Food Hydrocolloids 27 (2012) 448–455

Contents lists available at SciVerse ScienceDirect

Food Hydrocolloids

journal homepage: www.elsevier.com/locate/foodhyd

Inhomogeneous distribution of fat enhances the perception of fat-related sensory attributes in gelled foods

Ana Carolina Mosca [a,b], João Almeida Rocha [a,c], Guido Sala [a,d], Fred van de Velde [a,e], Markus Stieger [a,b,*]

[a] TI Food & Nutrition, P.O. Box 557, 6700 AN Wageningen, The Netherlands
[b] Wageningen University and Research Centre, Agrotechnology & Food Sciences Group, P.O. Box 8129, 6700 EV Wageningen, The Netherlands
[c] Instituto Superior Tecnico, Universidade Tecnica de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
[d] Wageningen University and Research Centre, Food & Biobased Research, Food Technology Centre, P.O. Box 17, 6700 AA Wageningen, The Netherlands
[e] NIZO Food Research, P.O. Box 20, 6710 BA Ede, The Netherlands

A R T I C L E I N F O

Article history:
Received 20 July 2011
Accepted 8 November 2011

Keywords:
Fat reduction
Fat spatial distribution
Creaminess enhancement
Mouthfeel
Layered gels

A B S T R A C T

This study investigated the effect of the spatial distribution of fat on the perception of fat-related sensory attributes using a model system that consisted of layered agar/gelatin gels containing oil-in-water (O/W) emulsion droplets dispersed in the gel matrix. Four layers of gel varying in the amount of emulsion droplets were combined to prepare samples with homogeneous and inhomogeneous distributions of fat (emulsion droplets). The composition of the gels was optimized to obtain samples with comparable mechanical properties.

A significant enhancement of mouthfeel attributes such as spreadable and melting was observed in samples with inhomogeneous distributions of fat in a Quantitative Descriptive Analysis (QDA) panel. Inhomogeneous samples with large differences in fat content between layers were perceived more spreadable and melting than the sample in which fat was homogeneously distributed. Creaminess ratings tended to increase as the difference in fat content between layers increased in the inhomogeneous samples. Additionally, the position of the high-fat layers in the sample affected the perception of fat-related attributes. The sample with high-fat layers on the outside had the highest ratings for all mouthfeel and afterfeel attributes. The enhancement of fat-related attributes by an inhomogeneous distribution of fat depended on the overall fat content. The enhancement at 15 wt% fat was larger than that at 5 wt% fat. We suggest that the modulation of the spatial distribution of fat can be used to reduce the fat content of food products without causing undesirable changes in the sensory properties.

1. Introduction

The excessive consumption of fat has been linked to the incidence of health problems, such as obesity and cardiovascular diseases. As a consequence, there is an increasing demand for low-fat products in an attempt to decrease fat intake. Given that the reduction of fat usually causes undesirable changes in the properties of foods, the development of low-fat products remains a challenge for food manufacturers.

The effect of fat content on the mechanical and sensorial properties of model systems has been reported in several studies. In emulsion-filled gels, an increase in the concentration of O/W emulsion droplets dispersed in the gel matrix enhanced the perception of fat-related mouthfeel and afterfeel attributes such as creamy, spreadable, sticky and coating (Sala, de Wijk, van de Velde, & van Aken, 2008). Besides the concentration of emulsion droplets, the droplet size, the characteristics of the matrix and the type of droplet–matrix interaction were also shown to affect the sensorial properties of emulsion-filled gels. An increase in the size of emulsion droplets led to a decrease in perceived hardness and to an increase in perceived oiliness of emulsion-filled agar gels (Kim, Gohtani, & Yamano, 1996). Sala et al. (2008) reported that gels that contained unbound emulsion droplets and that melted during oral processing were described as soft, smooth and creamy in a Quantitative Descriptive Analysis (QDA) panel.

Changes in the properties of real food products due to variations of fat content have also been reported. Low-, reduced- and full-fat Cheddar cheeses showed different textural and mechanical properties (Rogers et al., 2009) and different flavor profiles (Drake, Miracle, & McMahon, 2010). In a study conducted on commercial cream cheeses, full-fat products had higher firmness, higher

* Corresponding author. Wageningen University and Research Centre, Agrotechnology & Food Sciences Group, P.O. Box 8129, 6700 EV Wageningen, The Netherlands. Tel.: +31 317 481694; fax: +31 317 483669.
E-mail address: markus.stieger@wur.nl (M. Stieger).

0268-005X/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodhyd.2011.11.002

cohesiveness, higher difficulty to dissolve and to spread and lower stickiness than Neufchatel and fat-free cheeses (Brighenti, Govindasamy-Lucey, Lim, Nelson, & Lucey, 2008). de Wijk, van Gemert, Terpstra, and Wilkinson (2003) reported that the fat content of custard desserts affected the perception of sensory attributes related to the rough-creamy/soft dimension. High-fat custards were perceived creamier, fattier, less dry and less rough than fat-free custards. Therefore, a successful fat reduction strategy should not cause prominent changes in the physico–chemical and sensorial properties of the low-fat product.

This study presents the modulation of the spatial distribution of fat in food matrices as a new strategy that can allow for a reduction of fat content while maintaining the overall quality of low-fat products. It has been shown that an inhomogeneous distribution of tastants leads to an enhancement of taste intensity. Holm, Wendin, and Hermansson (2009), Mosca, van de Velde, Bult, van Boekel, and Stieger (2010) and Mosca, van de Velde, Bult, van Boekel, and Stieger (in press) reported that sweetness intensity was enhanced in layered gel systems in which sucrose was heterogeneously distributed. Similarly, Noort, Bult, Stieger, and Hamer (2010) reported that the saltiness intensity of bread was enhanced by an inhomogeneous distribution of NaCl. In all cases, the largest taste intensity enhancement was observed in inhomogeneous samples with the highest taste contrast level (tastant concentration differences). The inhomogeneous distribution strategy was shown to allow for a sucrose reduction up to 20% in gelled products (Mosca et al., 2010) and for a salt reduction up to 28% in breads (Noort et al., 2010) without loss of sweetness or saltiness intensity. In line with the studies mentioned above, we hypothesize that an inhomogeneous distribution of fat (O/W emulsion droplets) in semi-solid emulsion-filled gels enhances the perception of sensory attributes that are related to fat content and, consequently, allows for a reduction of fat without causing undesirable changes in the sensorial properties. To test this hypothesis, emulsion-filled gels varying in the spatial distribution of fat (O/W emulsion droplets) were prepared. The mechanical properties and the microstructure of the gels were analyzed to have well characterized stimulus materials for the sensory test. A QDA panel was carried out to characterize the sensory properties of samples with homogeneous and inhomogeneous distributions of fat. The results of the QDA panel were used to investigate the effect of the spatial distribution of fat and the effect of the position of the layers containing different amounts of fat on the perception of fat-related attributes as well as the dependency of the enhancement on the overall fat content.

2. Material and methods

2.1. Materials

Powdered whey protein isolate (WPI; Bipro™) was obtained from Davisco International Inc. (La Sueur, MN, United States). Gelatin (PGB 07 bloom 270-290) was purchased from PB Gelatins (Vilvoorde, Belgium). Agar powder (Organic Flavor B.V., Veenendaal, The Netherlands), sucrose and sunflower oil were purchased from a local retailer. Titanium dioxide (TiO_2) suspension (30 wt% suspension of TiO_2 in glucose syrup stabilized with gum acacia and preserved with potassium sorbate) (Overseal, Avignon, France) was purchased from Tefco Ingredients (Bodegraven, The Netherlands). Water purified by reverse osmosis was used.

2.2. Sample preparation

2.2.1. O/W emulsions

Stock emulsions containing 40 wt% sunflower oil in a water phase consisting of 1 wt% WPI were prepared by pre-homogenization using an Ultra Turrax (Polytron, Kinematica AG, Lucerne, Switzerland), followed by homogenization at 500 bar using a high pressure homogenizer (Ariete, Model NS1001L 2K - Panda 2K, Niro Soavi S.p.A, Parma, Italy). The average Sauter diameter ($d_{3,2}$) of emulsion droplets obtained with this homogenization procedure was 1.5 μm. The size distribution of droplets in the emulsion was analyzed by light scattering using a Malvern Mastersizer 2000 (Malvern Instruments Ltd., Malvern, United Kingdom).

2.2.2. Gels

A solution of agar and water was heated to boiling. The solution was allowed to cool down to 80 °C. At this temperature, gelatin was added and the solution was kept under agitation in a water bath at 80 °C for 15 min. Sugar was added and the solution was cooled down to 50 °C. The required amount of O/W emulsion (pre-heated to 50 °C) was added and the solution was stirred for 5 min. Water was added to account for evaporation during heating. To obtain a similar color for all gels, 1 wt% TiO_2 suspension was added as a whitening agent in gels with low-fat content (0, 2 and 5 wt% fat). The final solution was stirred for 10 min. The concentrations of the ingredients are listed in Table 1.

Layered samples were composed of four layers of gel. To prepare the layers of gel, solutions of agar/gelatin/sucrose/emulsion were poured into plastic Petri dishes. The volume poured into the Petri dishes was varied according to the fat content in the gel to obtain layers with similar weight (Table 1). This procedure ensured that the final layered samples had the same overall fat content. Each of the four layers was prepared individually. After the gelation of each layer, the subsequent layer was added on top of the previous one. This step was repeated until all four layers were poured into the Petri dish. After storage overnight at 17 °C, gels were removed from the conditioned room and were allowed to equilibrate to room temperature (~23 °C). Gels were cut into pieces (20 × 20 × 13 mm) (length × width × height) and were used in the sensory test.

Layered samples varying in the spatial distribution of fat (homogeneous and inhomogeneous distributions) were obtained by the combination of layers containing different amounts of fat. The layered samples prepared are listed in Table 2.

2.3. Compression measurements

The large deformation properties of the gels were characterized by uniaxial compression tests using an Instron 5543 test system (Instron International Ltd., Edegem, Belgium) equipped with a plate-plate geometry. Cylindrical pieces of gel of approximately 25 mm diameter and 25 mm height were compressed between two parallel plates (150 mm diameter) lubricated with a thin layer of paraffin oil. Compression was applied at a constant crosshead velocity of 1 mm/s up to a compression strain of 80%. Measurements were performed at ambient temperature (23 ± 1 °C). Eight replicates of each gel were analyzed.

Table 1
Composition and volume of gel layers.[a]

Fat (wt%)	Agar (wt%)	Gelatin (wt%)	Sugar (wt%)	TiO_2 (wt%)	V (mL)
0	0.3	2.3	10	1	48
2	0.3	2.3	10	1	48
5	0.3	2.4	10	1	49
10	0.25	2.3	10	0	49
15	0.3	2.4	10	0	49
20	0.2	2.5	10	0	50
25	0.2	2.5	10	0	50
28	0.2	2.5	10	0	50

[a] Agar, gelatin and sugar concentrations are expressed as wt% on the aqueous phase. Fat and TiO_2 concentrations are expressed as wt% on the total mass of gel.