración del aceite.

Palabras clave: Margarina; Emulsión; Cera de candelilla; Ácidos grasos saturados.

1. Introdução

The consumption of fats with high contents of saturated fat acids (SFA) and trans fatty acids is related to the increase on the risk of cardiovascular diseases (Roche et al., 2007; Woodside & Kromhout, 2007) and also type II diabetes (Bergman & Ader, 2000), making them an important threat for human health. The search for reduction of saturated and the exclusion of trans fatty acids (Zevenbergen et al., 2009) from diets became a new challenge for food industry.

Currently, new raw materials and technologies and production processes are been studied as potential alternatives for margarines (Garcia et al., 2013; Hwang et al., 2013).

As an alternative for saturated triacylglycerol aiming to reduce saturated and eliminate trans fatty acids, the replacement of the lipid phase at food products for organogels is being studied (Rogers et al., 2009b). Organogels are by definition viscoelastic materials made of a structuring agent (or organogelator) and a continuous nonpolar phase. They are in a more specific definition; semisolid systems where an oil phase is immobilized by a tridimensional self sustaining network (Dassanayake et al., 2009; Rogers et al., 2009a).

Such materials are presented as a viable option, compared to the actually used technology (fractioning and interesterification), specially because uses liquid vegetable oils (with lower saturated fatty acid content) and does not change the chemical structure of the triacylglycerols (TAG), keeping its nutritional characteristics, saturated fatty acids amounts and natural stereospecificity of fatty acids (Sundram et al., 2007).

At the presente moment candelilla wax (CW) presents a huge potential as a

organogelator; this raw material can be used to structure vegetable oils, opening new possibilities for the production of low sat and trans free vegetable oil based food products (Morales-Rueda et al., 2009). The cited organogelator is the most studied material to produce food grade organogels

Although had already been considered as the “fat of the future” (Rogers et al., 2009b), just a few studies evaluated the use of organogel structured materials as a fat replacement. Ice-cream had been developed using ricebran wax organogels with good results (Zulim Botega et al., 2013), while margarines had been produced with some good results, using candelilla and sunflower wax organogels (Hwang et al., 2013) a more direct application was suggested, using the spreadable ability of organogels directly as a margarine and butter with good acceptance (Yilmaz & Öğütcü, 2015).

The margarine production is based on the formation of an emulsion and the maintenance of a β’ polymorphism that allows the material to stay spreadable, such characteristic is needed due to the expected physical behavior margarines (Chrysan, 2005) and is achieved due to high shear during crystallization followed by a crystal maturation period.

Considering the previously studied effect of shear at the organogel structure, that showed that shear could improve organogel structure (Alvarez-Mitre et al., 2012), the present study aimed to change the high shear margarine production process to achieve the optimal formation of the organogel network and produce a margarine with characteristics similar to commercial products optimizing saturated fatty acid reduction.

2. Metodologia

Materials

High oleic sunflower oil (HOSO), supplied by Cargill Agricola S.A., São Paulo, Brazil, soybean Oil (SO), from ADM Brazil, low trans interesterified fat (IF) TRI HW 2.5, supplied by Triangulo Alimentos, Itápolis, Brazil, candelilla wax from Multiceras, Mexico, monoacylglycerol (M) Grindsted Crystallizer 100 supplied by DuPont, Brazil.

To produce the margarines it was also used water, sodium chloride and defatted milk powder from Itambé, Brazil at the water phase. At the lipid phase it was also added GRINDOXTM 204 as antioxidant, beta carotene as colorant and butter aroma. The commercial samples named A, B and C were bought on a local market.

Methods

Fatty acid composition

Fatty acid composition were determined by gas liquid chromatography using esterification according to Hartmann & Lago (Hartmann & Lago, 1973) and the methyl esters were separated according to method AOCS Ce-2-66 (AOCS, 2004).

A gas chromatograph using a DB-23 Agilent capilar column (50% cyanopropyl - methylpolysiloxane, dimentions 60m, Ø int: 0,25mm, 0,25µm thick film).

The identification of fatty acids were performed by comparison of retention times of the peaks to its respective standards and the quantification by area percentage.

Spreadability and consistency

The margarine samples were evaluated at a texturometer (TA-XTi2 Stable Microsystems, England), using method specific for spreadability of spreads and creams from TA XTPlus Application STUDY (Spreadability/Softness of Margarine). A conical 90° probe (male), enters a conical container (female) forcing the material to flow spreading it between the two conical surfaces. A distance of 63 mm and a speed of 3 mm/s were used. As response were obtained the shear work as spreadability (kg.s) and softness as consistency (kg).

Hardness

The hardness of the margarine samples were performed using a texturometer (TA-XTi2, Stable Microsystems, England), according to Rocha et al., (2012). Samples of 30 ml were conditioned at 50 ml beakers and kept at controlled temperature oven for 24 h.

The compression extrusion test were performed using a 25 mm wide and 35 mm long cylindrical probe at 1,0 mm/s and penetration depth of 15 mm. The maximum force was considered as the result for hardness.

Stability by cyclization

The emulsion stability for all margarines were evaluated (water or oil exudation) using temperature cycles according to Garcia et al., (2013).

All samples were submitted to two temperature cycles; first were kept at 5°C for 48 h to complete crystallization, then kept at 35°C for 24 h and again kept at 5°C for 24 h, then the samples visually assessed for oil/water exudation. After the first cycle the samples were kept at 35°C for 48 h, then kept at 5°C for 72 h and assessed again for oil/water exudation.

Experimental procedure

Margarine processing

Lipid and water phases of margarines were prepared according to formulations shown on Table 1.

Table 1. Margarine formulation

Ingredient	Amount (%)
Water phase	
Water	16.20
Salt (Sodium chloride)	2.00
Defatted milk powder	1.80
Total	**20.00**
Lipid phase	
Interesterified fat (TRI HW LT 2.5)	0.00 – 24.00
High oleic sunflower oil	50.927 - 74.927
Candelilla wax	0.00 – 6.00
Monoacylglycerol (Grindsted Crystallizer 100)	0.00 – 4.00
β-carotene	0.003
Butter flavor	0.04
Antioxidant (Grindox ™ 204)	0.03
Total	**80.00**

Samples processing were performed at a bench scale batch (1kg) following 4 steps. First the molten lipid phase at 80°C were mixed to a water phase at 60°C at 300 rpm at a glass beaker, then the samples was cooled to 30°C under shear, using an electrical ice cream machine (Cuisinart ICE 21 with 1.5 L bowl) at 37 rpm and temperature at 5°C, the partially crystallized samples were then transferred to 100g plastic cups sealed with aluminum foil and aged at 5°C for 24 h before analysis.

Experimental design

A complete experimental design using three variables; monoacylglycerol, interesterified fat and candelilla wax concentrations (Box & Behnken, 1960) were made to optimize the formula of a trial margarine aiming to achieve a mechanical behavior similar to those observed for three commercial samples. The formulation of the 17 samples are shown at Table 2.

Table 2. Experimental design for the 17 margarine formulations*

Trials	Monoacylglycerol (%)	Interesterified fat (%)	Candelilla wax (%)
1	0.81	4.86	1.21
2	3.19	4.86	1.21
3	0.81	19.14	1.21
4	3.19	19.14	1.21
5	0.81	4.86	4.79
6	3.19	4.86	4.79
7	0.81	19.14	4.79
8	3.19	19.14	4.79
9	0.00	12.00	3.00
10	4.00	12.00	3.00
11	2.00	0.00	3.00
12	2.00	24.00	3.00
13	2.00	12.00	0.00
14	2.00	12.00	6.00
15	2.00	12.00	3.00
16	2.00	12.00	3.00

17	2.00	12.00	3.00

*x_1, monoacylglycerol (%), x_2, interesterified fat (%) e x_3 candelilla wax (%).

Comparison with commercial margarines

An optimized formulation based on the mechanical properties of the commercial samples and the response surfaces were produced using soybean oil (SO) and also high oleic sunflower oil (HOSO), such samples were then tested and the results compared again with the commercial samples to verify if the expected behavior where indeed achieved.

Statistical analysis

The data obtained from the experimental design were evaluated using Statistica 8.0 software (Statisoft, USA), to calculate the regression coefficient, probability (p-value) and analysis of variance (ANOVA) using significant level of 5%. To the present study a minimum R^2 was established as 0.80 to assure the validity of the mathematical model prediction and allow the elaboration of the response surfaces. Using the same software a comparison among the commercial samples and the tested margarines were made using a Tukey test at 5% of significance.

Results and Discussion

Raw materials composition

Fatty acid compositions for all raw materials are presented at Table 3, high oleic sunflower oil (HOSO) and soybean oil (SO) presented an amount of oleic acid (C18:1) of 82 and 27%; linoleic acid (C18:2) presented 10 and 51% respectively, these results are in accordance with the Codex Stan 210 (Codex, 2001). The result also shows that such materials are mainly composed of unsaturated fatty acids and the amount of trans fatty acids for soybean oil was similar for those found by Sanibal et. al. (Sanibal & Mancini-Filho, 2004) and as expected for a deodorized oil (Kemeny et al., 2001).

Table 3. Fatty acid composition of all raw materials*

Fatty acids (%m/m)	**SO**	**HOSO**	**IF**	**MAG**

C6:0	Caproic	-	-	0.09 ± 0.02	-
C8:0	Caprilic	-	-	0.40 ± 0.01	-
C10:0	Capric	-	-	0.38 ± 0.01	-
C12:0	Lauric	-	-	4.86 ± 0.08	0.21 ± 0.02
C14:0	Miristic	0.08 ± 0.00	0.05 ± 0.01	2.19 ± 0.01	0.11 ± 0.01
C16:0	Palmitic	10.83 ± 0.02	4.05 ± 0.01	35.01 ± 0.05	4.24 ± 0.20
C16:1	Pamitoleic	0.10 ± 0.01	0.11 ± 0.00	0.10 ± 0.00	-
C18:0	Estearic	3.17 ± 0.02	2.58 ± 0.11	11.61 ± 0.04	51.94 ± 0.37
C18:1t	Elaidic	-	-	1.14 ± 0.11	-
C18:1	Oleic	26.64 ± 0.04	81.17 ± 0.06	22.94 ± 0.05	0.15 ± 0.06
C18:2t	Linolelaidic	0.16 ± 0.00	0.03 ± 0.04	0.27 ± 0.01	-
C18:2	Linoleic	51.45 ± 0.04	9.93 ± 0.10	18.42 ± 0.01	-
C18:3t	Linolenelaidic	0.41 ± 0.00	-	0.42 ± 0.02	-
C18:3	Linolenic	5.73 ± 0.02	0.24 ± 0.03	1.11 ± 0.00	-
C20:0	Araquidic	0.33 ± 0.00	0.26 ± 0.00	0.38 ± 0.00	4.18 ± 0.05
C20:1	Gadoleic	0.30 ± 0.00	0.29 ± 0.00	0.16 ± 0.00	0.10 ± 0.00
C22:0	Behenic	0.45 ± 0.00	0.79± 0.00	0.21 ± 0.00	38.34 ± 0.57
C24:0	Lignoceric	0.16 ± 0.00	0.36 ± 0.00	0.12 ± 0.00	0.60 ± 0.00

Saturated	15.14 ± 0.02	8.17 ± 0.09	55.41 ± 0.04	99.75 ± 0.53
Unsaturated	84.29 ± 0.02	91.80 ± 0.13	42.76 ± 0.04	0.25 ± 0.06
Trans	0.57 ± 0.00	0.03 ± 0.04	1.83 ± 0.13	0.00 ± 0.00

* soybean oil (SO), high oleic sunflower oil (HOSO), interesterified fat (IF) and monoacylglycerol (MAG). Average of three replicates.

Although HOSO presented the lowest amount of saturated fatty acid, SO was considered as a viable option to be considered during formulation due to raw material availability and cost and as expected the monoacylglycerol (MAG) and interesterified fat (IF) presented the higher amounts of saturated fatty acids, but they were used at smaller quantities ranging from 0 to 4% for the MAG and 0 to 24% for the IF.

According to the fatty acid composition it is possible to observe that the interesterified fat is palm based, due to the high amounts of palmitic acid as observed by Garcia et. al. (2013) to a commercial fat used to produce zero trans margarine.

Margarine characterization

Fatty acid composition of commercial margarines

The lipid content of all samples were around 80% (as described on the labels), they presented very similar fatty acid composition and similar amounts of saturated fatty acids ranging from 20.52 to 23.93% and trans fatty acids of 0.74 up to 1.19%. The main fatty acids were the same for all samples, making it possible to say that all samples are based at the same lipid source.

Experimental design margarines

At Table 4 the results for mechanical properties of trial margarines and saturated fatty acid reduction are presented, the calculated value for saturated fatty acid reduction was made considering the average amount of saturated fatty acid for all commercial samples and the amount measured for each of the trial samples.

Table 4. Mechanical properties of trial margarines

Trial	Real levels			Spreadability (kg.s)	Consistency (kg)	Hardness (N)	Saturated Fatty Acid Reduction
	MAG (%)	IF (%)	CW (%)				
1	0.81	4.86	1.21	0.88 ± 0.03	0.56 ± 0.01	2.38 ± 0.23	54.10
2	3.19	4.86	1.21	0.43 ± 0.04	0.35 ± 0.02	1.23 ± 0.10	44.75
3	0.81	19.14	1.21	2.52 ± 0.19	1.48 ± 0.06	13.42 ± 1.08	25.18
4	3.19	19.14	1.21	6.50 ± 0.17	4.46 ± 0.13	19.25 ± 1.23	15.83
5	0.81	4.86	4.79	1.98 ± 0.07	1.45 ± 0.04	6.28 ± 0.21	39.99
6	3.19	4.86	4.79	3.92 ± 0.39	2.77 ± 0.29	8.48 ± 0.34	30.65
7	0.81	19.14	4.79	7.37 ± 0.32	4.92 ± 0.19	20.81 ± 2.34	11.07
8	3.19	19.14	4.79	11.12 ± 0.85	7.37 ± 0.58	35.97 ± 0.89	1.73
9	0.00	12.00	3.00	2.00 ± 0.25	1.51 ± 0.11	8.48 ± 0.84	35.77
10	4.00	12.00	3.00	3.59 ± 0.26	2.67 ± 0.08	10.44 ± 1.07	20.06
11	2.00	0.00	3.00	1.16 ± 0.02	0.99 ± 0.01	3.33 ± 0.43	52.22
12	2.00	24.00	3.00	6.24 ± 0.34	3.79 ± 0.12	20.72 ± 0.45	3.61
13	2.00	12.00	0.00	1.58 ± 0.03	1.25 ± 0.04	5.91 ± 0.84	39.73

14	2.00	12.00	6.00	6.76 ± 0.60	4.78 ± 0.25	19.92 ± 2.79	16.1
15	2.00	12.00	3.00	4.64 ± 0.07	2.96 ± 0.08	15.78 ± 1.77	27.91
16	2.00	12.00	3.00	5.74 ± 0.70	3.71 ± 0.02	10.21 ± 0.64	27.91
17	2.00	12.00	3.00	3.64 ± 0.74	2.66 ± 0.55	8.61 ± 0.97	27.91

* monoacylglycerol (MAG), interesterified fat (IF) and candelilla wax (CW). Average of four replicates.

The raw materials that caused higher changes of the spreadability, consistency and hardness were, the ones with higher amounts of saturated fatty acids (IF, candelilla wax and MAG), evaluation of the obtained mathematical model for spreadability, as presented at Equation 1, allows to found similar results to those measured for the commercial margarines (from 2.46 to 3.63 kg.s) at the concentration ranging from 6 to 9% (w/w) of interesterified fat, intermediate levels of candelilla wax (2.2 – 3.3%) and monoacylglycerol (2.2 – 2.6%).

For consistency and hardness the results were similar to those observed for spreadability with the amount of IF ranging from 6 to 9% and the intermediate levels of CLW and MAG, the mathematical model, presented at Equation 2 and 3, allow to achieve a value between 1.89 and 2.78 kg for consistency and 5.78 and 7.84 N for hardness. The observation of the physical characteristics indicate that the increase of IF and CLW affected positively the response, while the MAG also increased spreadability and consistency, but the effect was less pronounced and it not presented any influence on hardness probably due to the smaller amounts used for this ingredient during the experiment.

Calligaris et al. (2013), showed that the structuring of palm oil and sunflower oil was possible due to the self assembly properties of the saturated monoacylglycerols at the organogels and hydrogels samples forming a hydrophobic or hydrophilic network. It was also observed that the firmness of breads made with the palm oil organogels and hydrogels were higher than the ones formed using sunflower oil due to the presence of the saturated fatty acids which were at their crystalline form.

Using the experimental design it was possible to confirm that lower amounts of IF, CLW and MAG resulted as expected in higher saturated fatty acid reduction, once all of them presented considerable amounts of saturated fatty acids at their composition, although a high saturated fatty acid reduction is desirable, the margarines that presented higher values for these parameters (trials 1 and 11), presented mechanicals properties that were not similar with the achieved for commercial samples.

The margarines that presented mechanical properties similar to commercial samples presented a saturated fatty acid reduction of 35 – 37%. The reduction was calculated using the fatty composition of each raw material (Manzocco et al., 2012). The stability at 5°C for all margarines was adequate, without any oil/water exudation, except for the trial 13 of the experimental design, this sample used no CLW and also presented low stability at both 35°C temperature cycles, such result confirms that the ingredient plays an important role on the stability of the tested formulations (Hernandez & Baker, 1991). The importance of CLW at the stability of the tested emulsions can also be attested comparing the stability of the trial that

used no interesterified fat and kept 2% of monoacylfglycerol (similar to trial 13) but 3% of CLW as was stable at the tested conditions. The formation of a tridimensional network (Dassanayake et al., 2009; Morales-Rueda et al., 2009; Rocha et al., 2013), should be the responsible for the better stability due to the immobilization of the liquid oil.

As comparison the use of an elevated amount of fat (15%) and the use of glycerol monooleate as emulsifier was needed to achieve a structure for ice cream using rice bran wax organogels that was resistant to ice cream melting (Zulim Botega et al., 2013), so the use of an amount of saturated fatty acids on the organogels formula might be needed to get the desired structure for several food applications and should be considered.

Comparison of test margarines and commercial samples

Using the experimental design a formulation was calculated using Equation 1 for spreadability, 2 for consistency and 3 for hardness aiming to achieve mechanical properties similar to the commercial samples using 2.21% of monoacylglycerol, 6.14% of interesterified fat and 3.32% of candelilla wax, the remaining 88.33% of the lipid phase was soybean or high oleic sunflower oil.

Spreadability=4.12+0.87x1+2.11x2+1.67x3 R^2=0.8334 Equation 1
Consistency=2.8+0.62x1+1.3x2+1.14x3 R^2=0.8293 Equation 2
Hardness=12.42+7.34x2+4.3x3 R^2=0.7910 Equation 3

The obtained product had a calculated fatty acid reduction of 17.3% using SO and 36.6% with HOSO compared with the commercial samples. The designed margarines presented better emulsion stability at the evaluated temperature cycles, oil exudation were higher on all commercial samples after temperature cycles, the same behavior was reported at literature (Garcia et al., 2013).

Recent research using waxy organogels to produce margarines showed that sunflower wax was very effective as organogelator for margarine and that ricebran wax did not achieved the desired consistency even though it forms a relatively hard organogel, candelilla wax did not present stability after the emulsion phase according to Hwang et al. (2013).

The success of the present study in developing a stable margarine using soybean oil and CLW, with mechanical properties similar to commercial products should be explained due to the fact of the simplified technological process that were used, considering the process, the main difference comparing with the conventional margarine was the use of a high shear

during cooling up to the temperature of the start of the crystallization, such process increased the mechanical resistance as previously reported (Alvarez-Mitre et al., 2012) due to a better organization of the crystalline structure.

At the present study the same effect was observed using the simplified process where the high shear was used only when the temperatures where above the crystallization temperature for CLW organogels as observed at the literature (Rocha et al., 2013; Toro-Vazquez et al., 2007), the posterior static crystallization was responsible for crystal growth and therefore related to major stability of the emulsions when compared with the tested conditions used presented at literature (Hwang et al., 2013).

At Table 5 the results for spreadability, consistency and hardness for the selected formulations using SO and HOSO and commercial samples are presented and it is possible to observe that the sample produced with HOSO presented lower spreadability compared with commercial sample “B” and that there was no difference between the other samples, all samples were in fact very similar for this parameter, for consistency the commercial sample “B” presented a higher value, that was statistically different from the margarines obtained with candelilla wax, but the commercial samples “A” and “C”, presented no difference, but on the other side a lower consistency may well be a desirable sensorial attribute (Garcia et al., 2013). The results for hardness did not differ at 5% for all samples, being possible to say that all samples presented equivalent hardness.

Table 5. Mechanical properties of formulated margarines and commercial (A, B and C)

Sample*	**Spreadability (kg.s)****	**Consistency (kg)****	**Hardness(N)****
Margarine HOSO	2.12 ± 0.35 ^{b}	1.63 ± 0.24 ^{b}	7.10 ± 1.59 ^{a}
Margarine SO	2.41 ± 0.74 ^{ab}	1.81 ± 0.53 ^{b}	5.76 ± 1.38 ^{a}
Margarine A	2.46 ± 0.22 ^{ab}	1.89 ± 0.22 ^{ab}	6.44 ± 0.53 ^{a}
Margarine B	3.63 ± 0.48 ^{a}	2.78 ± 0.35 ^{a}	7.84 ± 0.40 ^{a}
Margarine C	3.34 ± 0.36 ^{ab}	2.39 ± 0.25 ^{ab}	5.78 ± 0.45 ^{a}

* high oleic sunflower oil (HOSO), soybean oil (SO)

** Same letter at the same column mean there is no statistical difference at 5% of significance

Conclusion

The modified process using reduced shear at crystallization allowed to achieve 17.3% reduction of saturated fatty acid for the formulation using soybean oil and 36.6% for high oleic sunflower oil and using smaller amounts needed of candelilla wax, interesterified fat and monoacylglycerol. The obtained products presented a better stability to temperature cycles compared with the commercial products, also it was possible to produce a optimized formula for such product. Candelilla wax amounts showed an important role on the product structure, what was expected once the amount of wax is usually related to harder organogels and more stable mixtures, and also the use of sunflower or soybean did not show any relevant difference for mechanical properties while it almost doubles the saturated fatty acid reduction.

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Porcentagem de contribuição de cada autor no manuscrito

Kamila Ferreira Chaves – 40%

Júlio Cesar Barbosa Rocha – 30%

Daniel Barrera Arellano – 30%