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Fat replacement in shortbread cookies using an emulsion filled gel based on inulin and extra virgin olive oil

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ABSTRACT

The European Food Safety Agency recommends low intakes of saturated fatty acids. This study evaluated the replacement of 50% and 100% of butter in shortbread cookies with an emulsion filled gel (EFG) based on inulin and extra virgin olive oil (EVOO), and investigated its impact on product characteristics (volatile profile, fracture behaviour and crumb pore size, sensory properties). Cookies containing both 50% and 100% EFG had thinner pore walls than the control cookies, without EFG. The total substitution of butter with EFG gave products with higher number of small-sized pores and lower level of fracture stress, with poorer sensory properties than control cookies. The replacement of 50% of the butter fraction of shortbread with EFG based on inulin and EVOO did not substantially affect cookie microstructure, compared to control. Cookies with 50% butter replacement showed comparable fracture properties, and were well accepted by consumers, resulting a product with potentially healthier properties (19% less total fat, 39% less saturated fats) respect to control cookies.

1. Introduction

Fat mimetics or replacements in food products are highly desirable as dietetic alternatives for reducing calories, fat, and cholesterol intake (Haque & Ji, 2003). However, it is often difficult to preserve desirable sensory properties of the food product with regards to breaking strength, crumb texture, moisture content, and mouthfeel (Zahn, Pepke, & Rohm, 2010).

Shortbreads are biscuits characterized by being brittle due to their high quantities of fat (Manohar & Rao, 1999), containing high level of saturated fatty acids (SFA) (Caponio, Summo, Delcuratolo, & Pasqualone, 2006). Their recipe can vary widely: fat can range between 20 and 60% (as percentage of weight of flour), and sucrose can range between 25 and 55% (Baltsavias, Jurgens, & van Vliet, 1999).

Recently, the European Food Safety Agency recommended that intakes of SFA should be as low as possible, on the basis of the relationship between dietary SFA intake and increased blood cholesterol/low density lipoprotein (LDL) concentrations (European Food Safety Agency, 2010). Hence, the use of fat mimetics, shortenings, and emulsifiers with a healthier fatty acid profile is an alternative for developing new biscuits recipes.

Inulin is a polydisperse β(2–1) fructan. The presence of β(2–1) bond prevents it from being digested like a typical carbohydrate and is responsible for its reduced energetic value and dietary fibre behaviour (Niness, 1999). When thoroughly mixed with water or another aqueous solution, inulin forms a particle gel network resulting in a white creamy structure with a short spreadable nature, which can easily be incorporated into foods to replace fat (Paradiso et al., 2015).

The use of inulin as fat replacer in biscuits formulation was reported by several authors coming to conflicting results. Zoulias, Oreopoulou, and Tzia (2002) examined the effect of carbohydrate- or protein-based fat mimetics, used to replace up to 50% fat, on the textural properties of cookies. In particular, the addition of inulin as fat replacer resulted in more tender low-fat cookies. Devereux, Jones, Mccormack, and Hunter (2003) investigated on the consumer acceptability of low-fat foods containing inulin and oligofructose. The results indicated that inulin had a noticeable influence on the texture of baked goods, showing that it has not the ability to "shorten" gluten strands in baked flour products as fat does. Cookies containing less fat tend to have higher moisture

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content and to be less crisp and less appreciated by consumers (Drewnowski, 1997). Rodríguez-García, Laguna, Puig, Salvador, and Hernando (2013) tested five formulations with different shortening/inulin proportions. At higher fat replacement levels, flour was more available for hydration and gluten formation, leading to harder biscuits. The authors concluded that shortening may be partially replaced, up to 20%, by inulin.

The use of emulsion filled gels (EFG) offers a range of tools to engineer foods without compromising the organoleptic properties of the product (Sala, de Wijk, van de Velde, & van Aken, 2008). Our recent paper (Paradiso et al., 2015) was aimed to setting up the production of EFG based on inulin and extra virgin olive oil (EVOO). The aim of this work was to replace butter with an EFG based on inulin and EVOO in order to obtain shortbread cookies with a healthier fatty acid profile and with sensory properties close to those of full-fat ones.

2. Materials and methods

2.1. Raw materials

Commercially available refined soft wheat flour (type 00, according to Italian regulations, having particle size similar to that of US pastry flours), leavening agent (sodium bicarbonate and tartaric acid), butter, EVOO, fresh whole eggs and food grade sodium chloride were purchased from retailers. Inulin (Orafti® HPX, with degree of polymerization ≥ 5 accounting for not less than 99.5% of total, Beneo-Orafti SA, Oreye, Belgium) and soy lecithin were kindly provided by Eigenmann & Veronelli SpA (Milan, Italy). All reagents were purchased from Sigma Aldrich (Milan, Italy), unless otherwise stated.

2.2. Preparation of the EFG

The preparation of the EFG was made according to a previous paper (Paradiso et al., 2015). The amounts of the ingredients were selected to obtain a homogeneous EFG, with the appearance of a white-yellowish cream, and consistency similar to that of commercial spreadable cheeses (Paradiso et al., 2015). The formulation was: EVOO (37% w/w), inulin (19% w/w), soy lecithin (2% w/w), and water (42% w/w). Homogenization was performed by means of high power ultrasound using a 200 W transducer (Sonopuls HD 3200, Bandelin Electronic, Berlin, Germany) with 6 mm diameter tapered tip (KE 76, Bandelin Electronic, Berlin, Germany) for 5 min.

2.3. Preparation of shortbread cookies

Three shortbread cookie typologies were prepared by using the same quantity of all the ingredients and different butter:EFG proportions: 100:0 (EFG-0), 50:50 (EFG-50), and 0:100 (EFG-100) (Table 1). The dough, sheeted to a thickness of 5 mm and cut into rectangular shape (60 mm × 45 mm), was baked in an air circulation oven at 180 °C for 25 min. The trays were filled with all three types of cookies according to the Latin-square design (6 × 6) to minimize any effect of tray location. Two independent replicate baking experiments were carried out (12 cookies per type in each experiment). Cookies for the consumer test were prepared in further baking procedures.

Table 1
Cookies formulations (g).

		EFG-0	EFG-50	EFG-100
Flour		300	300	300
Butter[a]/EFG		130	130	130
of which	*Fat/oil*	*106.6*	*77.3*	*48.1*
	Water	*13.4*	*34*	*54.6*
	Inulin	–	*12.4*	*24.7*
	Soy lecithin	–	*1.3*	*2.6*
Sucrose		100	100	100
Egg		120	120	120
Leavening agent		8	8	8
Sodium chloride		2	2	2

[a] 82% fat content was considered for butter.

2.4. Chemical characterization of cookies

Moisture content of cookies was determined according to the AACC method 44-15A (AACC, 2000). Fat was extracted and determined by Soxhlet apparatus using diethyl ether as solvent. Fatty acid composition was determined according to Pasqualone, Paradiso, Summo, Caponio, and Gomes (2014).

2.5. Image analysis

Images of the shortbread cookies section (10-mm thick) were captured using a digital camera DCM-TZ8 (Panasonic, Newark, USA). A central field of view (FOV) (35 mm × 6 mm), capturing the majority of the area of each section, was evaluated for each image. Images were analysed by ImageJ software (National Institutes of Health, Bethesda, USA) using the Otsu's algorithm for setting the threshold. Crumb grain was characterized by enumerating the pores present in eight preselected dimensional classes (class 1 < 0.005 mm^2; 2: 0.005–0.010 mm^2; 3: 0.010–0.015 mm^2; 4: 0.015–0.020 mm^2; 5: 0.020–0.025 mm^2; 6: 0.0.25–0.030 mm^2; 7: 0.030–0.035 mm^2; 8 > 0.035 mm^2). The number of pores and the area occupied by each class (expressed as percentage of the total number of pores and of the total pore area, respectively) was evaluated.

The cookie images were also analysed by grey-level mathematical morphology. Crumb images were considered to contain grey level information from pixels, of which the darkest individuals belong to pore and the brightest belong to pore wall. It is possible to characterise crumb grain of cookies by applying successively two basic morphological operators (erosion or dilation) of increasing size and measuring at each step the sum of grey levels (erosion–dilation curves), as follows. Erosion and dilation, basic transformations in mathematical morphology (Devaux, Robert, Melcion, & Le Deschault de Monredon, 1997), were applied to the image through a structuring element of a given size (in pixel) and shape (usually squares or oriented lines). Twelve erosion and twelve dilation steps were applied using squared structuring elements, starting from 3 pixels × 3 pixels squares. Erosion modifies the grey level values by giving to each pixel the minimum value observed within the surrounding window defined by the structuring element. It consenquently causes a size reduction of bright objects and a decrease of the sum of the grey level in the image. Bright objects for which at least one dimension is smaller than the structuring element are removed. Dilation, on the opposite, applies to each pixel the maximum value observed within the structuring element, causing an increase of bright object size and, therefore, a reduction of dark objects. Progressive erosion and dilation steps based on structuring elements of increasing size cause bright and dark objects, respectively, progressively disappear. This allows to obtain erosion–dilation curves of the sum of grey level as a function of erosion and dilation steps. A complete granulometric texture characterisation is obtained by merging the curves assessed for erosion and dilation steps. The left part of the curves (dilation) represents grey-level variation caused by pore size, from the largest to the smallest size. The right part (erosion) represents grey level variations caused by pore walls thickness, from the smallest to the