Food Hydrocolloids 60 (2016) 186–198

Contents lists available at ScienceDirect

Food Hydrocolloids

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

Effect of microparticulated whey protein on sensory properties of liquid and semi-solid model foods

Kun Liu [a, b], Markus Stieger [a, c], Erik van der Linden [a, b], Fred van de Velde [a, d, *]

[a] TI Food & Nutrition, P.O. Box 557, 6700 AN Wageningen, The Netherlands
[b] Wageningen University, Agrotechnology & Food Sciences Group, Laboratory of Physics and Physical Chemistry of Foods, P.O. Box 17, 6700 AA Wageningen, The Netherlands
[c] Wageningen University, Agrotechnology & Food Sciences Group, Division of Human Nutrition, P.O. Box 8129, 6700 EV Wageningen, The Netherlands
[d] 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 19 January 2016
Received in revised form
21 March 2016
Accepted 28 March 2016
Available online 30 March 2016

Keywords:
Microparticulated whey protein (MWP)
Lubrication
Particle size
Creaminess
Roughness
Sensory

A B S T R A C T

This work describes the sensory properties of microparticulated whey protein (MWP) particles in relation to their rheological and tribological properties. The aim of this work is to obtain a better understanding of the sensory perception of MWP particles compared to oil droplets in liquid and semi-solid matrices. We used liquid MWP-o/w emulsions with controlled viscosities and semi-solid MWP-emulsion-filled gelatin gels as food model systems.

Consistent with our previous findings, MWP showed good lubrication properties probably due to ball bearing mechanism in both liquid and semi-solid systems. Sensory results (QDA) revealed that small MWP particles contributed to perception of creaminess due to their lubrication property. Large MWP contributed to the rough and powdery perception, and thus suppressed perception of creaminess. MWP did not contribute to perception of fattiness in contrast to oil droplets. The perception of fattiness was probably related to the film formation properties of oil. As a result, MWP in liquid emulsions were generally perceived as rough but not creamy. In the case of MWP-emulsion-filled gels, although the gel matrix restrained the lubrication function of MWP particles, it also masked the rough perception of big MWP particles. Due to the combined effect of both oil droplets and MWP particles, MWP in gels resulted in an overall positive effect on the creamy perception.

We conclude that MWP contributes to fat-related sensations in a different way than oil does. The perception of MWP particles is related to the size of the particle as well as the properties of the surrounding matrix.

1. Introduction

Microparticulated whey protein (MWP) has been introduced as a texture modifier or fat replacer in many types of foods including thickened emulsions (Chung, Degner, & McClements, 2014), mayonnaises (Tamime, Kalab, Muir, & Barrantes, 1995), yoghurts (Tamime et al., 1995; Torres, Ipsen, Knudsen, & Østergaard, 2009, 2011), ice creams (Yilsay, Yilmaz, & Bayizit, 2006), cheeses (McMahon, Alleyne, Fife, & Oberg, 1996; Sahan, Yasar, Hayaloglu, Karaca, & Kaya, 2008; Singer, 1996; Sturaro, De Marchi, Zorzi, & Cassandro, 2015) and emulsion-filled gels (Liu, Tian, Stieger, van der Linden, & van de Velde, 2016). MWP particles are manufactured from whey protein concentrate through different methods (Cheftel & Dumay, 1993; Ritzoulis, Karayannakidis, & Rosenthal, 2015). The fat mimicking functionality of MWP has been mainly attributed to the particles' spherical shape and small size (typically <5 μm), which is comparable to that of oil droplets in food emulsions. MWP particles in aqueous phase have been suggested to roll freely over one another under applied shear, which has been suggested to be responsible for a creamy and smooth mouthfeel perception (Cheftel et al., 1993; Kilcast & Clegg, 2002; Singer, 1996). Our previous study showed evidence for such ball-bearing lubrication properties of MWP in liquid and semi-solid food matrices (Liu et al., 2016). However, the extent by which MWP can impart fat-related sensory perceptions and the contribution of MWP lubrication properties to fat-related sensations is not well understood. We note that although MWP particles can fulfill the friction

* Corresponding author. NIZO Food Research, P.O. Box 20, 6710 BA Ede, The Netherlands.
E-mail address: fred.vandevelde@nizo.com (F. van de Velde).

http://dx.doi.org/10.1016/j.foodhyd.2016.03.036

reduction function of oil droplets, the underlying mechanisms for this might be considerably different from oil droplets. MWP can reduce friction in foods by a ball-bearing mechanism, while oil droplets can be deformed and coalesce with adjacent oil droplets to form an oil film that reduces friction (Schmid & Wilson, 1996). The difference in mechanisms underlying the reduction in friction may induce differences in sensory perception of fat-related attributes, such as creaminess.

Creaminess is a complex sensory attribute that is considered as one of the most appreciated fat-related sensations. Creaminess is related to multiple food properties. Several pivotal studies have suggested that creaminess can be predicted from thickness, smoothness and slipperiness, which are mainly related to the viscosity of the foods and their lubrication properties in the mouth (Cussler, Kokini, Weinheimer, & Moskowitz, 1979; Kokini, 1987; Kokini & Cussler, 1983). Melting of foods in mouth can also influence perception of creaminess, which might be related to the lubrication effect of the molten layer (Kokini, 1987). Apart from these factors, the presence of particles also plays an important role in creaminess perception (Kilcast et al., 2002; Krzeminski et al., 2013). Large and non-smooth particles added to foods are often associated with several unappreciated sensory attributes, such as roughness, dryness, grittiness and powdery (Cheftel et al., 1993; Krzeminski et al., 2013; Petersson, Eliasson, & Tornberg, 2013). Perception of these sensory attributes might suppress creaminess perception (Singer, 1996; de Wijk & Prinz, 2006a; Wood, 1974). In contrast, when the particles are small, soft, and are able to roll over each other, they contribute to creaminess perception. However, when the particles are too small, they are thought to be unable to provide a so-called "substantialness" impression, and might instead contribute to "watery" perception (Singer, 1996).

As we have outlined, the sensory perception of particles can be associated with roughness, dryness, grittiness, and powdery. The perception of these attributes results from the friction between the particles and the oral mucosa (Hollins, Fox, & Bishop, 2000; de Wijk & Prinz, 2005). The detection of particles in mouth is related to the size, concentration, shape, and hardness of the particles, properties of the matrix in which the particles are dispersed, interactions between particles and matrix, as well as interactions of the particles with oral surfaces and saliva (Engelen, de Wijk, van der Bilt, & Prinz, 2005a; Engelen, van der Bilt, Schipper, & Bosman, 2005b; Heath & Prinz, 1999; Imai, Hatae, & Shimada, 1995; Kilcast et al., 2002; Minifie, 2012; Petersson et al., 2013; Sala & Scholten, 2015; Tyle, 1993; de Wijk et al., 2005, 2006a). Therefore, the particle size threshold for perception of particles embedded in a food matrix may depend on all factors mentioned above. For example, hard particles with irregular shape may already be perceived at low concentrations even when their size is very small, while soft and smooth particles may not be easily detected at a larger size range (Engelen et al., 2005b; Tyle, 1993; de Wijk et al., 2005). Despite the fact that MWP is often found to give a creamy and smooth mouthfeel, there is rarely any information available regarding the other potential particle-related perceptions of MWP. In addition, the effect of the rheological properties of the matrix in which particles are dispersed on sensory perception is not well understood. Engelen et al. (2005b) observed that the viscosity of the liquid phase did not influence perceived particle size of SiO_2 and polystyrene spheres. They ascribed this finding to the fact that they only investigated two viscosities that were both adequately high to disguise particles. Petersson et al. (2013) found that in the case of starch gels, the viscosity of the dispersed phases did not influence the detection threshold of rye bran particles. They suggested that saliva dilution and enzymatic breakdown of the foods is more important for sensory perception than the effect of viscosity prior to ingestion. Imai et al. (1995) observed that the perceived grittiness of microcrystalline cellulose decreased as the viscosity of the dispersed phase increased. One may notice that the particles in these references are all different. In the case of MWP, most literature on the perception of MWP particles is limited to their applications in thick foods, such as yoghurts, cheeses or semi-solid emulsions, whereas to our knowledge sensory perception of MWP in thin, liquid foods has not been reported.

Consequently, by investigating the sensory properties of MWP particles in relation to their rheological and tribological properties in liquid and semi-solid foods, we aim for a better understanding of the sensory perception of MWP particles compared to oil droplets in different food matrices. We also aim to clarify the relationships between different sensory attributes, such as roughness, fattiness and creaminess. In this study, we used liquid MWP-o/w emulsions and semi-solid MWP-emulsion-filled gelatin gels as food model systems. In order to study the influence of viscosity on perceived creaminess, liquid MWP-o/w emulsions were designed to have two sub-groups of iso-viscosity.

2. Materials and methods

2.1. Materials

Microparticulated whey protein (MWP) (Simplesse® 100) was provided by CPKelco (Lille Skensved, Denmark). Powdered whey protein isolate (WPI, Bipro™) was obtained from Davisco International Inc. (La Sueur, MN, USA). Sunflower oil was bought from a local supermarket (Wageningen, the Netherlands). Porcine skin gelatin (bloom value 240–260) was provided by Rousselot (Gent, Belgium). All materials were used without further purification. All samples for sensory evaluation were prepared under food grade conditions. All samples were prepared with tap water.

2.2. Sample preparations

2.2.1. Preparation of MWP-o/w emulsions

An aqueous phase containing 1% (w/w) whey protein isolate (WPI) as emulsifier was prepared. A stock o/w emulsion was prepared by mixing 40% (w/w) sunflower oil and 60% (w/w) aqueous phase. The mixture was pre-homogenized using an Ultra Turrax Polytron (Kinematica AG, Switzerland) for 2 min, and then homogenized at 310 bar (wherein the second stage was 30 bar) using a lab homogenizer Ariete (NS1001L-Panda, Niro Soavi, Parma, Italy).

A stock MWP dispersion 20% (w/w) was prepared at room temperature by dispersing MWP powder in water under stirring for 2 h. MWP-o/w emulsions were prepared by mixing the stock o/w emulsion, stock MWP dispersion and water at calculated ratios. The ratio of mixing was calculated to yield the compositions listed in Table 1. These emulsions were divided as two sub-groups based on their viscosity values at 50 s^{-1}. Within each sub-group their viscosities are comparable.

All MWP-o/w emulsions were freshly prepared on the day of the physical measurements and stirred until the moment of further analysis to minimize sedimentation of MWP particles in the emulsions. For sensory evaluations, 20 g of the emulsion were filled in 30 mL plastic cups. All samples were prepared one day before sensory evaluation. These samples were stored in the refrigerator at 4 °C, and kept at 20 °C prior to sensory evaluation. The samples were gently shaken by the panelists prior to sensory evaluation to avoid sedimentation.

2.2.2. Preparation of MWP-emulsion-filled gelatin gels

The previously described 20% (w/w) stock MWP dispersion and 40% (w/w) stock emulsion were mixed with gelatin solutions at different ratios to yield the MWP-emulsion filled gels listed in