International Journal of Food Science + Technology

International Journal of Food Science and Technology 2021, **56**, 5071–5079

Original article

Can a structured emulsion (fat in water-fibre system) substitute saturated fat in cookies without hampering their quality?

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(Received 13 May 2021; Accepted in revised form 17 August 2021)

Summary Replacing fat and saturated fat in baked goods without affecting their quality characteristics is a challenging task. This study evaluated complete and partial substitution of saturated fats (butter and palm oil) by structured emulsions [SE, oil (sunflower) – in – water (fibre-water) emulsion] in cookies by investigating its impact on product quality. Nutritional labelling underlined a drastic reduction in saturated fatty acids [−35% (50% substitution) and −73% (100% substitution)] compared to their conventional counterparts (butter and palm oil). Partial substitution did not markedly affect physicochemical properties, while complete substitution resulted in thinner, harder and darker cookies compared to the controls. Particularly, cookies made with (50:50) structured emulsion – palm oil had the highest sensory scores, and they were perceived as soft, buttery and crunchy. Thus, the use of structured emulsion might be a valuable alternative to develop a potentially healthier product with acceptable sensory properties.

Keywords Cookie, fat-reduced, nutritional label, sensory evaluation, texture.

Introduction

In the last decades, the design of functional foods has been driven by the demand for nutritionally improved and convenient foods (Xu *et al*., 2020). For instance, cookies are very popular worldwide, and they are traditionally eaten for breakfast or as a snack. Nevertheless, these kinds of biscuits are high caloric due to their high sugar and fat contents. Nutritional properties of cookies can be enhanced throughout fortification using additional health-beneficial ingredients (e.g. protein isolates and fibre) (Jan *et al*., 2018; Pasqualone *et al*., 2020; Boukid, Rosell, & Castellari, 2021) or replacement of the basic ingredients (wheat flour, sugar and fat) by healthier alternatives such as protein-rich flours (e.g. pulses flours), low-calorie sweeteners and rich unsaturated fats (Aggarwal, Sabikhi, & Sathish Kumar, 2016; Thongram *et al*., 2016; Curti *et al*., 2018; Xu *et al*., 2020).

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Given the evidence sustaining the association of the overconsumption of saturated fat with the expansion of health problems (e.g. blood cholesterol, coronary heart diseases and diabetes), there is a need to develop reduced-fat products with desirable sensory profiles that match those of their full-fat counterparts (Aggarwal, Sabikhi, & Sathish Kumar, 2016; Chung *et al*., 2016). Although substituting saturated fats (e.g. butter) with unsaturated fats (e.g. sunflower oil) can improve the fatty acid profile, sensory and technological properties of cookies can be hindered (Škrbić & Cvejanov, 2011; Oh *et al*., 2017; Palla *et al*., 2017). Fat replacers may also be useful in helping to meet dietary guidelines by reducing fat intake (O'Connor & O'Brien, 2011). At present, two categories of substances can be used for fat replacement: fat mimetics or fat substitutes. Fat mimetics are molecules that can mimic the functional and sensory properties of fat, while fat substitutes are molecules that provide the physical and functional characteristics of conventional fat molecules, but do not provide calories (O'Connor & O'Brien, 2011; Conroy *et al*., 2018). A wide variety of ingredients can be employed for fat replacement including polydextrose, maltodextrin, pectin, fibre and guar gum (Mieszkowska & Marzec, 2016; Moriano, Cappa, & Alamprese, 2018; Paciulli *et al*., 2020). Because fat is closely associated with cookies softness, crumbliness, flavour, mouth-feel and taste to the product, a complete reduction of saturated fats can result in the loss of the desirable quality

doi:10.1111/ijfs.15301

parameters and reduction in sensory acceptability (Curti *et al.*, 2018; Tarancón, Salvador, & Sanz, 2013; Moriano, Cappa, & Alamprese, 2018).

In this light, a preliminary work was conducted to evaluate SE as a butter substitute focusing on changes in physicochemical properties (Curti *et al.*, 2018). As such, the use of SE (50% oil – in – 50% water-fibre emulsion) resulted in reducing saturated fat content in cookies. Furthermore, these cookies showed harder texture compared to those made with butter but still at sensorial level their texture and overall acceptability were appreciated (Curti *et al.*, 2018). Therefore, more studies were carried out to optimise the structured emulsion formulation and consequently to improve the nutritional, sensory and physicochemical properties of cookies. For this reason, a more complex formulation design was proposed by considering the effect of different fat (types, amounts and combinations) on dough properties (Boukid *et al.*, 2020). Results underlined that the use of SE for fat reduction induced relevant changes in dough properties (^{1}H molecular dynamics, rheological and physicochemical), where the partial substitution (50%) of conventional fats (butter and palm oil) by SE resulted in less sticky and moistened doughs compared to complete substitution (Boukid *et al.*, 2020). Thus, the present study aims to produce sugar-reduced cookies using different formulations of SE without hindering their quality. Therefore, changes in quality characteristics of cookies are monitored from a multi-driven perspective (nutritional labelling, physicochemical and sensory).

Materials and methods

Ingredients

Soft wheat flour (ash ≤ 0.55% (d.b.), proteins ≥ 9% (d.b.), moisture ≤ 14.5% (w.b.); flour strength (W) = 134 10^4 J; resistance extensibility ratio (P/L ratio) = 0.49) was kindly provided by Molino Agugiaro & Figna (Collecchio, PR, Italy). Sugar, fat, leavening agent (Lievito Bertolini, sodium bicarbonate and disodium diphosphate) and fresh egg yolks (2 large egg yolks in 500 g flour basis dough) were obtained from a local supermarket.

Structured emulsions (SE) were prepared as previously reported (Boukid *et al.*, 2020). Briefly, 8% of commercial fibre (HI-FIBREWF, HI-FOOD, Italy; fibre sources: pea, potato, potato alpha-dextrin, psyllium, flaxseed) was mixed (25 °C, 1 min, 280 g) with 55% sunflower oil in a bowl chopper (Polyfunctional Qbo 8-3, Roboqbo, Bologna, Italy), then water (37%) was added, and the blend was further mixed (4 min, 1120 g) until obtaining a uniform and shiny mass. SE were then stored at refrigerated temperature until use.

Cookies: formulation and baking process

Cookies formulations (Table 1) and dough preparation were reported in Boukid *et al.* (2020). Nine cookie formulations were developed. Three formulations contained only SE as fat source at three levels [SE1: 15% (g fat/ 100 g flour); SE2: 20% (g fat/ 100 g flour); SE3: 23% (g fat/ 100 g flour)]; 3 formulations were designed combining SE with other sources of fats [butter (SE + B), palm oil (SE + PO) and sunflower oil (SE + SO)] to reach same total fat and water contents in the dough (20 g fat/100 g flour and 20 g water/ 100 g flour, respectively). Furthermore, 3 control doughs (with 20 g fat/100 g flour and 20 g water/ 100 g flour) were produced: butter (B), palm oil (PO) and sunflower oil (SO). The SO dough was too soft and not workable and hence lecithin was added to enable oil-water interaction and to help maintaining a stable emulsion between these two unmixable liquids allowing for cookies production. This modification of the SO dough was necessary to have a control thus providing a complete comparison among samples, as previously explained (Boukid *et al.*, 2020).

Doughs (1.5 kg dough per each formulation) were laminated to a thickness of 4 mm through a dough sheeter (ECONOM, Rondo, Burgdorf, Schweiz), into 250 rectangular pieces (0.4 cm × 3 cm × 5 cm), and placed on five trays over baking paper. Cookies were baked (180 °C, 12 min) using an industrial forced convective oven (LOGIUDICE oven, Model: ROTATIVO FOX 15). After cooling (30 min at room temperature), cookies were stored in plastic bags (under 30% vacuum) at room temperature and analysed 24 h after

Table 1 Formulation of cookies (expressed in g)

Ingredients	SE1	SE2	SE3	B	PO	SO	SE + B	SE + PO	SE + SO
Flour	100	100	100	100	100	100	100	100	100
Sugar	40	40	40	40	40	40	40	40	40
Fresh eggs	20	20	20	20	20	20	20	20	20
Leavening agent	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Water	15	20	23	20	20	20	20	20	20
Structured emulsion	32	42	48	–	–	–	21	21	21
Anhydrous butter	–	–	–	20	–	–	10	–	–
Anhydrous palm oil (whole)	–	–	–	–	20	–	–	10	–
Sunflower oil	–	–	–	–	–	20	–	–	10
Lecithin	–	–	–	–	–	–	–	–	0.3

production. Two productions were made for each formulation.

Nutritional labelling of cookies

Nutritional labelling of cookies was computed following the European Institute of Oncology and USDA databases (USDA (US Department of Agriculture) 2017; European Institute of Oncology, 2015). Energy value was calculated using the energy factors provided in Regulation (EU) No 1169/2011; in which: carbohydrates (excluding polyols): 4 kcal g^{-1}; protein: 4 kcal g^{-1}; fat: 9 kcal g^{-1}; fibres: 2 kcal g^{-1}.

Physicochemical evaluation of cookies

Water activity

Water activity was measured at 25 °C with an Aqualab 4TE (Decagon Devices, Inc., Pullman, WA, USA). Water activity was measured in triplicate for each formulation.

Moisture content

Moisture content of cookies (three measurements for each formulation) was measured by drying ground sample (5 g) in a forced air oven (ISCO NSV 9035, ISCO, Milan, Italy) at 105 °C to constant weight.

Dimensional properties

Thickness, height and width of cookies were measured with a digital calliper and used to derive cookies' area and volume. For each cookie, three measurements were taken in three different locations (centre and both extremes). Ten determinations were carried out for each formulation.

Texture

Texture analysis was carried out with a cutting test using a TA.TXplus Texture Analyzer (490 N load cell, Stable Micro Systems) with an HDP/BS knife edge probe. Samples were placed centrally under the knife edge, and the force at breakage was taken as hardness (N), where the setting parameters were: pre-test speed 2 mm s^{-1}; test speed 2 mm s^{-1}; post-test speed 10 mm s^{-1}; distance 8 mm; trigger force 0.2 N. Fifteen cookies were evaluated for each formulation.

Colour

Shot breads' upper surfaces colour was determined using a colorimeter (CM 2600d, Minolta Co., Osaka, Japan) with the CIE $L^*a^*b^*$ system. L^* (L = 0 black; L = 100 white), a^* (a = greenness; $+a$ = redness), and b^* (b = blueness; $+b$ = yellowness) were measured 24 h after baking, in three selected positions (sides and centre) on the upper surface of five cookies for each formulation. Total colour difference of cookies, ΔE (eqn 1) was calculated using B as reference. *ix* cookies were evaluated for each formulation.

$$\Delta E = \sqrt{\left(L^*_{\text{sample}} - L^*_B\right)^2 + \left(a^*_{\text{sample}} - a^*_B\right)^2 + \left(b^*_{\text{sample}} - b^*_B\right)^2} \quad (1)$$

Sensory evaluation of cookies

Sensory analysis was performed with acceptability and CATA tests on 50 untrained judges for each session. Judges were consumers recruited among the University of Parma bachelor and master graduate students. Participants ranged in age from 20 to 28 and were 56% males and 44% females. Samples were coded using three-digit random number codes and were simultaneously presented in a plate to each judge in a balanced and randomised order. Judges were allowed to drink water in each sampling to cleanse their pallet.

Acceptability test

Judges were asked to evaluate the texture, flavour and overall acceptability of samples using a nine-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like, 8 = like very much and 9 = like extremely).

CATA test

Judges were asked to check all attributes 'that applied' to the sample and to their 'ideal' cookie (Valentin *et al.*, 2012; Varela & Ares, 2012; Alexi *et al.*, 2018). The terms included in the CATA question were selected based on the sensory attributes emerged by a previous focus group of students (n = 10). Attributes were: good, mediocre, excellent, crumbly, hard, soft, rubbery, crunchy, buttery, oily, dark, golden and pale (Curti *et al.*, 2018; Boukid *et al.*, 2020). The order of terms and samples were randomised on each ballot for each single judge. Data were collected as the times each attribute was selected for each sample and then converted to a percentage of the total judges' number.

Statistical analysis

Significant differences ($P \leq 0.05$) among cookies were verified by one-way ANOVA. Significant differences among the mean values were calculated using Duncan's test ($P \leq 0.05$). For CATA dataset, correspondence analysis was performed. All experimental data were statistically analysed using SPSS software (version 24.0; SPSS Inc., Chicago, IL, USA).

Results and discussion

Nutritional labelling of cookies

Nutritional labelling of cookies is reported in Table 2. When SE were used at 100% fat substitution (SE1, SE2 and SE3), increasing the fat content of SE increased the energy, fat and fibre contents, as expected. On the contrary, considering balanced formulations in terms of fat and water contents, no significant differences were found in the energy content or total fat content among conventional formulations and those including SE, as expected. Partial inclusion of SE induced an important reduction in saturated fatty acids, as compared with control formulations [35% (SE + PO) vs PO; 37% (SE + B) vs B]. Furthermore, saturated fatty acids were drastically reduced at 100% substitution when using SE [−76%: SE2 vs B; −70%: SE2 vs PO]. These results suggested the potential use of cookies with structured emulsions for children and teenagers for whom the biscuit category represents 4-5% energy intake (Sette *et al.*, 2011). No differences were found among SE2, SO and SE + SO in terms of saturated acid content as expected, since they contained the same source of fat (sunflower oil). Carbohydrates, sugar, protein and salt contents were in the same range for all formulations as expected, while fibre slightly increased [from B (25.9) to SE + B (26.4)] due to fibre deriving from the SE.

Physicochemical properties of cookies

As shown in Table 3, significant differences were observed among the studied formulations in terms of moisture content and water activity. Moisture content ranged from 4.99 to 7.60 g water/100 g product, while water activity (a_w) values ranged from 0.400 to 0.513, comparable with those obtained in previous study (Curti *et al.*, 2018) and in the expected range of commercial products (Xu *et al.*, 2020). The increase of amount of structured emulsion increased both moisture content and water activity for the larger water amount of the formulation. A similar trend was observed in the dough counterparts (Boukid *et al.*, 2020). At balanced water/fat amounts formulations, partial inclusion of structured emulsion induced a similar impact on moisture content and water activity. The addition of SE induced a reduction in both parameters from B to SE + B and an increase from SO to SE + SO and PO to SE + PO. Nevertheless, the changes are quite small and can be attributed to different behaviour during baking depending on the formulations. As well, this result highlighted that when structured emulsion was incorporated in the formulation, the moisture of cookies was not hindered.

Although specific volume of cookies was not influenced by fat substitution (complete and partial), dimensional properties (thickness, area and volume) varied significantly among the studied formulations (Table 3). Regarding thickness, increasing the fat content of SE increased the thickness of cookies, particularly those made with SE3 were similar to those made from PO. At 20 g fat/100 g flour, cookies from reduced-fat formulations were thinner than B or PO, where SE + PO and SE + SO had similar thickness and slightly higher that of SE + B. The results of surface areas were not influenced by fat/water content of the SE (SE1, SE2 and SE3), which had higher surface suggesting a higher spread than B and PO. Reduced-fat cookies (SE + B and SE + PO) had the highest areas, while SE + SO had the lowest values, probably for the presence of lecithin in this formulation. Such a result might be attributed to the fact that formulations with more unsaturated fats were characterised by a lower viscosity thereby a faster spread rate of the dough prior to structural setting in the baking phase (Boukid *et al.*, 2020). Moreover, a different thickness can be caused by the different capacities of the different formulations to hold gas during the cooking step. Overall, the addition of structured emulsion reduced the thickness and slightly increased the surface of the biscuits in concordance with previous findings (Zoulias, Oreopoulou, & Kounalaki, 2002; Chugh, Singh, & Kumbhar, 2013).

Complete fat substitution resulted in harder cookies (SE3 > SE2 > SE1) compared to conventional

Table 2 Nutritional labels of cookies

Item (100 g^{-1})	SE1	SE2	SE3	B	PO	SO	SE + PO	SE + B	SE + SO
Energy (Kcal)	424.6	453.4	476.3	449.4	461.1	454.4	456.2	457.8	453.5
Fat (g)	11.2	14.2	16.2	14.1	14.4	14.2	14.3	14.3	14.2
of which saturated (g)	1.6	1.9	2.2	7.8	6.5	1.9	4.2	4.9	1.9
Carbohydrates (g)	72.2	72.5	73.6	72.0	73.9	72.8	73.0	73.3	72.6
of which sugars (g)	26.0	26.1	26.5	25.9	26.6	26.2	26.3	26.4	26.1
Fibre (g)	0.9	1.2	1.4	0.0	0.0	0.0	0.6	0.6	0.6
Protein (g)	8.7	8.7	8.9	8.7	8.9	8.8	8.8	8.8	8.7
Salt (g)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table 3 Physicochemical properties of cookies

	Water activity (a_w)	Moisture content (%)	Specific volume (cm^3 g^{-1})	Thickness (mm)	Surface area (mm^2)	Volume (mm^3)	Hardness (N)	*a**	*b**	*L**	Δ*E**
SE1	0.400 ± 0.005f	5.03 ± 0.08e	2.03 ± 0.15a	11.20 ± 0.29d	15.90 ± 0.67abc	17.98 ± 0.77b	80.07 ± 1.80a	8.5 ± 0.4b	30.4 ± 0.5b	75.2 ± 0.5c	8.7 ± 0.5b
SE2	0.457 ± 0.006d	6.14 ± 0.16c	2.03 ± 0.26a	11.57 ± 0.35cd	15.88 ± 0.99abc	18.01 ± 0.69b	71.11 ± 2.77b	7.7 ± 0.7a	27.5 ± 1.1d	75.1 ± 0.6c	7.1 ± 0.83c
SE3	0.459 ± 0.001d	6.23 ± 0.13c	2.14 ± 0.25a	12.53 ± 0.39b	15.83 ± 1.11abc	17.91 ± 0.74b	63.16 ± 2.50c	8.5 ± 0.8c	28.8 ± 0.7cd	72.5 ± 1.7d	10.2 ± 1.19a
SE + B	0.430 ± 0.001e	5.80 ± 0.06d	2.03 ± 0.08a	11.31 ± 0.40d	16.69 ± 0.96a	18.97 ± 0.73a	47.81 ± 2.50e	6.3 ± 0.8c	27.6 ± 1.1d	77.5±1b	4.6 ± 0.63d
SE + PO	0.472 ± 0.009c	6.20 ± 0.25c	2.12 ± 0.10a	11.51 ± 0.47cd	16.46 ± 0.60ab	18.06 ± 0.57b	37.43 ± 2.10f	6.1 ± 0.6ab	29.1 ± 1.7bc	77.7 ± 1.3b	4.6 ± 0.76d
SE + SO	0.506 ± 0.006a	6.74 ± 0.21b	2.25 ± 0.17a	11.67 ± 0.37cd	15.17 ± 0.54c	17.41 ± 0.46b	58.60 ± 2.79d	7.8 ± 0.6d	32.9 ± 1.4a	74.4 ± 0.6c	10.7 ± 1.2a
B	0.513 ± 0.003a	7.60 ± 0.14a	2.22 ± 0.11a	13.29 ± 0.40a	15.36 ± 0.92c	17.75 ± 0.59b	41.06 ± 2.70f	4.9 ± 0.8c	25.2 ± 0.9e	81.1 ± 0.7a	–
PO	0.407 ± 0.005f	4.99 ± 0.10e	2.28 ± 0.20a	12.43 ± 0.66b	15.56 ± 0.73bc	17.74 ± 0.55b	46.26 ± 2.33e	6.3 ± 0.7d	27.9 ± 0.7cd	77.5 ± 1.1b	4.7 ± 0.61d
SO	0.488 ± 0.004b	6.37 ± 0.10c	2.11 ± 0.20a	11.81 ± 0.43c	15.79 ± 1.00abc	17.76 ± 0.50b	30.84 ± 2.01g	4.1 ± 0.7e	25.1 ± 1.7e	77.4 ± 1.3b	3.8 ± 0.76d

Different letters in the same column indicate significant differences among samples ($P \leq 0.05$).

formulations in concordance with previous works (Sudha *et al.*, 2007; Laguna *et al.*, 2014; Curti *et al.*, 2018). Such a result might be attributed to the fact that the fat is hidden inside the emulsion structure and cannot work as a lubricant as in the case of a 'free' fat. Consequently, the presence of free fat–hidden fat can induce a different way of interaction between proteins-water and fat-proteins and fat-air during the creaming stage (Sudha *et al.*, 2007; Pareyt & Delcour, 2008). Also, compared to conventional fats, increasing structured emulsions increased moisture content, which may favour flour hydration and possibly lead to a partial formation of gluten network resulting in harder biscuits (Laguna *et al.*, 2013). The added fibre can interact with flour particles and create junction zones, which will reduce the tendency for the water to exit the cavities thereby the biscuit will be harder and more compact (Laguna *et al.*, 2012). This can be supported by the small but significant increase in water content/activity in structured emulsions-based formulations (SE + SO and SE + PO). As such, 100% fat substitution increased hardness probably due to the low shortening effect of sunflower oil (Curti *et al.*, 2018). At balanced fats and water contents, SE + PO (~37 N) was significantly softer than PO (~46 N) manufactured with pure fat. However, partial substitution of butter slightly increased the hardness of cookies [from B (~41 N) to SE + B (~47 N)]. Notably, SE + PO and B had similar hardness, as well as SE + B and PO. Such behaviour was also observed in their relative doughs, where the partial substitution of B and PO resulted in moisturised and soft doughs (Boukid *et al.*, 2020).

Regarding colour attributes, 100% fat substitution resulted in the reduction of *L** values compared to the conventional cookie (B), where no significant difference was found between SE1 and SE2. Regarding balanced formulations (same water and fat contents), B was the brightest followed by PO, SO, SE + PO and SE + B. Regarding *a**, the inclusion (partial or complete) of SE and sunflower oil increased the redness, whereas B showed the lowest redness. As generally fat represents the continuous phase of cookie matrix covering flour and sugar particles, the reduced fat formulations could have favoured reducing sugar-proteins interactions for non-enzymatic browning in a higher extent than conventional cookies (Dapčević Hadnađev et al., 2015; Curti *et al.*, 2018). Consistently, previous studies reported an association of fat reduction with *L** reduction and *a** increase, also, considered as browning indicators (Dapčević Hadnađev et al., 2015; Curti *et al.*, 2018). Yellowness (*b**) was also influenced by fat substitution, where SE + SO had the highest value, while B and SO had the lowest values. Considering the overall colour (Δ*E*), cookies made with SE (SE1, SE2 and SE3) were considered very different from B. Partially substituted cookies (SE + B and SE

+ PO) were considered different from B similarly to PO (~4.7) and SO (~3.8); while SE + SO was considered very different ($\Delta E > 10$).

Sensory evaluation of cookies

Figure 1 summarised the cookies' acceptability data to determine the sensory characteristics responsible for changes in acceptability. The texture of PO and SE + PO were the most appreciated (with scores of about 7 corresponding to a 'like' judgement of the panel) followed by SE + B, whereas the most of remaining formulations received scores of about 5, corresponding to a 'neither like or dislike' judgement of the panel. Likewise, SE + PO had the most appreciated flavour receiving a score of about 7 ('like' judgement) followed by PO, SE + B, SO, SE1 and SE3; while SE + SO, B and SE2 were judged as 'neither liked or disliked'.

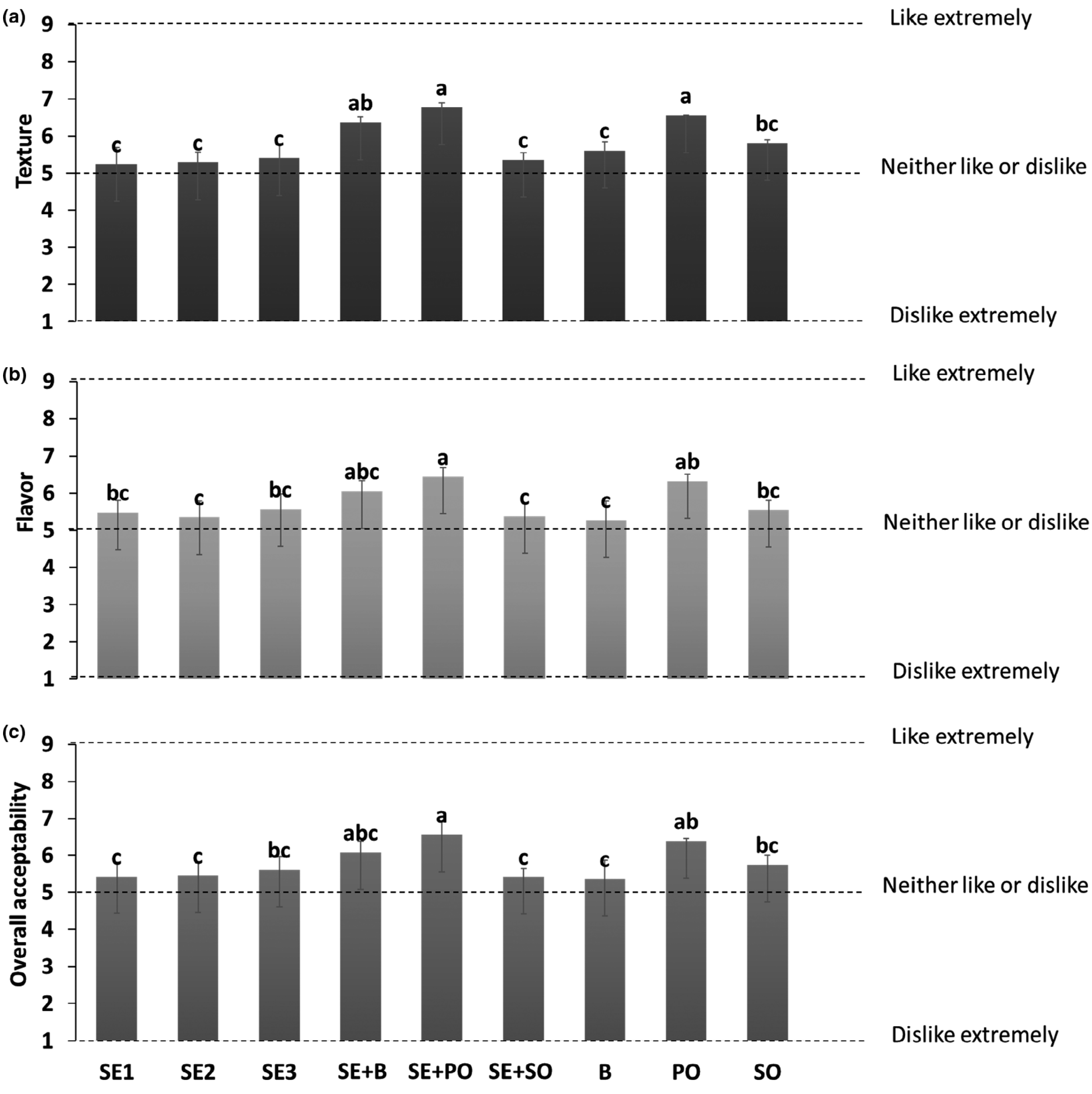

Figure 1 Sensory scores for (a) texture, (b) flavour and (c) overall acceptability of cookies made with different fats. Different letters indicate significant differences among samples ($P \leq 0.05$).

The overall acceptability revealed that cookies made with SE (SE1 and SE2) were perceived neither liked or disliked (scores around 5) similarly to SE + SO and B. The results are consistent with previous studies, where panellists did not associate the reduction of fat with a decrease in sensory properties (Biguzzi, Schlich, & Lange, 2014; Paula Tarancón *et al*., 2014). However, when different formulations of SE (using olive oil and sunflower oil) were compared to butter, butter-based were the most likeable cookies compared to those made with SE (Curti *et al*., 2018). An intermediate group was identified including SE + B, SO and SE3 with acceptability scores that ranged between 5 (neither like to dislike) to 6 (like slightly). SE + PO had the most liked scores (with scores of about 7) followed by PO confirming that partial reduction of saturated fat content did not hinder the product acceptability.

An interesting and surprising result was the low sensory performance of B, the cookie taken as reference, if compared with other samples. These results could be related to different factors. From the product point of view, nowadays consumers are very much used to commercial products that are mostly produced using palm oil and this could have moved the liking towards PO, rather than B. Otherwise, the recipes used in this study could be considered more 'artisanal' recipes than 'industrial' recipes, since generally industrial formulations include more than 10 ingredients, and our formulations were made with 6 ingredients. These simpler formulations than commercial ones could have partially changed the liking towards the reference sample (Biguzzi *et al*., 2014). In addition, from the methodologies point of view, the possibly specific sensory perception and food habits of participants due to the strict range of age could have affected the liking of cookies.

Overall, this result suggests that proper tailoring of the structured emulsion formulation may allow the achievement of good product acceptability (Curti *et al*., 2018).

For a better sensorial profiling of cookies, CATA questionnaire was carried out considering 13 attributes of the products to be described by assessors (n = 50, two sessions). To describe lipid mouthfeel, two terms 'oily' and 'buttery' (to avoid biased description) were suggested instead of a general term such as 'fatty' (so accessors can clearly describe what they perceive). As illustrated in Fig. 2, the first two components of correspondence analysis explained 82% of the total variability (Component 1: 51%; Component 2: 31%). The biplot of CATA enabled to distinguish 5 groups:

- B, SE + B and PO were perceived as pale cookies.
- SO was characterised by oily texture.
- SE2, SE3 and SE + SO were described with hard texture in concordance with the instrumental measurements of hardness.
- SE1 was characterised by mediocre, oily, rubbery and crumby. This formulation contained the lowest fat

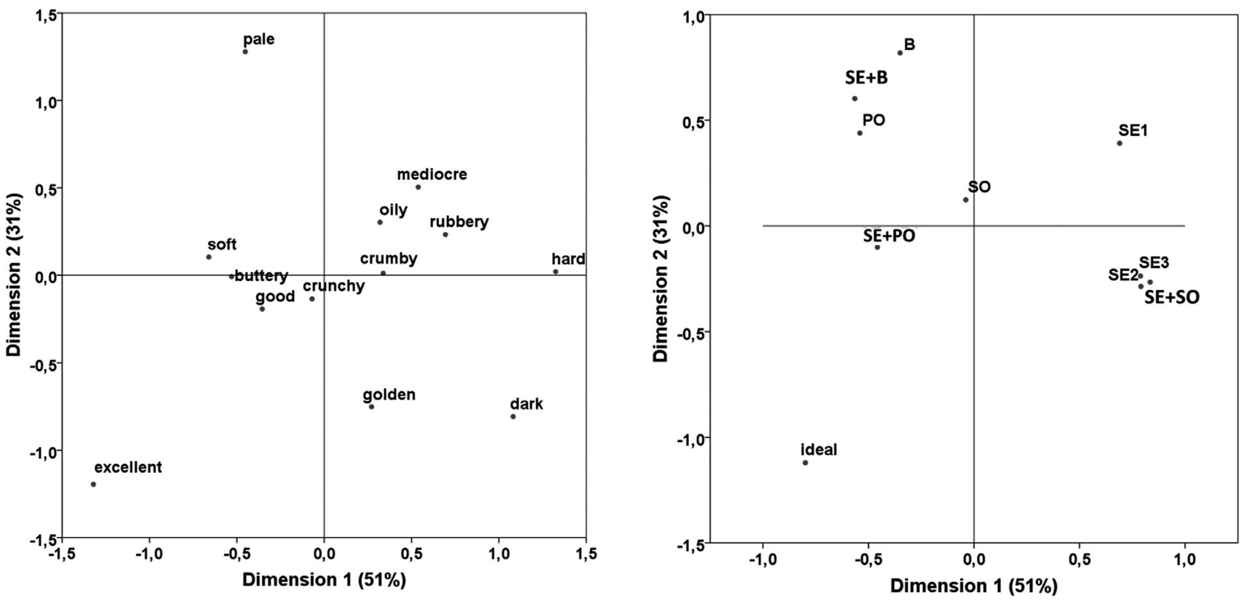

Figure 2 Sensory characteristics of cookies using CATA. SE: Cookies made with structured emulsions at different levels (SE1: 15%; SE2: 20%; SE3: 23%); B: cookies made with anhydrous butter; PO: cookies made with anhydrous butter palm oil; SO: cookies made with sunflower oil; SE + B: cookies made with combining SE2 and butter; SE + PO: cookies made with combining SE2 and palm oil; SE + SO: cookies made with combining SE2.

content (15%), and consequently it was perceived more compact than those with higher content fat.

- SE + PO was perceived soft, buttery, good and crunchy. This result is in concordance with the overall acceptability (received the highest rating for texture and flavour). Partial replacement of fat did not hinder the texture, in contrast they were described soft and crunchy. This result is in concordance with Biguzzi, Schlich, & Lange (2014). Softness is more about the mouthfeel of biscuit, but the breakage pattern is more related to the crunchiness by teeth and is usually accompanied by a low-pitched sound (Laguna *et al.*, 2013).
- Ideal was described as excellent and golden.

When comparing cookies formulations to the ideal product, no formulation directly corresponds to the ideal product. As a matter of fact, SE + PO was the closest, while B was not particularly liked. Thus, the use of SE is able to mask the fat reductions, at least to some extent (Biguzzi, Schlich, & Lange, 2014), and modulate the sensations experienced during the biscuit oral assessment (Laguna *et al.*, 2013).

Conclusion

Structured emulsions were assessed as a possible substitute of solid fat in cookies. To further optimise their performance, in this work different formulations were tested and modulated to completely or partially replace solid fat in cookies, taking into account saturated and unsaturated fats. Quality of cookies was assessed in terms of nutritional labelling, physicochemical and sensory properties. The results of nutritional labelling proven a drastic reduction (around −73%) of saturated fats, when conventional fats (butter or palm oil) were completely removed. Complete substitution of fat, however, hindered the physicochemical (particularly an increase in hardness and redness) and sensory quality of cookies. Instead, partial substitution of palm oil with SE had the highest rating of overall acceptability. Therefore, the use of SE as fat substitutes offers the advantage of producing healthier and more appreciated products than their conventional counterparts depending on the degree and type of fat replaced.

Conflict of interest

No potential conflict of interest was reported by the author(s).

Author contribution

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Ethical approval

Ethics approval was not required for this research.

Peer review

The peer review history for this article is available at https://publons.com/publon/10.1111/ijfs.15301.

Data availability statement

No data available.

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