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Australian milk fat—Seasonal and regional variation of melting properties

Cornelis Versteeg,* Amy Logan,*[1] and Warren Müller†
*CSIRO Food and Nutrition, 671 Sneydes Road, Werribee, Victoria, Australia, 3030
†CSIRO Digital Productivity, GPO Box 664, Canberra, ACT, Australia 2601

ABSTRACT

The solid fat content and dropping point of milk fat obtained over 2 yr and from 19 bulk milk production sites across Australia were characterized. Solid fat content at 5°C and 20°C, respectively, ranged between 49.9 and 66.1% and between 14.6 and 29.6% across all sites. Dropping point ranged between 30.5 and 35.4°C. The dropping point did not correlate with solid fat content at lower temperatures across several sites, indicating that it is not an accurate or useful measure of functionality at temperatures of 15°C or below. Although at times, considerable variation was observed in milk fat melting properties between sites located in similar geographic regions, statistical analysis by means of boxplots and multidimensional scaling revealed broad similarities within regions over the 24 mo. Multidimensional scaling also revealed similarities between some quite distant and diverse regions (e.g., Queensland and South Australia with constant and seasonal production, respectively). These analyses were used to make 5 groups from the 19 sites to describe seasonal melting properties. The groups with sites in west Victoria, southeast Victoria, and Tasmania showed the largest seasonal variation and range of values, with peaks and lows in southeast Victoria and Tasmania occurring up to 3 mo later than in west Victoria. The group with sites in New South Wales, Queensland, and South Australia had the least variation and range of values, which were relatively high throughout. The group with Western Australian sites showed medium levels of variation but distinct seasonal patterns, with solids fats typically below and dropping points higher than the national average. The Victorian group's lows in dropping point occurred about 2 mo later than did the low values of solid fat content. No single factor stood out as determining the variation in melting properties.

Key words: milk fat, melting properties, solid fat content, dropping point

INTRODUCTION

Considerable regional variation occurs from country to country, or regions thereof, in milk composition and functionality with diet, stage of lactation (Kefford et al., 1995), and season (Johnson, 1965; Precht, 1994). This includes the melting properties of milk fat based on the solid fat content (Cox and McDowall, 1948; Norris et al., 1973; Auldist et al., 1998; Walker et al., 2013). Melting properties are an important characteristic of milk fat for processors and consumers alike, as they affect properties such as butter spreadability (Norris et al., 1973), oiling off (Cullinane et al., 1984) and "stand up" (i.e., the relative change in height of a plug of butter) in hot climates (Banks et al., 1983); suitability of milk fat for pastry and other baked products (Deffense, 1993); the whipping properties of cream (Smith et al., 2000); foam stability (Bazmi et al., 2007; Huppertz, 2010); oxidative stability (Hillbrick and Augustin, 2002); and the suitability of milk fat for further processing such as blending and fractionation (Deffense, 1993; Shen et al., 2001).

Milk fat has a large melting temperature range of about −40 to 40°C (Kankare and Antila, 1988; Lopez et al., 2007) and contains both liquid and solid fat fractions under refrigerated storage conditions. Using differential scanning calorimetry (**DSC**), Kankare and Antila (1988) noted 84.1% of milk fat to be in a solid state at 0°C. This decreased to 64.8% at 10°C and the fat was completely melted at 38°C. As such, milk fat exhibits melting over a wide temperature range rather than the sharp melting point of pure substances (Deman et al., 1983) or the narrow range exhibited by some other edible fats, such as hardened coconut oil (Kaisersberger, 1989). Measures for melting and solidification points quantify the end and starting points of this range to some level of certainty (McCarthy, 2006). Common methods of analysis for solid fat content (**SFC**) and the melting properties of a sample as a function of temperature include low-field nuclear magnetic resonance (**NMR**; Knightbridge and Black, 1978; Auldist et al., 1998), DSC (Kankare and Antila, 1988), near-infrared (**NIR**) spectroscopy (Meagher et al., 2007), and ultrasound velocity (McClements and

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[1]Corresponding author: amy.logan@csiro.au

Povey, 1987). Analysis using NMR and NIR can quantitatively determine the proportion of solid to liquid milk fat at a given temperature, whereas DSC and ultrasound techniques provide information about the melting profile of a sample over a temperature range. All measures, however, can be influenced by tempering or temperature cycling (Boode et al., 1991) and it is essential that samples be completely melted before analysis (usually to 60–70°C) to remove the thermal history, and cooled under standardized conditions. The solid fat content measured by NMR and that derived from DSC measurements can be quite different (Walker and Bosin, 1971), which must be kept in mind when comparing literature values.

A study investigating the thermal properties of milk fat in New Zealand found that the degree of fat in a liquid state was higher in July (mid-winter) compared with October and November (mid- to late-spring), so that SFC increased as the first half of the milking season progressed. The amount of SFC was then observed to decrease into autumn, although not returning to the original July value (Norris et al., 1973). This agrees with Auldist et al. (1998), and as such, maximum hardness in New Zealand butter occurs in mid-summer, whereas the softest butters are made in the spring (Cox and McDowall, 1948; Dolby, 1949; MacGibbon and McLennan, 1987). A study measuring butter firmness and milk fat SFC from factories in the southeast (Gippsland), southwest, and northern regions of Victoria in Australia showed a significant difference in SFC based on region at 5 and 15°C, but not at 25°C (Knightbridge and Black, 1978). This was similar to the observations of Meagher et al. (2007) in New Zealand butter for SFC between 10 and 20°C. Knightbridge and Black (1978) found higher levels of SFC from samples collected in the southwest region compared with the other Victorian locations between December and March (summer). Moreover, the SFC of milk fat from both southwest and southeast Victoria progressively decreased from March onward but remained constantly high between December and May in samples from the northern region. All regions recorded low SFC levels during the winter period.

Following the work of Knightbridge and Black (1978), a 2-yr Australian-wide survey was conducted in 1994 and 1995. In that study, milk fat properties were determined each month from 19 bulk collection or processing sites in broadly 8 geographic regions spread across Australia. A small part of the data was previously published with limited interpretation (Papalois et al., 1996; Thomas and Rowney, 1996). Considering the richness of the data set, we believe that it is important to further analyze, interpret, and publish the results of this reference work in much more detail. This survey is unique as it covered 2 complete consecutive years and a large number of geographical, climatic, and production system differences within Australia. This work will provide benchmarks for any changes in milk fat properties that may be found in future studies. Furthermore, the confidentiality on the locations of the participating sites has been lifted, allowing a more meaningful interpretation and reporting of the results than was possible at the time of the survey.

In this examination, the geographical, climate, and some farming practices of the surveyed production regions will be detailed. Low-field NMR analysis was used to define the SFC of milk fat extracted from the collected milks and products at 0, 5, 10, 15, 20, 25, 30, and 35°C. Further, the milk fat Mettler dropping point (**DP**) was measured, which determines the temperature at which the first drop of milk fat is detected upon heating from a chilled start-point (Timms, 1978). The fatty acid compositions and triglycerides will be presented, together with any correlations between properties and composition, in subsequent publications.

MATERIALS AND METHODS

Sample Sites

Nineteen bulk milk collection sites were surveyed (most of these were also dairy product manufacturing factories). These were located in New South Wales (1 site at the central coast), Queensland (2 sites in the southeast), South Australia (1 site in the southeast), Tasmania (3 sites in the north of the island), Victoria (3 sites in the southwest, 3 sites in the north, and 3 sites in the southeast, or "Gippsland"), and Western Australia (3 sites in the southwest). A single herd research farm in Ellinbank, eastern Victoria, also took part in the survey. Figure 1 shows the geographic location of the participating sites. Seasonal milk production data were made available by several of the participating sites, and weather data and typical farming data were collected where possible. Tables 1 and 2 list the participants and detailed locations of the sites.

Sample Collection and Preparation

Whole milk, cream, butter, or anhydrous milk fat (**AMF**) samples were collected at 2 different times of 2 consecutive days in the middle of the month and sent refrigerated overnight to the laboratory. Samples were frozen until further processing within a month. The same type of product sample was collected from each location for the duration of the survey and AMF prepared accordingly with the remaining steps required;