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Effect of cream aging temperature and agitation on butter properties

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ABSTRACT

Aging of cream is an important process to manage production time and to produce butter with consistent quality. The objective of this study was to evaluate the combined effect of temperature (5, 10, and 15°C) and agitation rate (0, 40, and 240 rpm) during aging of cream on the physical properties of cream and butter in a model system. Cream's solid fat content (SFC), melting behavior, and droplet size distribution were measured during and after 90 min of aging. Butter physical properties such as melting behavior, water content, and hardness were measured. The effects of agitation on SFC and droplet size are dependent on aging and churning temperature. Solid fat content increased faster at 5°C, and the maximum SFC was the highest at this temperature. An effect of agitation on SFC was observed only when cream was aged at 15°C. Agitating cream at 40 rpm increased the droplet size regardless of aging temperature. Two melting peaks, medium melting fraction (MMF) and high melting fraction (HMF), were found in cream samples aged at 5 and 10°C, but only a HMF melting peak was seen in the cream aged at 15°C. The enthalpy of MMF in the cream aged at 10°C with 40 rpm and without agitation was significantly lower than that in samples aged at 5°C regardless of agitation rate. Butter can be formed only from cream aged under certain conditions during 14.5 min of churning, which are 5°C with high agitation and 10°C regardless of agitation level. Butter produced with cream aged at 5°C with high agitation showed significantly higher MMF and total enthalpy values. However, no significant difference in enthalpy values was observed among the butter samples made from the cream aged at 10°C. Further crystallization of MMF occurred in the butter produced with cream aged at 10°C during 24 h of storage at 5°C, whereas no further crystallization occurred in the butter made with the cream aged at 5°C with high agitation. The hardest butter was obtained when cream was aged at 5°C with 240 rpm and at 10°C with 40 rpm. Softer butter was obtained when cream aged at 10°C with 240 rpm was used. This butter also had the highest water content. This study shows that butter hardness can be tailored by changing the aging conditions of the cream. Cream can be aged at higher temperature with low agitation without altering the hardness of butter. These results will help dairy producers to optimize butter making processes to obtain desired properties in the final product.
Key words: crystallization, aging, agitation, cream, butter

INTRODUCTION

Butter is a water-in-oil emulsion that contains at least 80% fat and no more than 16% water. Butter is made from cream, which is an oil-in-water emulsion, and it is obtained through a phase inversion from oil-in-water to water-in-oil emulsion that occurs during churning. Prior to phase inversion, pasteurized cream is aged to induce crystal formation. Crystallization of milk fat in cream is essential for butter making to form a continuous fat network during churning. Controlling crystallization of milk fat in cream is very important for the final quality of butter because crystal number and size, crystal size distribution, solid fat content (**SFC**), and polymorphic form affect the microstructure of butter (Rønholt et al., 2013). In bulk fats, crystallization can be controlled by processing conditions such as crystallization temperature, cooling rate, and agitation rate (Tang and Marangoni, 2007). High shear rates and low temperatures promote nucleation (Herrera and Hartel, 2000a; Pérez-Martínez et al., 2012). In addition, better heat transfer generated by high agitation rates may promote co-crystallization of triacylglycerols (**TAG**; Breitschuh and Windhab, 1996). Slow cooling rates can yield large and dense crystals, whereas high cooling rates generate narrow crystal size distributions (Herrera et al., 1999; Herrera and Hartel, 2000a; Wiking et al., 2009). High cooling rates can also result in high SFC of anhydrous milk fat (Herrera and Hartel, 2000b; Campos et al., 2002). Small size of crystals associated

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with high cooling rate will ultimately lead to harder materials (Kaufmann et al., 2012a,b).

Crystallization in oil-in-water emulsions such as cream is more complicated than in bulk fat because crystallization occurs within the oil droplets. Crystallization in oil-in-water emulsions is often thought to be driven by primary nucleation because oil droplets are too small to contain impurities. Coupland (2002) pointed out that crystallization behavior of emulsions is affected by the TAG composition of the fat phase, the compatibility of TAG, and the type of emulsifier. In addition, emulsion droplet size can affect the crystallization behavior in oil-in-water emulsions. Walstra et al. (2005) mentioned that partial coalescence rate during churning increases with increasing milk fat droplet size in cream because the chance of colliding globules increases with increase of globule size. Tippetts and Martini (2009) and McClements et al. (1993) observed that smaller droplets hindered and inhibited crystallization in oil-in-water emulsions. More uniform small droplets can lead to homogeneous crystallization because nucleation is more likely to occur from the fat and not from impurities present in the emulsion (Rousseau, 2000; Coupland, 2002).

Similarly, crystallization of milk fat globules in cream is influenced by many factors such as cooling rate, aging time and temperature, churning temperature, and phase inversion that occurs during churning (Walstra et al., 2005; Rønholt et al., 2012, 2014a,b; Buldo et al., 2013). Few studies have evaluated the effect of various processing conditions in cream to change butter quality. For example, to understand how processing of cream influences butter quality, some studies have studied the effect of aging time and temperature, cooling rate, and churning temperature on the physical properties of cream and butter. Bylund (2003) and Walstra et al. (2005) stated that the heat treatment history before churning including aging time and temperature, and temperature fluctuations affect the rate of partial coalescence and crystallization behavior in the globules. Walstra et al. (2005) stated that solid fat is required for partial coalescence, but too much solid fat in globules delays partial coalescence due to the lack of liquid oil phase to develop a bridge between droplets. Rønholt et al. (2012) reported that cream temperature during aging can influence the crystallization behavior. These authors reported that more stable crystals could be formed when cream is aged at lower temperature due to a higher degree of shear by a longer churning time. Rønholt et al. (2014b) also examined the effect of churning temperature (22.8 and 10.8°C) on water droplet size and water content and on rheological properties of the butter. When cream was aged and churned at 22.8°C, the butter had bigger water droplets and lower SFC compared with the cream aged and churned at 10.8°C; however, churning temperature did not affect the water content of butter. In addition, cooling rate of the cream before churning can affect the water content and the rheological properties of butter. Rønholt et al. (2014) reported that a harder butter was produced with a fast cooling rate (7.5°C/min) compared with butter produced with a slow cooling rate (0.4°C/min) because of a shorter churning time of slowly cooled cream. A shorter churning time can be expected in slow-cooled cream because larger crystals formed at a slow cooling rate are more prone to damage the milk fat globule membrane than smaller crystals for partial coalescence, which is required for phase conversion (Boode and Walstra, 1993; Rønholt et al., 2014a). No difference was found in water content between the butters that were made with slow- and fast-cooled cream (Rønholt et al., 2014a). Even though these studies provide valuable information on how processing conditions of cream affect the physical properties of butter, no research has assessed the combined effect of agitation rate and aging temperature on the quality of butter.

Thus, the objective of this study was to evaluate the combined effect of agitation rate and aging temperature before churning on the physical properties of butter such as hardness, thermal behavior, and water content in a model system. Agitation and temperature are 2 important processing parameters that affect fat crystallization; therefore, it was our hypothesis that the combination of these 2 parameters will affect churning time and therefore physical properties of butter.

MATERIALS AND METHODS

Butter Making

Pasteurized heavy whipping cream (40% fat; Organic Valley, La Farge, WI) without stabilizer was purchased at a local grocery store. Cream (100 g) was heated to 55°C for 30 min in an oven to erase crystal memory and then transferred into a jar in a water bath that was set up to 1 of 3 aging temperatures (5, 10, and 15°C). These 3 temperatures were within normal aging temperatures (Chandan et al., 2015). The cream was aged for 90 min while agitated with an overhead stirrer (IKA RW basic 16, IKA, Wilmington, NC) at 0 rpm (no agitation; **NA**), 40 rpm (low agitation; **LA**), or 240 rpm (high agitation; **HA**). The slowest agitation level chosen in our study was the minimum speed that was allowed by the stirrer, and the highest agitation level chosen was the maximum speed allowed without splashing cream. These agitation speeds are within the