Journal of Food Engineering 146 (2015) 172–181

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Effect of particle size in chocolate shell on oil migration and fat bloom development

Hanna Dahlenborg [a,b,*], Anna Millqvist-Fureby [a], Björn Bergenståhl [b]

[a] SP, Technical Research Institute of Sweden, Box 5607, SE-114 86 Stockholm, Sweden
[b] Lund University, Department of Food Technology, Engineering and Nutrition, P.O. Box 124, SE-221 00 Lund, Sweden

ARTICLE INFO

Article history:
Received 26 February 2014
Received in revised form 15 August 2014
Accepted 2 September 2014
Available online 16 September 2014

Keywords:
Chocolate
Cocoa butter
Particle size
Fat bloom
Migration
Surface structure

ABSTRACT

The effects of chocolate shell particle size were investigated by means of its influence on rate of oil migration and fat bloom development. The particle size of the non-fat particles in the chocolate, i.e. sugar and cocoa particles was varied between 15, 22 and 40 μm. A novel set of analytical techniques was used and by combining migration results with surface topology results clear differences could be observed between the samples. At 23 °C storage the samples with a particle size of 15 μm showed higher rate of oil migration and further, the earliest development of fat bloom at the surface. This could be observed both macroscopically and microscopically. Thus, it appears as a larger specific surface area of the non-fat particles facilitates migration of filling oil, possibly due to a more heterogeneous and coarser crystal network with higher permeability. Molecular diffusion cannot explain the level of oil migration observed and, thus, convective flow is assumed to be an important contribution in addition to the molecular diffusion.

1. Introduction

Migration of the internal filling fat into the surrounding chocolate shell in chocolate pralines is a major concern for the confectionery industry. This migration leads to textural quality loss in addition to fat bloom development, giving the product a dull, whitish haze resulting in rejection by the consumers (Ghosh et al., 2002; Hartell, 1999; Lonchampt and Hartel, 2004; Smith et al., 2007; Talbot, 1990). The driving force behind this migration is usually explained by a triacylglycerol (TAG) concentration gradient between the liquid filling fat and the liquid cocoa butter (CB) in the chocolate shell, tending towards a thermodynamic equilibrium (Ziegleder et al., 1996a,b; Ziegleder and Schwingshandl, 1998). However, the mechanism of oil migration in chocolate pralines is not yet fully understood, and it has been explained by molecular diffusion (Deka et al., 2006; Lee et al., 2010; Maleky et al., 2012; McCarthy and McCarthy, 2008; Miquel et al., 2001; Ziegleder et al., 1996a,1996b; Ziegleder and Schwingshandl, 1998), capillary flow (Aguilera et al., 2004; Choi et al., 2007; Guiheneuf et al., 1997; Marty et al., 2005; Quevedo et al., 2005; Rousseau and Smith, 2008) and a pressure driven convective flow (Altimiras et al., 2007; Dahlenborg et al., 2011, 2012; Loisel et al., 1997).

Due to migration of liquid fat from the filling, the solid fat content (SFC) is reduced in the chocolate shell in addition to polymorphic changes within the solid fat phase (Motwani et al., 2011; Timms, 1984). These polymorphic changes are usually connected to formation of fat bloom, where form β_1VI, the most stable CB TAG polymorph, has developed within the chocolate fat matrix (Smith et al., 2007; Wille and Lutton, 1966). Further, when the needle shaped β_1VI crystals are formed on the chocolate surface and these are larger than 5 μm, a whitish haze, connected to fat bloom, appears due to scattering of light (Hartell, 1999; Kinta and Hatta, 2005; Lonchampt and Hartel, 2004). In contrast, when producing chocolate products the desired crystalline form or polymorph of the CB TAGs is β_2V, which is achieved when it undergoes a controlled crystallisation during production.

The rate of oil migration can be influenced by different parameters. Higher storage temperatures have shown to increase the migration rate (Ali et al., 2001; Altan et al., 2011; Dahlenborg et al., 2014; Guiheneuf et al., 1997; Khan and Rousseau, 2006; Miquel et al., 2001; Ziegleder and Schwingshandl, 1998), and the chocolate shell microstructure has also been shown to affect the migration rate (Dahlenborg et al., 2014; Lee et al., 2010; Maleky et al., 2012; Miquel et al., 2001; Motwani et al., 2011; Svanberg et al., 2011, 2013). Studies have demonstrated that by using

* Corresponding author at: SP, Technical Research Institute of Sweden, Box 5607, SE-114 86 Stockholm, Sweden. Tel.: +46 10 516 60 62 (Dir), mobile: +46 70 587 60 62; fax: +46 8 20 89 98.
E-mail address: hanna.dahlenborg@sp.se (H. Dahlenborg).

http://dx.doi.org/10.1016/j.jfoodeng.2014.09.008
0260-8774/

different ways of pre-crystallisation, e.g. by following a defined tempering scheme or by using a seeding programme, differences in crystal size and crystal density of the product can be achieved, and thus, the rate of oil diffusion is affected (Svanberg et al., 2011, 2013). Another way of changing the microstructure of the chocolate shell is by varying the particle size of the non-fat ingredients, i.e. sugar crystals and cocoa particles, and in some cases milk particles. It has been suggested that larger particles give rise to a higher migration rate (Choi et al., 2007). However, other researchers have also reported the opposite, i.e. that smaller particles give rise to a higher migration rate (Altimiras et al., 2007).

Thus, the objective of this study is to further investigate the influence of particle size on oil migration and fat bloom development in chocolate pralines by combining a set of novel analytical techniques. Model pralines with a chocolate shell of varied particle size were analysed as a function of time and storage temperature. By using profilometry combined with low vacuum scanning electron microscopy (LV SEM) the surface microstructure development could be monitored. This was further connected to the migration data produced by energy dispersive X-ray spectroscopy (EDS) analyses of labelled oil. The particle size in a chocolate product is an accessible parameter for the industry, thus the study of the particle size influence on migration and fat bloom is of relevant interest.

2. Materials and methods

2.1. Materials

Model pralines, consisting of a filling layer in contact with a shell layer, were produced on a lab scale. The model filling consisted of 73 wt% CB (Bühler AG, Uzwil, Switzerland), 22 wt% triolein (OOO) (Penta Manufacturing, New Jersey) and 5 wt% brominated vegetable oil (BrTAG) (Penta Manufacturing, New Jersey) with an estimated molar mass of 978 g mol^{-1}. This composition yielded a sufficiently hard filling with a solid fat content (SFC) of 53% at 20 °C, and without any separation of BrTAGs. In order to mimic a fat based filling the amount of added triolein was based on the assumption that hazelnut paste contains approximately 70% triolein (Alasalvar et al., 2009; Amaral et al., 2006; Bernardo-Gil et al., 2002). This corresponds to 22% triolein of total fat content in a typical hazelnut based filling and thus, the model filling contained 22% triolein on a total fat basis. The shells consisted of dark chocolate that was ground into varied particle size, i.e. 15, 22 and 40 μm, respectively. These particle sizes are referring to the largest particle size (D_{90}) from the analysed particle size distribution (PSD) of the ground chocolate masses by using laser diffraction (Malvern Mastersizer 2000, Malvern, UK). Table 1 shows the PSD of the non-fat particles (sugar and cocoa particles) included in the three chocolate masses. The chocolate masses were kindly produced and ground at Bühler AG, Uzwil, Switzerland. Table 2 shows the composition of the chocolate shells and the filling. The premade seed CB crystal suspension, containing crystals of form β_1VI, that was used for seeding was kindly supplied by Swiss Federal Institute of Technology, ETH (Zurich, Switzerland).

2.2. Production of model systems

In order to keep a controlled production, seed tempering was applied. The CB seeds were stirred and heated in a sealed beaker in a water bath, to a temperature of 33–33.7 °C prior to mixing with the shell and filling masses. The model systems consisted of a filling layer (a disc of 10 mm in diameter and 3 mm high) in contact with a chocolate shell layer (a disc of 10 mm in diameter and 1.5 mm high) as can be seen in Fig. 1A. By keeping the chocolate masses and the filling mixture in an oven, set to a temperature of 50 °C for 24 h, presence of crystal nuclei could be prevented. The chocolate shells, with particle sizes of 15, 22 and 40 μm, were prepared in a first step. The chocolate masses of 50 °C were cooled in a sealed water bath at 31 °C and stirred until the masses had reached a temperature of 33.8 °C. This temperature was held for 2 min and then the heated CB seeds were added to the chocolate masses, which were then stirred for 3 min at a temperature of 33.7–33.8 °C. The seeded chocolate was poured into 1.5 mm high moulds, that were shaken to reduce air bubbles, and then the overload was scraped of the moulds. The moulds containing chocolate shells were stored at 15 °C for 30 min and then allowed to rest for 20 min at room temperature (20 ± 0.5 °C) after which the filling was added to the shells, a process that mimics conventional praline preparation. For preparation of the model filling CB, triolein and BrTAGs at 50 °C were mixed in the proportions given in Table 2. The filling was prepared in the same way as the seeded chocolate masses. Then the filling was poured in 3 mm high moulds overlaying the moulds containing the shells. The moulds were stored at 15 °C for at least 1 h before the samples were de-moulded. This was followed by storage at 15 °C for 48 h approximately before final storage at 20 °C and 23 °C.

2.3. Storage conditions

2 days after production, the model pralines were stored at two different temperature controlled environments. The samples were stored in heating cabinets (temperature accuracy ± 0.5 °C) where the temperature was kept at either 20 °C or 23 °C. The actual temperature was additionally controlled by a k-type thermocouple

Table 1
Particle size distribution (PSD) represented by volume fractions 10%, D(v, 0.1); 50%, D(v, 0.5); 90%, D(v, 0.9), Sauter mean diameter, D[3.2], and specific surface area of chocolate masses.

Model system	D(v, 0.1) (μm)	D(v, 0.5) (μm)	D(v, 0.9) (μm)	D[3.2] (μm)	Specific surface area (m^2/g)
15 μm	1.268	5.009	14.547	3.002	2
22 μm	1.452	6.535	22.441	3.586	1.67
40 μm	1.633	8.034	40.302	4.141	1.45

Table 2
Composition of shells and filling.

Model system	CB (wt%)	CB seeds (wt%)	Sugar (wt%)	Cocoa particles (wt%)	Lecithin (wt%)	Triolein (wt%)	BrTAG (wt%)	Fat content (wt%)
15 μm	30.4	1.2	50	18	0.4			32
22 μm	30.4	1.2	50	18	0.4			32
40 μm	30.4	1.2	50	18	0.4			32
Filling	69.4	3.6				22	5	100