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Effect of shell microstructure on oil migration and fat bloom development in model pralines

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ABSTRACT

This study investigated the influence of shell microstructure on oil migration and fat bloom development in chocolate model systems. The microstructure of the model shells was varied by means of tempering or seeding cocoa butter and the addition of non-fat particles. Further, the impact of different storage conditions was studied. By using a set of novel analytical techniques the migration rate could be connected to the development of fat bloom at the surface. The non-seeded cocoa butter samples showed significantly higher rate of migration together with the highest rate of developed fat bloom, whereas the over-seeded cocoa butter samples showed low migration rate and low rate of fat bloom development. Addition of particles (sugar, cocoa powder and defatted cocoa powder) proved to have a significant impact on the microstructure, since these samples showed a substantially higher rate of migration and fat bloom development compared to seeded cocoa butter samples. Molecular diffusion could not explain the migration behaviour, thus, convective flow is suggested as an important contribution in addition to the molecular diffusion.

1. Introduction

Fat bloom on chocolate pralines is a commonly encountered problem in the confectionery industry leading to rejection by customers due to visual and textural quality loss. When chocolate surrounds a filling with high oil content (e.g. hazelnut oil in a praline filling) the quality loss can be related to migration of filling oil into the crystallised fat phase of the chocolate shell (Ghosh, Ziegler, & Anantheswaran, 2002; Hartell, 1999; Lonchampt & Hartel, 2004; Smith, Cain, & Talbot, 2007; Talbot, 1990). The driving force behind this oil 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, aiming to reach a thermodynamic equilibrium (Ziegleder, Moser, & Geiger-Greguska, 1996a, 1996b; Ziegleder & Schwingshandl, 1998). The migrating liquid fat from the filling dissolves some of the crystallised CB TAGs in the shell which leads to a softer chocolate shell, while liquid CB from the shell fat matrix can migrate into the filling giving it a harder texture upon re-crystallisation (Ghosh et al., 2002; Lonchampt & Hartel, 2004; Ziegleder, 1997). In addition, liquid CB migrates to the chocolate surface where it re-crystallises into the most thermodynamically stable polymorphic form, β_1VI (Smith et al., 2007; Wille & Lutton, 1966). These fat crystals have a needle-shaped form and may grow to sizes above 5 μm. Light is scattered due to the size and a dull, whitish haze is formed at the chocolate surface that can be correlated to fat bloom (Hartell, 1999; Kinta & Hatta, 2005; Lonchampt & Hartel, 2004). The mechanism of oil migration in chocolate pralines is not yet fully understood. However, there are different theories describing this mechanism, such as molecular diffusion (Deka et al., 2006; Ghosh et al., 2002; Lee, McCarthy, & McCarthy, 2010; Maleky, McCarthy, McCarthy, & Marangoni, 2012; McCarthy & McCarthy, 2008; Miquel, Carli, Couzens, Wille, & Hall, 2001; Ziegleder et al., 1996a, 1996b; Ziegleder & Schwingshandl, 1998), capillary flow (Choi, McCarthy, & McCarthy, 2005; Choi, McCarthy, McCarthy, & Kim, 2007; Guiheneuf, Couzens, Wille, & Hall, 1997; Marty, Baker, Dibildox-Alvarado, Rodrigues, & Marangoni, 2005; Quevedo, Brown, Bouchon, & Aguilera, 2005; Rousseau & Smith, 2008) and a pressure driven convective flow (Altimiras, Pyle, & Bouchon, 2007; Dahlenborg, Millqvist-Fureby, Bergenstahl, & Kalnin, 2011; Dahlenborg, Millqvist-Fureby, Brandner, & Bergenstahl, 2012; Loisel, Lecq, Ponchel, Keller, & Ollivon, 1997).

The rate of oil migration in pralines can be influenced by both storage conditions and product properties (Choi et al., 2007). Several authors have found that the migration rate increases at

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higher storage temperatures (Ali, Selamat, Man, & Suria, 2001; Altan, Lavenson, McCarthy, & McCarthy, 2011; Guiheneuf et al., 1997; Khan & Rousseau, 2006; Miquel et al., 2001). Further, the migration rate of filling oil has been shown to be affected by the microstructure of the surrounding shell (Svanberg, Ahrne, Loren, & Windhab, 2011a, 2013). The shell microstructure is highly dependent on the crystallinity of the CB, which can be affected by varying the crystallisation regime. Generally, CB can crystallise into six different polymorphic forms named as form I–VI (Wille & Lutton, 1966) or as form sub-α, α, β'_2, β'_1, β_2, β_1 (Larsson, 1966), with respect to increasing stability and increasing melting points. Form β_2V is the desired form in chocolate, giving it the characteristics of gloss, fine texture, snap, a smooth melting in the mouth and relatively good fat bloom stability. This outcome is secured by a controlled crystallisation, where creation of nuclei induces the formation of β_2V crystals. There are two ways to achieve this; either by tempering or seeding. The tempering procedure is the conventional way to pre-crystallise chocolate, where liquid chocolate mass is treated mechanically and thermally, i.e. under shear and through a defined temperature profile. During this process crystals are formed that can act as seed crystals, from which the remaining fat in the chocolate solidifies. Pre-crystallisation by seeding can be realised in different ways, still, all procedures use seeds in order to induce formation of crystal form β_2V (Hachiya, Koyano, & Sato, 1989a, 1989b; Zeng, Braun, & Windhab, 2002). Zeng et al. (2002) have developed a seeding technique where a premade seed CB crystal suspension, containing crystals of form β_1VI, is added to the pre-cooled chocolate in quantities from 0.2 to 2%. This results in a large number of well-defined nuclei, and although the seed crystals are in form β_1VI, the CB in the chocolate solidifies and develops into the desired form, β_2V. In recent studies, this pre-crystallisation process has been shown to create chocolate products with increased fat bloom stability (Svanberg et al., 2011a; Svanberg, Ahrne, Loren, & Windhab, 2011b; Svanberg et al., 2013; Zeng et al., 2002). Another way to affect the microstructure of the surrounding chocolate shell in a praline is by varying the size and amount of non-fat particles (Afoakwa, Paterson, Fowler, & Vieira, 2009b; Altimiras et al., 2007; Motwani et al., 2011; Svanberg et al., 2011a, 2011b). Research done by Svanberg et al. (2011a, 2011b) indicated that addition of sugar and cocoa particles to CB affected the nucleation and growth of cocoa butter crystals and thus the microstructure of the shell. Further, Motwani et al. (2011) investigated migration of peanut oil into samples composed of CB with or without the addition of cocoa particles, and observed that migration was enhanced when cocoa particles were present. Migration of TAGs in chocolate and model pralines has mostly been studied by using magnetic resonance imaging (Altan et al., 2011; Choi et al., 2007; Guiheneuf et al., 1997; Khan & Rousseau, 2006; Lee et al., 2010; Maleky et al., 2012; Miquel et al., 2001; Walter & Cornillon, 2002) and HPLC (Ali et al., 2001; Depypere, De Clercq, Segers, Lewille, & Dewettinck, 2009; Khan & Rousseau, 2006; Kinta & Hatta, 2007). Further, the relationship between surface microstructure and oil migration has been studied by using atomic force microscopy (Hodge & Rousseau, 2002; Khan & Rousseau, 2006; Nightingale, Lee, & Engeseth, 2011; Rousseau, 2006; Rousseau & Sonwai, 2008; Smith & Dahlman, 2005; Sonwai & Rousseau, 2008, 2010), surface roughness measurements (Briones, 2006; Dahlenborg et al., 2011; Quevedo et al., 2005; Rousseau, Sonwai, & Khan, 2010; Sonwai & Rousseau, 2010), scanning electron microscopy (Dahlenborg et al., 2011; James & Smith, 2009; Rousseau & Smith, 2008) and confocal Raman microscopy (Dahlenborg et al., 2012).

Development of routes for quality improvement, leading to less oil migration from filling to chocolate shell is of importance for the confectionery industry. Therefore, it is of relevance to understand how the chocolate shell microstructure influences oil migration induced fat bloom in chocolate pralines. Thus, the objective of this study was to investigate the migration characteristics together with the fat bloom development in model pralines due to differences in shell microstructure by combining a set of novel analytical techniques. The microstructure in the chocolate shell is assumed to be possible to control by means of tempering or seeding protocols, addition of non-fat particles and storage conditions. Low vacuum scanning electron microscopy (LV SEM) and profilometry have been used to determine the fat bloom development at the shell surface as a function of time and temperature. Further, the migration between filling and shell was followed by energy dispersive X-ray spectroscopy (EDS), where brominated triacylglycerols (BrTAGs) were used as probe molecules for the migration. In addition, differential scanning calorimetry (DSC) results provided information of the polymorphic forms in the shells over time. Through these results we can achieve a deeper understanding of the influence of shell microstructure on oil migration and thus, also extend the understanding of fat bloom development in chocolate pralines.

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% cocoa butter (CB) (Bühler AG, Uzwil, Switzerland), 22 wt% triolein (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, 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, Amaral, Satir, & Shahidi, 2009; Amaral et al., 2006; Bernardo-Gil, Grenha, Santos, & Cardoso, 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 choice of using BrTAG as a probe for oil migration from filling into shell is based on several conditions. Primarily, due to the presence of bromine the BrTAG is easy to detect by using energy dispersive X-ray spectroscopy (EDS), and further, it is liquid at room temperature similar to e.g. triolein. The BrTAG used within this work consists of soybean oil that has been subjected to partial bromination, where 2 bromine atoms have been added to a double bond (on average there are 1.34 bromine atoms per TAG molecule). Soybean oil TAGs mainly consist of linoleic, oleic, palmitic, linolenic and stearic fatty acids (iodine value ~ 130), and thus, soybean oil is expected to behave similar to other TAGs in the model filling, such as triolein (iodine value ~ 86). It should be noted that for the BrTAG used within this work, bromine atoms have been added at the centre of the fatty acid chain. Thus, the BrTAG might interact somewhat differently with the solid cocoa butter compared to e.g. triolein. However, compared to other available labelled molecules that are used as probes for oil migration within confectionery products, such as dyes, the BrTAG is expected to behave more similar to migrating filling oil.

The shells consisted of CB (Bühler AG, Uzwil, Switzerland), CB and powdered sugar (AAK, Aarhus, Denmark), CB and cocoa particles (CP) (Bühler AG, Uzwil, Switzerland), and CB and defatted cocoa particles (dCP) (Bühler AG, Uzwil, Switzerland). The composition of both shells and filling is provided in Table 1. Further, the particle size distribution (PSD) was analysed using laser diffraction (Malvern Mastersizer 2000, Malvern, UK). The