Food Research International 53 (2013) 156–163

Contents lists available at SciVerse ScienceDirect

Food Research International

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

Comparison of the physicochemical behavior of model oil-in-water emulsions based on different lauric vegetal fats

Prudent Placide Anihouvi [a,*], Sabine Danthine [a], Yves Kegelaers [b], Anne Dombree [b], Christophe Blecker [a]

[a] Unité de Science des Aliments et Formulation, Gembloux Agro Bio Tech, Université de Liège, Passage des Déportés 2, 5030 Gembloux, Belgium
[b] Puratos Group, Industrialaan 25, Zone Maalbeek, 1702 Groot-Bijgaarden, Belgium

ARTICLE INFO

Article history:
Received 10 January 2013
Accepted 19 April 2013

Keywords:
Lauric vegetal fats
Oil-in-water emulsion
Droplet size
Flow behavior
Emulsion stability

ABSTRACT

The physicochemical properties of lauric fats-in-water (O/W) emulsions were examined through a simplified model composed of 30% fat, and buttermilk powder as the emulsifier agent. Four types of lauric fats were studied and their influence on droplet characteristics, rheological properties and creaming stability were evaluated by optical and rheological methods after 24 h of aging at 4 °C. The fat type showed no significant effect on the size and the distribution of droplets just after the emulsification process. However, a slight modification occurred in the droplet size distribution (DSD) of the emulsions after 24 h of storage at 4 °C. The major differences were observed for the emulsion stability and for the rheological behavior even if the fats belonged to the same group. All emulsions presented a shear thinning behavior and showed a higher shear thinning profile at 20 °C compared to 4 °C. Significant differences were also noticed in the emulsion behavior for gelling.

1. Introduction

Several food systems basically exist in the form of emulsions which consist of two immiscible liquids (usually oil and water), where one liquid is dispersed as small spherical droplets in the other (Dickinson, 1992). Emulsions are thermodynamically unstable and the mechanisms by which an emulsified oil can return to thermodynamic stability (two macro-phases) are creaming, flocculation, coalescence, partial coalescence, Ostwald ripening and phase inversion (Dickinson, 1992, 2010; Friberg & Larsson, 1997; McClements, 1999; Vanapalli, Palanuwech, & Coupland, 2002). Examples of O/W food emulsion systems are the dairy and vegetal emulsions. They can be used either as an ingredient for the manufacturing of many food products (ex. cheese), or as a final product for direct consumption. Over the last decade, O/W emulsions recombined from milk ingredients have received increasing interest because of their obvious advantages in the industrial processes compared to fresh cream: low cost storage of raw materials, possibility to standardize and adapt the composition and the desired final properties of the cream, independence of the milking seasons (Kieseker, 1988; Van Lent, Le, Vanlerberghe, & Van der Meeren, 2008; Vangerdhem, 2009).

The development of recombined emulsion systems opened the possibility to develop vegetal O/W emulsions (VE) formulated from vegetal fats (VF) thus replacing milk fat. VEs appear today, more and more, as an alternative to dairy emulsion (DE) for many reasons. VEs are more functional than DE, especially for formulation of ice cream and whipped products (Berger, 1998; Nesaretnam, Robertson, Basiron, & Machphie, 1993). Indeed, manufacturers can choose to use a more suitable fat characterized by a specific solid fat content profile with complementary emulsifier systems (Shamsi, Che Man, Yusoff, & Jinap, 2002; Towler, 1982). VEs present satisfactory whipping properties and better stability at higher temperatures compared to DE. Furthermore, countries with insufficient milk production can import skimmed milk powder and reconstitute it with local available vegetal oil (Berger, 1998). VEs are often manufactured by UHT processing and therefore can be supplied as ambient-stable, aseptically-packaged liquids (Carr & Hogg, 2005). However, the choice of VF into a wide variety of VFs in order to obtain desired final properties of VEs, can also constitute an inconvenience in the formulation of VEs.

VEs are formulated with ingredients from both dairy and non-dairy origin. Dairy ingredients include different powders like milk proteins, skimmed milk, whey and buttermilk. The non-dairy elements used in VE formulation concern mainly VFs, carbohydrates, emulsifiers and water. Among non-dairy ingredients, VFs are probably the ingredients that greatly influence the emulsion properties and the final properties of products such as ice-cream and whipped cream. The choice of adequate VF to obtain desired end properties constitutes thus a crucial stage in the formulation of VEs.

Unfortunately, few data exist in the literature about the effect of composition and physicochemical characteristics of VFs on emulsions properties (and their end products). A study evaluating the physicochemical stability of all-in-one mixtures containing medium-chain triacylglycerides (MCTs) along with conventional long-chain triacylglycerides (LCTs) as a 1:1 physical mixture (by weight), demonstrated to be more stable than lipid emulsions containing a single LCT made from soybean oil (Driscoll et al., 2001, 2002). The authors attributed this result to a great miscibility of MCT with soybean oil in the O/W emulsion. Granger, Barey, Combe, Veschambre, and Cansell

* Corresponding author. Tel.: +32 81622303; fax: +32 81601767.
E-mail address: bental2@yahoo.fr (P.P. Anihouvi).

0963-9969/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodres.2013.04.011

(2003), Granger, Barey, Veschambre, and Cansell (2005), Granger, Leger, Barey, Langendorff, and Cansell (2005) conducted studies on VEs made from various types of fat (oleic oil, hydrogenated and refined coconut oils, refined palm oil), milk protein and lipid emulsifier. They reported significant differences in the emulsions properties. These authors attributed the stability of emulsions with less unsaturated oils to interfacial interactions among the oil phase, emulsifier fatty acids and the adsorbed protein. Recently, Cornacchia and Roos (2011a) studied the freeze–thaw stability of VEs formulated from sucrose, dairy proteins and VFs (sunflower oil or hydrogenated palm kernel oil). They highlighted that during freeze–thaw cycling the crystallization temperature of the dispersed lipid phase plays a major role in the emulsion stability. Indeed, lipid crystallization prior water crystallization caused destabilization and oiling-off at low sucrose concentrations (0, 2.5 and 5% w/w). Furthermore, Nor Hayati, Che Man, Tan, and Nor Aini (2007) showed that the replacement of palm kernel olein (PKO) in concentrated emulsions based on soybean/PKO blends resulted in a significant increase in droplet mean diameters and a decrease in rheological properties.

The main goal of this work was to study the influence of lauric vegetal fats (LVF) on physicochemical properties of O/W emulsions formulated using a simplified model in order to better highlight the fat effect. Emulsions were characterized in terms of fat particle size distribution, rheological properties and physical stability. Four types of lauric industrial fats, known under the same commercial description, were compared in the present study in order to better highlight their influence on emulsions properties. Indeed, LVFs are commonly used in food industry namely in aerated food emulsion products, shortening, margarine, confectionery, etc. (Jin, Zhang, Shan, Liu, & Wang, 2008; Traitler & Dieffenbacher, 1985). Additionally, compared to non-lauric vegetal fats (except palm oil), LVFs are good fat ingredients for the production of ice cream and whipped products according to Che Man, Shamsi, Yusoff, and Jinap (2003) and Wan Rosnani and Nor Aini (2000). Because of their high content of medium-chain saturated fatty acids (about 50% lauric acid) (Traitler & Dieffenbacher, 1985) and their great polymorphic stability in β′ form (Anihouvi, Blecker, Dombree, & Danthine, 2012; Che Man et al., 2003), these fats are mostly characterized by a melting profile that seems appropriate for the production of aerated food emulsion products (Berger, 1998).

2. Materials and methods

Four kinds of lauric fats (coded A, B, C, D) were used for the preparation of O/W emulsions. These fats were kindly provided by Puratos Group (Groot-Bijgaarden, Belgium). Their major fatty acids (FA) are lauric acid, stearic acid, and myristic acid.

Dry buttermilk powder (DBP), used as emulsifier agent, was kindly supplied by Corman S.A. (Goé, Belgium). The lactose, protein, fat, phospholipids, and ash content of this DBP were 52.2, 33.4, 7.1, 2.4, and 5.1%, respectively.

2.1. Fat characterization

2.1.1. Fatty acid (FA) compositions

FA compositions were determined by gas chromatography (GC) on a HP 6890 Series GC System (USA) apparatus fitted with a HP 7683 Series Injector (splitless mode) and a flame ionization detector (FID, temperature 250 °C). Fatty acid methyl esters (FAMEs) were made by transesterification of oils in methanol. The operating conditions were as follows: 25 m × 0.32 mm × 0.25 μm HP-Innowax polyethylene glycol capillary column; temperature program, from 50 to 150 °C at 30 °C/min and from 150 to 240 °C at 4 °C/min, 240 °C for 10 min; injector temperature 240 °C. Helium at 75 kPa was used as carrier gas. FAMEs were identified on the basis of their retention data compared with those of a standard injected in the same conditions (Anihouvi et al., 2012).

2.1.2. Solid fat content (SFC)

A pulsed nuclear magnetic resonance (pNMR) spectrometer (Minispec MQ20; Bruker, Germany) was used to measure the SFC of the fat samples according to the IUPAC 2.150(a) non tempered serial method, slightly modified. Indeed, the waiting time at each temperature was 45 min instead of 30 min. Automatic calibration was made daily by using three standards (supplied by Bruker) containing, respectively 0.0, 31.1, and 74.8% of solid. Data are reported as averages of three measurements (Anihouvi et al., 2012).

2.2. Emulsion preparation

O/W emulsions (100 g) were prepared in a lab-scale proportion using 30% VF (A or B or C or D), 6.69 wt.% DBP adjusted to 100% with water. This formulation is derived from that used by Danthine, Blecker, Paquot, and Deroanne (2003) and Vangerdhem (2009) for DE (milk fat, buttermilk, water) by simply replacing milk fat with VF. This simplified formulation was chosen in order to better highlight the effect of fat on the properties of the emulsions.

The aqueous phase was prepared by dissolving DBP into distilled water at room temperature. They were then stirred with a magnetic stirrer for 1 h to ensure complete hydration and dispersion of the DBP. The oil phase was warmed at 75 °C during 40 min, in order to ensure complete melting of all the fat crystals. Preheated fat was then incorporated to the premix of water and buttermilk. Emulsification was performed (into 400 ml pyrex beaker: 11 cm height, 8 cm diameter) by shearing for 2 min in a water bath at 75 °C by means of Ultra-Turrax T-45 laboratory homogenizer (IKA, Staufen, Germany) at 10,000 rpm (circumferential velocity of 20 m s^{-1}). After emulsification the mixes were immediately stored in a cold chamber at 4 ± 0.5 °C to age for 24 h before the characterization tests. Each type of formulation was prepared for three independent replications. In this paper, emulsions prepared with fat A, fat B, fat C, and fat D were named emulsion A, emulsion B, emulsion C, and emulsion D, respectively.

2.3. Droplet size distributions

The droplet size distribution (DSD) of the emulsions was determined by laser light scattering using a Malvern Mastersizer 2000 (Malvern Instruments, Malvern, UK), connected to a Hydro 2000S mixing device (Malvern Instruments) for liquid measurements. A few drops of emulsion were dispersed with distilled water in the measuring vessel of the instrument under moderate stirring (dilution is approximately 1:1000). Measurements were performed with an obscuration of about 20% at room temperature on the freshly made emulsions or after aging (24 h at 4 °C).

In order to transform the experimentally determined angular light scattering pattern to a DSD, the general Mie light-scattering theory (Bohren & Huffman, 1998) was used. The software used the refractive index (RI) of vegetal fats (1.465) and the dispersant RI (1.33) to calculate fat globule distribution parameters. The particle sizes of emulsions were characterized by the volume-weighted mean diameter $d_{4,3}$, the median particle diameter $d_{0.5}$ and the $d_{0.1}$ diameter. The volume-weighted mean diameter $d_{4,3}$ was determined by following expression: $d_{4,3} = \sum n_i d_i^4 / \sum n_i d_i^3$ where d is droplet diameter and n_i is number of droplets of d_i diameter. The $d_{0.5}$ and $d_{0.1}$ values are size values which correspond to the cumulative distribution at 50% and 10%, respectively. Each result was a mean of nine measurements (3 repetitions × 3 replications).