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Effect of palm oil replacement with monoglyceride organogel and hydrogel on sweet bread properties

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ABSTRACT

The potentialities of monoglyceride (MG) organogel and hydrogel containing sunflower oil in replacing palm oil were studied in sweet breads. This substitution was addressed to reduce the total saturated fat content of the product. The effects of the palm oil substitution were determined by assessing bread specific volume, moisture, crumb grain, firmness, and proton density/mobility by magnetic resonance imaging (MRI).

Sweet bread prepared with hydrogel has quality characteristics comparable to that of control palm oil sample. This result was attributed to the capacity of MG crystallized lamellas to favor oil spreading over flour, replacing the typical functionality of triacylglycerol crystal networks. On the contrary, when oil was embedded in the organogel structure, less leavened and firmer bread with inhomogeneous lipid distribution was obtained. In this case, monoglycerides were probably engaged in oil networking and were less available to interact with other ingredients and exert their softening and anti-staling activities.

1. Introduction

In recent years much effort has been directed towards the development of foods with improved or novel functional properties by applying structural design principles (Betoret, Betoret, Vidal, & Fito, 2011; Co & Marangoni, 2012; McClements, Decker, Park, & Weiss, 2009). Biopolymers, such as lipids (e.g. mono- di- and tri-glycerides, surfactants, phospholipids), proteins (e.g. milk or egg proteins) and polysaccharides (e.g. starch) have been proposed as efficient structuring agents (Co & Marangoni, 2012; McClements et al., 2009; Simo, Mao, Tokle, Decker, & McClements, 2012). Among different possible applications, there has been a strong and timely focus on using novel structural approaches to obtain low fat and/or low saturated fat foods, designed to have similar sensory attributes and shelf-lives as conventional products. This is the consequence of the evidence that high intakes of saturated fatty acids have been associated with negative health implications, including adverse effects on cholesterol profiles as well as an increase in the incidence of heart disease, metabolic syndrome and Type II diabetes (Roche, 2005; Woodside & Kromhout, 2005). One of the greatest public health challenges of the 21st century is the achievement of the reduction of total fat and saturated/trans fat intake to improve wellbeing, reducing the health and economic burden of overweight, obesity and their clinical *sequelae* (Azaïs-Braesco et al., 2009). [Bakery products seem to be good candidates for fat/saturated fat reduction through food reformulation because of their high frequency of consumption.] Thus, an improvement of the nutritional feature and healthy properties of these products would have great impact on a large portion of population.

In this context, the interest on the structuring properties of saturated monoglycerides is growing due to their excellent capacity to self-assemble in both hydrophobic and hydrophilic domains (Goldstein, Marangoni, & Seetharaman, 2012). Once introduced in oils, these molecules are able to self-assemble into inverse bilayers leading to the formation of a continuous network preventing oil from flowing (Co & Marangoni, 2012; Da Pieve, Calligaris, Co, Nicoli, & Marangoni, 2010). These systems can be regarded as organogels that are self-standing, thermoreversible, anhydrous, viscoelastic materials structured by a three-dimensional supramolecular network of self-assembled molecules (organogelators) with limited solubility in an organic liquid (Co & Marangoni, 2012). Organogels have been indicated as the "fat of the future" and proposed as novel formulation strategy to reduce saturated/trans fat content of fatty foods (Rogers, Wright, & Marangoni, 2009). Similarly, when introduced in water under given physicochemical conditions, monoglycerides can organize themselves to obtain lamellar phases forming a gel network able to encapsulate large amounts of oil (Batte, Wright, Rush, Idziak, & Marangoni, 2007; Goldstein et al., 2012; Heertje, Roijers, & Hendrickx, 1998; Larsson, 2009; Marangoni et al., 2007; Sagalowicz, Leser, Watzke, & Michel, 2006).

Different attempts to use monoglyceride gels as structuring phase in low-fat or low-saturated fat products have been reported in literature (Goldstein & Seetharaman, 2011; Manzocco, Anese, Calligaris, Quarta, & Nicoli, 2012; Manzocco, Calligaris, Da Pieve, Marzona, & Nicoli, 2012). Data mainly focus on the applicability of monoglyceride hydrogels in bakery products. Results clearly demonstrate that these gels could affect the product macro-scale structure, reflecting complex

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interactions among ingredients. On the contrary, at our knowledge, no information is available on organogel performance in the same product category.

This study aims to replace palm oil in the formulation of sweet breads with monoglyceride organogels (OG) and hydrogels (HG) containing sunflower oil. The final aim was to reduce the total saturated fat content in the sweet bread of about 81% (w/w). To this aim samples containing i) palm oil; ii) sunflower oil; iii) palm oil OG and HG; iv) sunflower oil OG and HG were considered. Additional samples were prepared by adding the unstructured ingredients used to obtain OG to the basic formulation instead of the lipid matrix. The reformulation was made maintaining constant the total fat content (18.7% w/w) as well as the ratio among ingredients. In this study sweet bread was chosen as study-case representing leavened sweet bakery products. The effects of the incorporation of different lipid matrices were determined by assessing specific volume, moisture, water activity, crumb grain, firmness and proton density/mobility by magnetic resonance imaging (MRI). The latter was used to study the homogeneity of ingredient distribution in bread.

2. Materials and methods

2.1. Materials

Myverol™ saturated monoglyceride (MG) (fatty acid composition: 1.4% $C_{14:0}$, 59.8% $C_{16:0}$, 38.8% $C_{18:0}$; melting point 68.05 ± 0.5 °C) was kindly offered by Kerry Ingredients and Flavour (Bristol, United Kingdom). Palm oil (saturated fatty acid percentage 51.14% w/w) and sunflower oil (saturated fatty acid percentage 9.67% w/w) were kindly provided by Unigrà (Conselice, Italy). All other ingredients used to prepare sweet bread were purchased in a local market.

2.2. Sample preparation

2.2.1. Organogel

Sunflower oil and palm oil organogels (OG) were prepared as described by Da Pieve et al. (2010). Monoglycerides were added to the lipid matrix at a concentration of 5% (w/w). The mixtures were stirred with a magnetic road at 70 °C in a water bath. The samples were then cooled at 20 °C under static conditions. The organogels were examined and used after 24 h of storage at 20 °C.

2.2.2. Hydrogel

Sunflower oil and palm oil hydrogels (HG) were prepared according to Calligaris, Da Pieve, Arrighetti, and Barba (2010). Briefly, MG was mixed with a co-surfactant mixture of palmitic and stearic acid 1:1 (w/w) (Sigma Aldrich, Milano, Italy) in a ratio of 5:1 (w/w). The water phase was composed of 1 mM NaOH in deionized milli-ρ water to promote the partial neutralization of the co-surfactant mixture and obtain a properly swollen phase. The samples were prepared by mixing the water solution and the MG/co-surfactant/oil phase previously heated at 78 °C in a water bath and homogenizing by using a high speed homogenizer DI 25 (Ika-Werke, Staufen, Germany) at 59,000 ×*g* for 1 min. Finally, the mixture was cooled at 20 °C in a water bath and then stored at 4 °C for 24 h before usage. The concentration by weight of each constituent in the HG was as follows: monoglyceride/co-surfactant 2.7%, palm or sunflower oil 42.1%, water 55.2%.

2.2.3. Sweet bread

The basic formulation of sweet bread loaves consisted of 45.4% (w/w) flour, 23.1% (w/w) water, 18.7% (w/w) palm or sunflower oil, 7.1% (w/w) sugar, 3.9% (w/w) egg powder, 1% (w/w) yeast and 0.8% (w/w) salt. Loaves of approximately 500 g were obtained using a domestic bread making machine (OW200030, Moulinex, China), where mixing, leavening and baking were performed in situ. The ingredients were poured in the bread making machine basket having parallelepiped shape (length of 18.5 cm; width of 13.0 cm; height of 10.0 cm) in the following order: water, fat, premixed dry ingredients. The selected program included: 5 min kneading, 5 min resting, 20 min kneading, 65 min leavening, 1 min kneading, 52 min leavening, 45 min baking. At the end of baking, loaves were cooled at room temperature for 1 h before use. The basic formulations were modified substituting (w/w) palm oil and sunflower oil with their respective OG or HG. The substitution was made maintaining constant the ratio among ingredients of the basic formulation. In the case of HG containing formulations, water was added directly within the gel. In other words, the quantity of the gel added instead of palm oil allowed to include in the bread formulation the same quantity of water of the basic formulation. Additional samples were prepared by adding the unstructured ingredients used in OG containing samples to the basic formulation instead of the lipid matrix. Samples were prepared in triplicate.

2.2.4. Sample cutting and storage

Six slices of 20 mm thickness were cut from the central portion of each loaf, packed in high barrier film pouches and stored at 20 °C for up to 14 days.

2.3. Specific volume

Bread loaf specific volume (cm^3/g) was obtained by rapeseed displacement according to Approved Method 10-05 (AACC, 2000).

2.4. Moisture content

Moisture content was measured by using a gravimetric method (AOAC, 2000). Around 2 g of crumb sample was dried in a vacuum oven (1.32 kPa) at 75 °C until constant weight (circa 12 h).

2.5. Water activity

Crumb water activity was determined using a dew-point measurement system (Aqualab 4TEV, Decagon Devices, Inc. Pullman, WA, USA) at 25 ± 1 °C.

2.6. Crumb grain

Bread slice images were acquired by using an image acquisition cabinet (Immagini & Computer, Bareggio, Italy) equipped with a digital camera (EOS 550D, Canon, Milano, Italy). In particular, the digital camera was placed on an adjustable stand positioned 60 cm above a black cardboard base where the bread slice was placed. Light was provided by 4 100 W frosted photographic floodlights, in a position allowing minimum shadow and glare. Other camera settings were: shutter time 1/125 s, F-Number F/6.0, focal length 60 mm. Images were saved in *jpeg* format resulting in 3456 × 2304 pixels. Image-Pro® Plus (ver. 6.3, Media Cybernetics, Inc., Bethesda, MD, USA) was used to analyze crumb grain. Crumb area (10^6 pixels) was converted in gray scale (8 bit) and equalized by best fit tool. Pixels with luminosity in the 215–255 range were associated with crumb bubbles. Bubbles in each image were subdivided into three classes, depending on their

Table 1
Firmness of organogel (OG) and hydrogel (HG) containing palm oil or sunflower oil.

Oil type	Sample	Firmness (N)
Palm oil	OG	1.362 ± 0.004^a
	HG	0.082 ± 0.003^b
Sunflower oil	OG	0.068 ± 0.004^c
	HG	0.029 ± 0.002^d

a,b,c,d: means with different letters are significantly different ($p < 0.05$).