Properties of sugar-snap cookies as influenced by lauric-based shortenings

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ABSTRACT

The objective of this work was to assess the effect of different lauric-based shortenings with varying solid fat content (SFC) on sugar-snap cookie dough properties and cookie quality. Shortenings were produced by blending high oleic sunflower oil, palm kernel oil and palm stearin in different ratios, obtaining shortenings with different SFCs. It was observed that the SFC of the shortening largely influences the rheological properties of the cookie dough. At small deformations, fat crystals add elasticity to the dough; while at large deformations, fat-structure is disrupted, and it does not contribute to dough hardness. Fats with intermediate SFCs decrease dough resistance due to an enhanced shortening ability. Nevertheless, this effect is only obtained when shortening is homogeneously distributed in the dough. The SFC of the shortening influences dough and cookie structure by preventing gluten polymerization which was observed by a decrease in cookie break strength. A prerequisite for this effect is that shortening is finely dispersed in the dough. Good quality cookies were obtained using lauric-based shortenings, and best results were obtained with SFC between 20 and 25%. Higher SFC (around 45–50%) led to the production of unacceptable sugar-snap cookies.

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1. Introduction

Cookies are bakery products characterized by high sugar and fat contents and low in moisture. Sugar-snap cookies are obtained from a dough which mainly consists of wheat flour, sugar and fat. Wheat flour is the major ingredient but the quantities of fat and sugar solution present in the system create a plastic and cohesive dough with minimal formation of gluten network and thus a lack of elasticity. In this type of products, there is no continuous protein matrix, as moisture content is rather low (Manley, 2000a), and sugar and fat contents are elevated. Sugar delivers sweetness and influences the structural and textural properties of cookies. It plays a leading role in cookie spread, since during baking, the undissolved sugar progressively dissolves resulting in higher quantities of solvent phase, and, as a consequence, in higher spread rates (Hoseney, 1994; Pareyt et al., 2009). Moreover, it has an influence on cookie hardness, crispness, color, and volume. Fat is the

principle ingredient responsible for tenderness and overall texture of the final product (O'Brien, 2009a). It also influences the rheological properties of cookie dough (Jissy and Leelavathi, 2007) and contributes to cookie spread and to general product appearance, it enhances aeration for leavening and makes the cookies more easily breakable (Maache-Rezzoug et al., 1998). Several publications have shown that dough fat level has a huge influence on cookie quality. It has been found that decreasing fat level increases cookie breaking strength (Pareyt et al., 2010) and decreases air volume fraction (Baltsavias et al., 1999a). In cookie making it is generally accepted that, at a given fat content in the formulation, fat functionality is mainly based on its solid fat content (SFC). SFC is defined as the ratio of solid to total fat (Ghotra et al., 2002), and is a function of temperature, i.e. SFC is the solid fat present in fat system at a given temperature. While the liquid phase is necessary for air incorporation, fat crystals have a structural role and retain air at the end of mixing and during early baking stages. When liquid oil is used in a dough system, it gets dispersed on mixing throughout the dough in the form of small droplets which are far less effective in their shortening and aerating actions than are plastic fat films (Pyler, 1988). On the other hand, shortenings that are rather firm will form lumps when incorporated into the dough. SFC has an important relationship with the performance of the product at the

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temperature of cookie preparation. It is usually considered that at least 15–20% of fat should be in a solid state (Manley, 2000a) in order to obtain good quality cookies. Higher SFC shortenings do not have enough oil volume for adequate aeration, and lower SFC shortenings do not have the ability to hold the air until mixing is complete. The presence of some solid fat during mixing is thought to be essential and the use of liquid oil is reported to cause adverse changes in the handling characteristics of the dough (Jissy and Leelavathi, 2007). Although the role of SFC is of great importance during cookie making, to the best of our knowledge, scarce literature has been published on the effect of varying SFC values on cookie quality and cookie dough properties.

Consumer's awareness of health issues is turning the demand toward products with healthier profiles. Fat is one of the most important ingredients used in cookie manufacture, being the third largest component after flour and sugar, and is the most important contributor to the caloric value of cookies. High fat intake has been associated with cardiovascular disease, among other pathologies (Watkins et al., 2005). It has been reported that lauric acid decreases the total/HDL cholesterol ratio, due to a larger increase in HDL cholesterol (Mensink et al., 2003). Mensink et al. (2003) argued that even though consumption of saturated fatty acids should not be promoted, lauric acid-rich palm kernel oil and coconut oil, in terms of the effect on total/HDL cholesterol ratio, are still a better alternative for the food industry than partially hydrogenated oil in products that require solid fats for texture. Thus, the objective of the present work was to assess the effect of different lauric-based shortenings with varying solid fat contents on sugar-snap cookie quality and cookie dough properties.

2. Materials and methods

2.1. Shortening production

2.1.1. Fat blend formulation
Fat blends were prepared from high oleic sunflower oil (HOSO – Oleon, Belgium), palm kernel oil (PKO – Loders Croklaan, the Netherlands) and hard palm stearin (PS – Loders Croklaan, the Netherlands). Five formulations with different SFCs were prepared, namely BH12H10 (12.5% PS, 87.5% HOSO), BH50H10 (11.0% PS, 42.5% PKO, 46.5% HOSO), BH60H10 (10.5% PS, 53.8% PKO, 35.7% HOSO), BH70H10 (10% PS, 65.1% PKO, 24.9 HOSO) and BH93H10 (8.7% PS, 91.3% PKO). The blends were formulated based on grouping of the triacylglycerol (TAG) according to their melting point (mp). The TAGs in the fat blend were divided into four groups, more specifically chilled (C) (mp < 5 °C), room (R) (5 °C < mp < 25 °C), body (B) (25 °C < mp < 45 °C) and heated (H) (45 °C < mp) (O'Brien, 2009b). Each formulation of the fat blends was calculated and coded with B and H referring to the amount of TAGs from those melting groups (i.e., body and heated). For example, formulation BH60H10 consisted of 60% TAGs which is a combination of B/H groups (10% TAGs from H group and 50% of B TAGs). The rest of 40% of TAGs came from a combination of C/R groups. The amount of hard fraction in the fat blend would determine its SFC profile. Thus, changing the ratio of TAGs from different melting groups resulted in blends with different SFCs. However the H group was set at 10% for all of the fat blends since both the lower values could affect the texture (becoming soft) and the higher values might give undesired sensorial properties (waxiness and graininess) to the produced shortening.

2.1.2. Fat blend preparation
The blends were prepared by melting the combined oils/fats at 90 °C for 15 min and then stirred for several minutes to obtain homogeneity.

2.1.3. Plasticization procedure
Shortening was produced on a laboratory scale following a method described by Danthine et al. (2005) with some adjustments. Initially, 500 g fat blend was melted at 80 °C for 10 min to erase crystal memory. A pre-cooling stage was then introduced at 50 °C for 15 min before the blend was crystallized under shear at 20 °C and 125 rpm for 45 min. This procedure was performed in a 1 L jacketed glass reactor connected to a water-bath (Lauda, Germany). Then, the resulting slurry was transferred to a freezer at −20 °C for 45 min to complete the crystallization. The shortening was stored in a thermostatic cabinet at 15 °C until the time of usage.

2.2. Shortening analyses

2.2.1. HPLC
Separation of TAG components, including positional isomers, was achieved by high-performance liquid chromatography (HPLC). HPLC was performed using a Varian 9010 ternary pumping system (Varian Inc., UK) and a Gilson 231 autosampler (Anachem, UK). HPLC peak detection was achieved with a Polymer Labs 2100 light scattering detector (Varian Polymer Labs, Varian Inc.). TAG separation was made with solvents A (dichloromethane, 30%) and B (acetonitrile, 70%). A solvent gradient was programmed as follows: 31 min 1:1 A:B; 2 min 70:30 A:B, and 6 min 30:70 A:B. The solvent flow was set at 0.72 mL/min and the column was maintained at 25 °C. All chemicals and reagents were of HPLC grade. HPLC analysis was performed in duplicate.

2.2.2. GC
Fatty acid methyl esters (FAME) were produced by dissolving 70 mg of melted sample in 9 mL hexane and reacting with 1 mL 2 N KOH/methanol reagent. The mixture was shaken for 30 s at room temperature and then allowed to settle. Approximately 1.5 mL of the hexane layer was carefully decanted into a GC vial. High-resolution FAME GC was carried out on an Interscience Thermofocus gas chromatograph with an RTX-2330 column (cyanopropylpolysiloxane, 60 m length, 0.25 mm internal diameter, 0.2 mm layer thickness). Hydrogen was used as carrier gas. One mL of sample solution was injected via a split/splitless injector (split ratio 20:1) using an autosampler. The oven temperature was programmed starting from 50 °C for 8 min, from 50 to 182 °C at 5 °C/min, holding at 182 °C for 20 min, from 182 to 200 °C at 5 °C/min and holding at 200 °C for 5 min. Detection was via FID set to 250 °C. All chemicals and reagents were of HPLC grade. GC analysis was performed in duplicate.

2.2.3. SFC profile
Solid fat content was measured according to Calliauw et al. (2010) by using a Maran Ultra NMR (Oxford instruments, UK) equipped with R4 cryostat cooler (Grant Instruments, UK). NMR tubes (Bruker, Germany) were used for the direct SFC measurement. The samples were first melted at 70 °C and kept at this temperature for 15 min. Then the fats were cooled in a water-bath at 60 °C for 5 min before further cooling at 0 °C for 30 min. The SFC was determined from 5 °C until SFC was 0, at 5 °C intervals following 30 min incubations at each temperature. SFC analysis was performed in triplicate.

2.3. Dough evaluation

For cookie dough preparation, wheat flour, sucrose, salt and sodium bicarbonate were used. Commercial wheat flour was supplied by Paniflower (Ghent, Belgium [moisture content: 11.3%, protein content: 11.1%]), while salts and sucrose were purchased from the local market. Cookie dough was prepared according to

standard procedure (AACC 10-50.05, 2000) with slight modifications. Amounts of flour and water were adjusted for flour moisture. Before dough preparation, shortening was kept in a thermostatic cabinet overnight (20 °C), and room temperature was 20 °C during the whole cookie-making procedure. Shortening (64 g) was creamed with sugar (130 g), salt (2.1 g) and sodium bicarbonate (2.5 g) for 3 min at low-speed in a mixer (the bowl was scraped every minute). Then, 33 g of sucrose solution (5.9% w/v) and 22.8 g of deionized water were added, and mixing continued for 2 min at high speed. Finally, 218.2 g of wheat flour were added and mixed for 2 min at low-speed. The bowl was scraped every 30 s. At the end of mixing, dough was sticky so it was allowed to rest until a good machinability was achieved. After 10 min, dough could be easily handled.

2.3.1. Dough rheology

Frequency sweeps were performed on an AR2000 controlled-stress rheometer (TA Instruments, Brussels, Belgium) equipped with a cross-hatched parallel-plate geometry. After mixing, dough was allowed to rest for 15 min. Then, a small piece was taken from the inner part of the dough, loaded between the parallel plates (diameter: 40 mm), and compressed to obtain a gap of 3 mm. The excess edges of the sample were carefully trimmed, some water drops were placed around the sample, and a solvent trap was placed to measure with a constant ambient humidity. Before starting the assay, samples were rested for 5 min to allow residual stresses relaxation. The temperature of the dough was kept constant at 20 °C. The test was performed at 0.1–100 Hz, 0.05% strain (which was located within the LVR). Three independent dough batches were analyzed.

2.3.2. Dough consistency and hardness

Consistency of the cookie dough was measured using a Brabender Farinograph (Duisburg, Germany). After mixing, dough was allowed to rest for 10 min. Then, a dough piece (300 g) was transferred into the farinograph bowl, set at a constant temperature (20 °C) and mixed at 63 rpm for 20 min. Three independent dough batches were analyzed.

For dough hardness measurements, dough was rolled and cut (45 mm diameter, 20 mm thick). Three discs were evaluated with a texture analyser (TA-XT plus, Stable Microsystem, Surrey, UK) equipped with a 5 kg load cell and a cylindrical probe (75 mm diameter). The test speed was 1 mm/s, and dough was compressed until 50% deformation. The maximum force was recorded and evaluated as dough hardness. Three independent dough batches were analyzed.

2.3.3. Differential scanning calorimetry (DSC)

Dough (10–15 mg) was weighed in DSC aluminum pans, hermetically sealed and immediately ran in the calorimeter. The experiments were performed using a TA Q1000 DSC (TA Instruments, New Castle, Delaware) with a refrigerated cooling system. The DSC was calibrated with indium (TA Instruments, New Castle, Delaware), azobenzene (Sigma–Aldrich, Bornem, Belgium) and undecane (Acros Organics, Geel, Belgium). Nitrogen was used to purge the system. Samples were equilibrated at 20 °C for 5 min, and then heated at 10 °C/min to 120 °C. The enthalpic transitions were characterized by their onset temperature (To), peak temperature (Tp) and enthalpy (ΔH).

2.3.4. Confocal laser scanning microscopy (CLSM)

To visualize cookie dough microstructure, a double staining technique was used. The fat phase was stained by including Nile red (Sigma–Aldrich, Bornem, Belgium) (0.1%, fat basis) whereas Rhodamine B (Sigma–Aldrich, Bornem, Belgium) was used for staining the proteins (0.08%, flour wet basis). Both dyes were added during creaming. To reduce the sample size, the cookie dough was prepared in a small farinograph mixer (50 g). Visualization of the cookie dough microstructure was carried out with a Nikon A1r confocal microscope. A 10× microscopic objective was mostly used. Nile red was excited by a 488 nm argon-ion laser and its fluorescence detected through a 515/30 filter. Rhodamine B was excited by a 543 nm green helium-neon laser and detected through a 600LP filter. The laser intensity, gain, and offset were chosen in order to prevent oversaturation of the fluorescence signal. Kalman filtering was used to diminish the background noise on the picture. Imaging was performed in an air-conditioned room (18–20 °C). An overlay of the obtained images was performed by ImageJ freeware.

2.4. Cookie making and evaluation

Cookie making was carried out according to AACC method (AACC 10-50.05, 2000) with some modifications. The dough was allowed to rest for 10 min before sheeting and cutting (62 mm diameter, 5.5 mm thick). The cookie dough was then baked at 205 °C for 13 min. To evaluate the dough setting time during baking, a camera (Lumix DMC-F27, Panasonic) was positioned in front of the oven door, about 30 cm in front of the baking plate, and the baking process was filmed. Images every 30 s were analyzed to calculate the changes in cookie width using ImageJ software 1.41° (National Institutes of Health, USA). The width (W) and thickness (T) of cookies were measured with a Vernier caliper 1 h after baking, and spread ratio (W/T) was then calculated. Cookies were stored at room temperature (20 °C) in a sealed plastic bag for further measurements. Cookie surface color and hardness were measured 24 h after baking. Surface color was determined by the CIE$L^*a^*b^*$ colorimetric system (Minolta 508d, Osaka, Japan). Cookie hardness was evaluated with a texture analyzer (TA.XT plus, Stable Microsystems, Surrey, UK) equipped with a 30 kg load cell, using a three-point break (HDP/3PB) probe. Compression was applied until breaking at a speed of 1 mm/s. The maximum force required to break the cookie was considered as a hardness parameter.

2.5. Statistical analysis

A completely randomized design was used. The data obtained were statistically treated by analysis of variance (ANOVA) and the means were compared by the Fisher LSD test at a significance level of 0.05. A correlation test was made to evaluate the relationship between variables ($P < 0.05$). These tests were carried out with INFOSTAT statistical software (Argentina, 2011).

3. Results and discussion

3.1. Shortening composition

The composition of the shortenings is presented in Table 1. The dominant fatty acids (FA) were lauric (C12:0), myristic (C14:0), palmitic (C16:0) and oleic (C18:1). Their relative importance varied according to the shortening formulation. As expected, lauric acid (and also myristic acid) content increased as more PKO was added to the formulation. It is known that PKO is rich in lauric and, in a lower degree, in myristic acids (Gunstone, 2005). On the other hand, oleic and linoleic acids (C18:2) amounts decreased as oleic oil incorporation diminished, as HOSO consists of around 80% oleic and 10% linoleic acid (Grompone, 2005). Considering TAG composition, the trend was also as expected: the amount of lauric-based TAGs was increased as PKO content increased (from ≈40% in BH50H10 to ≈90% in BH93H10) and the opposite trend was

Table 1
Solid fat content, fatty acid and triacylglycerol composition (%) of the produced blends.

	BH12H10	BH50H10	BH60H10	BH70H10	BH93H10
Shortening SFC[a]	% (Measured at 20 °C)				
	10.2 ± 0.4a	15.3 ± 0.4b	20.1 ± 1.0c	26.5 ± 0.3d	47.1 ± 0.3e
Fatty acid[b]	Area (%)				
C8:0	–	1.971	2.439	2.855	3.823
C10:0	–	1.766	2.204	2.581	3.479
C12:0	–	23.781	29.576	34.858	46.723
C14:0	–	7.493	9.326	10.973	14.739
C16:0	15.382	14.506	14.427	14.265	13.924
C18:0	3.694	2.822	2.624	2.464	2.108
C18:1c	73.638	43.187	35.583	28.710	13.132
C18:2 n-6	6.900	4.474	3.820	3.293	2.070
UFA (%)	80.5	47.7	39.4	32.0	15.2
TAG[b]	Area (%)				
CCLa	–	3.09	3.95	5.17	7.79
CLaLa	–	3.45	4.59	6.30	10.06
LaLaLa	–	11.28	14.68	16.47	27.47
LaLaM	–	7.16	9.60	11.49	19.07
LaLaO	–	1.98	2.45	3.55	4.56
LaMM	–	3.31	4.71	6.59	10.54
LaMO	–	2.33	2.50	3.39	–
LaPM/LLO	–	1.33	1.83	2.83	3.83
LaOO	–	0.68	0.99	1.79	4.03
LaPP/OOL	3.55	4.33	4.04	4.70	2.55
OOO	70.11	42.62	33.31	21.67	0.58
POO	7.48	6.11	4.98	4.45	1.70
POP	1.15	1.42	1.38	1.80	1.43
PPP	16.27	10.93	11.00	9.78	6.38

UFA: unsaturated fatty acids. TAG: triacylglycerols.
C: capric acid, La: lauric acid, M: myristic acid, P: palmitic acid, O: oleic acid, L: linoleic acid.
[a] SFC: solid fat content. In this raw, values followed by different letters are significantly different ($P < 0.05$).
[b] Data are mean values of duplicates. Coefficient of variation was within 5%.

observed for oleic acid based TAGs (from 80% in BH12H10 to 10% in BH93H10).

3.2. Shortening SFC profile

As all the experiments in the present study were performed at a constant temperature of 20 °C, the SFC of different samples at this temperature are shown in Table 1. As PKO content increased and HOSO decreased, SFC of the shortenings increased.

Readers are referred to the Supplementary material section to find the SFC profile as a function of temperature of the blends.

For cookie making, it is necessary to maintain the proper balance between the solid and liquid phase in the shortening to have good dough machinability (Stauffer, 2005). It is recommended that there are at least 15–20% fat solids at the dough temperature (Manley, 2000a). According to this, reference values BH50H10 and BH60H10 should present the best properties for cookie making.

3.3. Dough properties

3.3.1. Small deformation rheology

In Table 2, the rheology results can be observed. All samples studied had some common characteristics. G' was higher than G'' in the whole frequency range studied (data not shown) which indicates a solid-elastic behavior of the doughs. The behavior of dough at small deformations is mainly governed by its microstructure. In these cookie doughs, microstructure has been altered by using shortenings of different SFC, i.e., different crystal quantity. It can be observed (Table 2) that both dynamic moduli (G' and G'')

Table 2
Effect of different shortenings on rheological properties (hardness, G', G'', G^* and tan δ) of cookie dough.[a]

Sample	Hardness (N)	Frequency sweep (1 Hz)			
		G' (kPa)	G'' (kPa)	G^* (kPa)	tan δ
BH12H10	23.5 ± 3.6c	47 ± 5a	27 ± 4a	55 ± 6a	0.577 ± 0.006d
BH50H10	20.9 ± 0.9b	70 ± 6a	37 ± 4a	79 ± 7a	0.524 ± 0.006c
BH60H10	16.3 ± 1.1a	178 ± 4b	75 ± 1b	193 ± 4b	0.422 ± 0.002b
BH70H10	22.2 ± 1.2b	319 ± 11c	132 ± 6d	346 ± 12c	0.414 ± 0.006b
BH93H10	79.1 ± 2.4d	838 ± 98d	317 ± 27e	896 ± 102d	0.392 ± 0.029a

[a] Values followed by different letters in the same column are significantly different ($P < 0.05$).

increased while the SFC of the shortening employed increased, and the higher the SFC the lower the tan δ, related to doughs with more solid-like viscoelastic behavior. This indicates that fat crystals may behave elastically during small oscillation tests. Our results are in agreement with Baltsavias et al. (1997) who found increasing G' as SFC increased, whereas a diminution in tan δ was also observed. These results are supported by findings that, during shortening preparation, when solid fat content decreases (oil content increases), the lower viscosity of the melt enhances molecular mobility resulting in the formation of larger crystals (Himavan et al., 2006). In the shortening, a fat network formed by larger crystals is softer, less elastic than a network built up from smaller crystals (Rye et al., 2005).

In this work, a linear and positive relationship was found between G' and SFC, more than 98% of G' variation being explained by SFC. Thus, at small deformation, the response of these systems seems to be primarily governed by crystals present in the fat phase.

3.3.2. Large deformation rheology

It has been established that, for cereal based products containing fats, during the mixing of the dough there is a competition for the flour surface between the aqueous phase and the fat. If water or sugar solution interacted with the flour protein, gluten would get developed, forming a cohesive and extensible network. But when fat coats the flour, this network is interrupted and the eating properties after baking are less hard or shorter (Manley, 2000b), which is the desired effect of adding shortening to these products.

Dough behavior was also studied under large deformation tests. Dough hardness results are shown in Table 2. The lowest hardness was observed for BH60H10, and then it increased for both, low and high SFC contents. This lowest value for BH60H10 may be related to
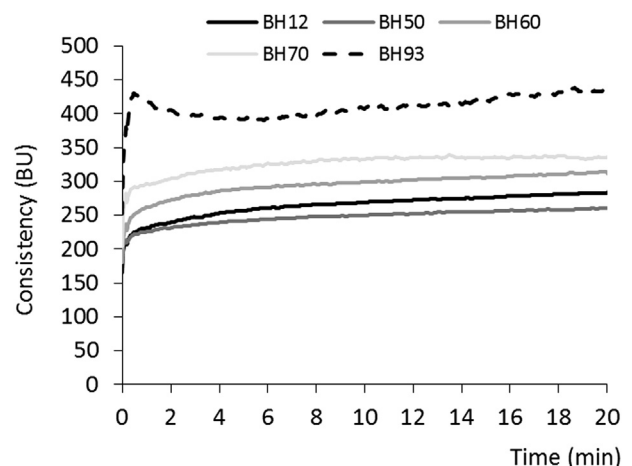
Fig. 1. Farinographic consistency for cookie doughs.

the fat showing enhanced shortening ability preventing gluten entanglements and crosslinks, which leads to a decrease in dough hardness. The more solid-like structure observed at small deformations − represented by fat crystal structure − is disrupted at large deformations, thus reducing dough hardness, except at higher amounts of fat crystals (BH93H10).

The effect of shortenings on cookie dough farinograph consistency is shown in Fig. 1. Dough consistency was the same for doughs with low SFC contents, i.e. BH12H10 and BH50H10 (10.2 and 15.3% solids, respectively), and it increased for higher SFC values, particularly for BH93H10 (41.7% SFC). If we look to the curves, we can see that consistency rose up during mixing in the farinograph. This increase in consistency can be explained in terms of gluten development during long mixing times (7 min in the mixer + 20 min in the farinograph). Jissy and Leelavathi (2007) observed a decrease in cookie dough consistency (also measured with a farinograph) as a function of mixing time when they used solid fats, but when they added sunflower oil to the dough, consistency increased over mixing, and they attributed this effect to gluten development. If we now take BH93H10 into consideration, consistency decreases during the first 10 min of farinographic mixing. This is probably due to the fact that the high amount of solid fat (∼50%) leads to inhomogeneous distribution during the mixing of the cookie dough. During mixing in the farinograph, fat further disperses showing a consistency decrease. This inhomogeneous dispersion of BH93H10 is not a desired behavior for

cookie making, so this shortening would not be suited for cookie production.

Although the rheological tests performed at large deformation and those at small deformation are different in nature, the behavior of the dough under both conditions was in good agreement, since significant correlations were found between G^* and hardness ($r = 0.93$; $P < 0.05$) (Table 2).

3.3.3. Dough microstructure

The structure of cookie dough has long been a subject of debate in the literature. In a cookie dough formulated with fat content around 15−20% (solids basis), Baltsavias et al. (1997, 1999b) conceive a dough structure as a bicontinuous system, with a fat and a non-fat phase, the non-fat phase being composed of a sucrose syrup binding flour/starch particles by means of liquid necks acting as bridges. In partial agreement, Chevallier et al. (2000) present it as a suspension of proteins, starch−proteins associations and isolated starch granules in a liquid continuous phase being based on an emulsion of lipids in a concentrated sugar solution, whereas Pareyt et al. (2010) consider that fat forms a dispersed (discontinuous) phase in the dough, which itself contains a sugar-water syrup phase, while they point to the importance of gluten network development during the first stages of baking on dough and cookie property structure. From Fig. 2, the distribution can be observed of fat (red) and proteins (green) in the cookie dough systems. In samples with lower SFC values (BH12H10 and BH50H10), fat (mainly present as
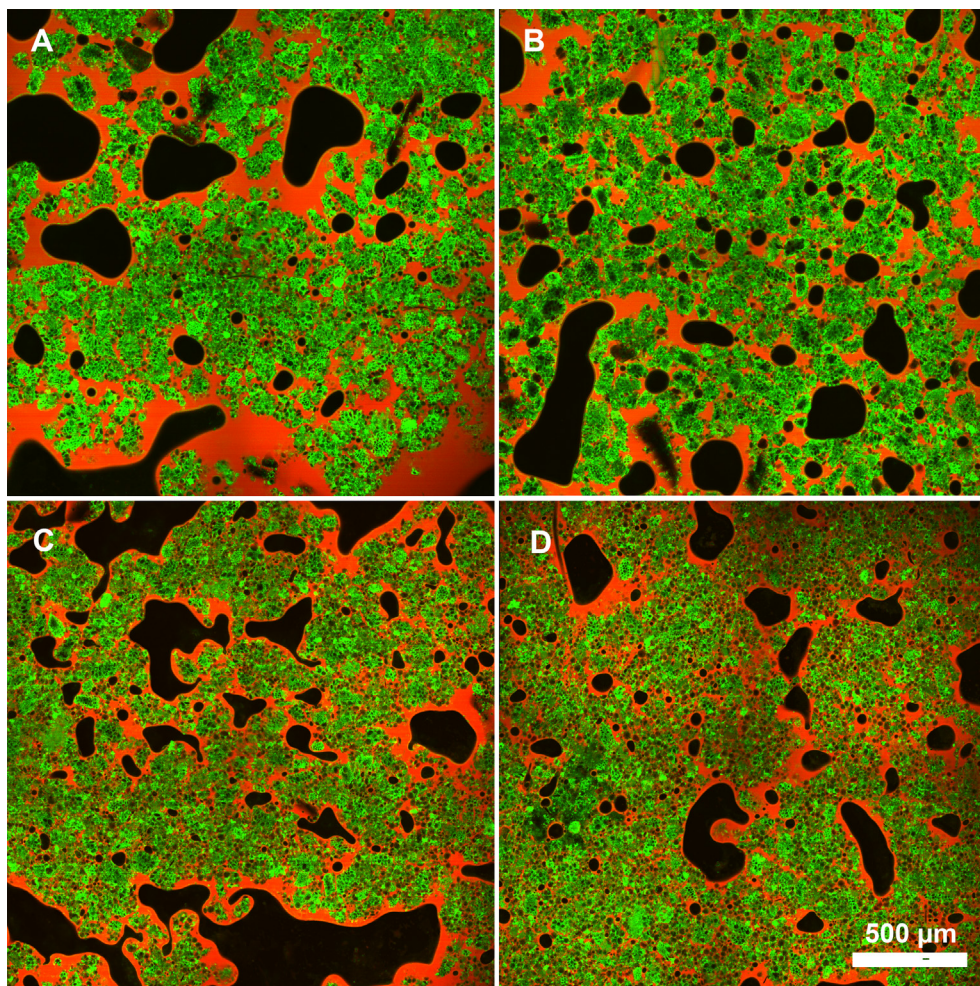

Fig. 2. Cookie dough microstructure visualized by CSLM. Fat phase: red; flour proteins: green. A = BH12H10; B = BH50H10; C = BH60H10; D = BH70H10. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
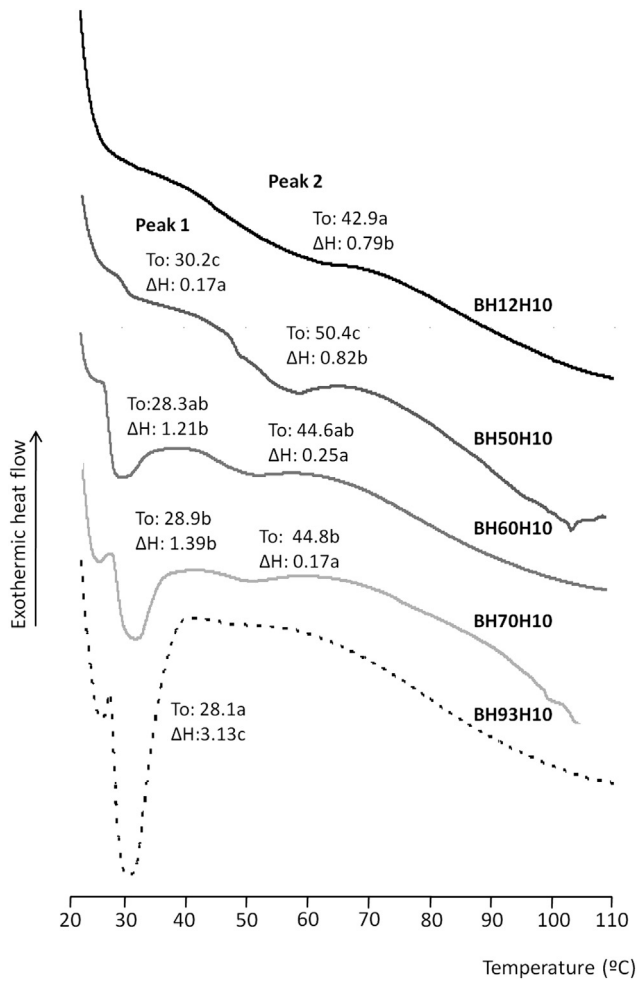
Fig. 3. DSC curves for analyzed cookie doughs. To: onset temperature of endothermic transitions, ΔH: enthalpy of endothermic transition. Values of the same parameter (To and ΔH) in the same peak followed by different letters are statistically different ($P < 0.05$).

liquid oil) seems to be dispersed in a separate phase, but when SFC increases, it distributes more finely throughout the dough system (BH60H10, BH70H10). This further supports the idea that fats with 20—25% of solids show a more pronounced shortening effect in cookie dough (as seen for dough hardness results).

3.3.4. Differential scanning calorimetry

When analyzing DSC thermograms (Fig. 3), two distinct peaks can be observed: the first at around 30 °C (Peak 1), and the second between 40 and 60 °C (Peak 2). Two exceptions to this trend were found. On the one hand, BH12H10 did not show Peak 1, associated with fat melting, since shortening was mainly in the liquid state at 20 °C. On the other hand, BH93H10 did not present Peak 2. Chevallier et al. (2000) reported that, in sugar-snap cookies, starch

granules were intact and birefringent in the cookie surface, while some of the granules were damaged in the center of the cookie; some granules lost their birefringence and others were slightly swollen. This partial loss of starch structure may appear here as Peak 2. It can also be observed that the enthalpy of this transition decreased as the SFC of the shortening increased (Fig. 3). During the creaming stage, a water-sucrose/oil emulsion could be formed. Fameau et al. (2012) have shown that salts of myristic, palmitic and stearic acids are capable of forming a stable o/w emulsion at room temperature. Thus, the emulsion capacity of the shortenings would increase as SFC is higher, given the higher content of myristic acid. This emulsion formation leads to lower water availability to interact with starch thus explaining the lower ΔH of peak 2 as SFC increases. The exception of this trend is BH93H10 due to it inhomogeneous distribution in the dough, which would decrease emulsion ability of the fat phase.

3.4. Cookie properties

For sugar-snap cookies, low thickness and a high spread, as well as a soft, easy to break texture are desired quality parameters for the final product. The cookie quality parameters are shown in Table 3. Cookie width decreased as SFC increased ($R^2 = 0.74$), whereas cookie thickness did not show a linear relationship with SFC. During baking, dough spreads as a result of sucrose dissolution and fat melting, until the structure is finally set due to an increase in dough viscosity, the phenomenon underlying this viscosity increase being protein aggregation (Doescher et al., 1987). In this work, and in agreement with Pareyt et al. (2009), no significant differences were found in dough setting time during baking (3 min), supporting the idea that different types of fats used may have an influence on dough spreading without affecting the time at which the structure is set. On the other hand, it was found that low SFCs were related to higher cookie thickness, which could be explained by the fact that doughs with lower consistencies expand more easily due to gas production during baking. In contrast, BH93H10 also showed high thickness, but in this case it was associated with the lower spreading of these cookies during baking. The spread ratio values found in this work are in good agreement with values reported by other authors (Goldstein and Seetharaman, 2011; Jissy and Leelavathi, 2007).

Table 3 shows hardness for the obtained cookies. A significant decrease of cookie break strength, even corrected for thickness, for samples BH60H10 and BH70H10 can be observed. This hardness decrease shows that fat SFC influences (prevents) gluten polymerization during dough mixing, since the shortenings with higher SFC are more finely dispersed among the flour and sugar particles (see CLSM pictures). Pareyt et al. (2010) have shown that, once fat is melted during baking, gluten entanglements occur more easily to form a continuous matrix due to lower physical hindrance. These gluten entanglements lead to harder cookies. As the SFC of the shortening increases, it takes longer to melt during baking. Once it is melted, gluten proteins can interact and set the final structure of cookies (after 3 min). So, one would expect that the lower SFC

Table 3
Effect of studied shortenings on the quality characteristics of cookies.[a]

Sample	Width (W, mm)	Thickness (T, mm)	Spread ratio	Hardness/T (N/mm)	L^*	a^*	b^*
BH12H10	73.0 ± 1.3cd	9.84 ± 0.21c	7.43 ± 0.19b	5.98 ± 0.34c	67.9 ± 0.8a	6.9 ± 0.0a	25.5 ± 0.5c
BH50H10	72.4 ± 1.8bc	9.62 ± 0.29b	7.53 ± 0.29b	6.18 ± 0.24c	67.8 ± 0.7a	7.5 ± 0.5a	25.8 ± 0.3c
BH60H10	73.4 ± 0.9d	9.28 ± 0.19a	7.91 ± 0.21c	3.71 ± 0.07b	69.9 ± 0.8b	7.2 ± 0.4a	25.4 ± 0.6c
BH70H10	72.3 ± 0.7b	9.27 ± 0.23a	7.80 ± 0.18c	2.46 ± 0.24a	70.5 ± 0.9b	6.8 ± 0.6a	23.5 ± 1.2b
BH93H10	71.1 ± 0.8a	10.03 ± 0.26d	7.09 ± 0.22a	7.15 ± 0.37d	70.5 ± 0.9b	6.5 ± 0.6a	21.8 ± 0.9a

[a] Values followed by different letters in the same column are significantly different ($P < 0.05$).

shortenings would melt faster during baking, thus facilitating more gluten interactions resulting in cookies with higher break strength.

Our results show that gluten polymerization is prevented by higher SFC (and thus cookie hardness is decreased) but a necessary requirement is that the shortening is dispersed homogenously throughout the dough which, again, was not the case for BH93H10. Also, enough solid fat is necessary, since this effect was only seen from 15% SFC and higher. It is worthy of note that cookie quality is not explained by dough rheology, since much of cookie characteristics are determined during baking. Considering cookie surface color, it can be observed in Table 3 that L^* was higher for doughs made with high SFC shortenings. The lower the L^* value the darker the surface of the cookie. In baked goods, surface darkness is related to Maillard and caramelization reactions (Martins et al., 2001). Maillard reactions include a group of complex reactions between a reducing sugar and an amino group from an aminoacid or a protein. Sugars may also lead to surface darkening when aminoacids are not present, through caramellization reactions. A negative correlation was found ($r = -0.99$, $P < 0.05$) between L^* and ΔH of Peak 2. This association is due to more sugars available for Maillard and caramellization, due to starch partial gelatinization (and some amylose leaching) during baking.

Although it has been stated in the literature that 15–20% of solid fat should be present in the shortening for cookie making (Manley, 2000a), we can conclude from our results that the best quality cookies were obtained using shortenings with 20–25% of SFC. It is noteworthy that the upper limit (higher SFC) seems to be more critical than the lowest limit (lower SFC). Although cookies made with BH12H10 and BH50H10 showed poorer quality (compared to BH60H10 and BH70H10), they still showed good technological parameters. On the contrary, BH93H10 resulted in narrow, thick and hard cookies, of overall unacceptable characteristics.

4. Conclusions

Sugar-snap cookies of good quality were obtained when using lauric-based shortenings, which present a healthier profile when compared to other saturated-fat based shortenings. It was shown that the shortening largely influences the small and large deformation properties of the cookie dough. At small deformation, fat crystals add elasticity to the dough. At large deformation, dough resistance decreased when intermediate SFCs were used, since an enhanced shortening ability was obtained, with a prerequisite of the shortening being homogeneously distributed in the dough. Moreover, fat structure is disrupted when applying large deformations and thus it does not contribute to the resistance of the dough, except at higher amounts of fat crystals (50%). The SFC of the shortening influences thermal properties of the dough and its structure by preventing gluten polymerization during baking which was observed by a decrease in cookie break strength. However, this effect is only obtained as the shortening is finely dispersed in the dough, as shown by CSLM.

Acknowledgments

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jcs.2013.07.005.

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