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Effect of double boiler heat treatment on the physicochemical properties of sweetened condensed filled milk

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Abstract

Sweetened Condensed Filled Milk (SCFM) is a widely used concentrated milk product in Malaysia. While there have been numerous articles on the physicochemical analysis of sweetened condensed filled milk (SCFM), not much research has been done on the effect of heating temperature on its physicochemical properties. This study investigated the impact of heating temperature on the physicochemical properties of SCFM using a 10 L double boiler. SCFM was heated at different temperatures (50°C, 60°C, 70°C, 80°C, and 90°C) and analysed for various properties such as total soluble solids (TSS), pH, carbohydrates (lactose, sucrose, and glucose), colour, water activity, moisture content, particle size analysis, and viscosity. The study found that higher heating temperatures decreased moisture content and increased TSS, protein and viscosity of the SCFM sample. The water activity of SCFM was found to be below 0.85, indicating a low risk of microbial contamination. Increasing the heating temperature significantly ($p < 0.05$) affected the colour, particle size and carbohydrate content (lactose, sucrose, and glucose) of the SCFM. Based on the analysis, a heating temperature of 70°C for 60 mins was chosen as the most suitable processing parameter for producing SCFM with acceptable physicochemical properties. In conclusion, this study sheds light on the impact of heating temperature on the physicochemical properties of SCFM and provides insights into the optimal conditions for producing SCFM with desirable properties.

1. Introduction

Sweetened condensed filled milk (SCFM) is a concentrated milk product produced by evaporating milk with added sugar to form a nearly saturated sugar solution. The fat content in SCFM may be derived from vegetable sources such as palm oil and soybean. Its extended shelf life is attributed to the high sugar concentration (Siahaan, 2002; Olaoye, 2015; Dian *et al.*, 2017). According to the Malaysian Food Regulation (Ministry of Health Malaysia, 1985), SCFM must contain a minimum of 8% milk fat and 28% total milk solids, with the fat derived from vegetable sources rather than exclusively from milk fat. Due to the limited availability of fresh milk from non-major fresh milk producers, milk powder, which has lower fat content, is often used (Nieuwenhuijse, 2016). Consequently, additional fat from alternative sources is added to meet the stipulated requirements. In Malaysia, two comparable commercial products that are popular among consumers are sweetened condensed milk (SCM) and sweetened creamer. While SCM incorporates a distinct source of fat, its application parallels that of SCFM. It finds widespread use in the preparation of sweet desserts such as ice cream, cakes, and cookies. Additionally, it is commonly employed for sweetening and whitening coffee and tea (Guimarães *et al.*, 2020; Jouki *et al.*, 2021; Fang *et al.*, 2023). Due to this widespread usage, SCFM and similar products are heavily consumed in Malaysia on a daily basis (Kasim *et al.*, 2018). Heating is a crucial step in the production of concentrated dairy products, as it significantly affects the quality of the final product (Tan, 2009; Lin *et al.*, 2018; Rafiee Tari *et al.*, 2021). It plays a key role in extending the shelf life of dairy products (Fox *et al.*, 2015). Previous research has shown that heating causes a change in colour in dulce de leche, a product similar to SCFM (Silva *et al.*, 2020), and increases the particle size of casein concentrate (Sauer and Moraru, 2012). Furthermore, increasing the

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temperature during the heating process can lead to an increase in the viscosity of whey protein (Jiang *et al.*, 2018). Various heating temperatures have been used for the production of concentrated products like SCM. For example, Tan (2009) found that a heating temperature of 80 to 85°C for 15 to 25 mins produced the desired initial viscosity with delayed age-thickening, while Nieuwenhuijse (2016) reported that heating at 105 to 120°C for 15 to 60 mins produced SCM with delayed age gelation. It is important to control the heating process to achieve the required viscosity level, prevent separation during storage, and avoid age-thickening (Chandan and Kilara, 2011; Sutariya *et al.*, 2017; Bista *et al.*, 2021; McCarthy *et al.*, 2022). Despite many studies on the physicochemical analysis of SCFM (Gaze *et al.*, 2015; Olaoye, 2015; Renhe *et al.*, 2017; Rahman *et al.*, 2019; Jafari *et al.*, 2021), no study has investigated the effect of different heating temperatures on the physicochemical properties of SCFM. Therefore, this study was carried out to determine the effect of temperature on the physicochemical properties of SCFM using a newly fabricated double boiler machine and to identify the suitable heating temperature for the production of SCFM product.

2. Materials and methods

2.1 Materials

Super olein palm oil used in this study was a kind gift from Sime Darby Oils Pasir Gudang Refinery Sdn Bhd. Skim milk was procured from Promac Industry, the sucrose was purchased from Mydin supermarket in Selangor, while the glucose syrup was bought from Meilun Food Chemical Sdn Bhd, Selangor, Malaysia.

2.2 Preparation of sweetened condensed filled milk

SCFM was prepared by combining skim milk (1.2 kg), sugar (2.4 kg), glucose syrup (300 g), super olein (480 mL), and distilled water (1.62 L), according to the formulation and methodology outlined by Zakaria (2018) with minor modifications. The SCFM was processed using a 10-litre capacity double boiler equipment (Figure 1), consisting of a vacuum fan, double boiler, temperature probe, and paddle agitator. This equipment was designed and manufactured by a local company, Zul Design Autotronic, in Selangor, Malaysia.

First, the skim milk, water, sugar, glucose liquid, and super olein were weighted, placed in a stainless-steel pot and mixed using a hand blender (Panasonic -MX-GS1, Malaysia) for 5 mins. Then, the mixture was transferred to the double boiler, to be heated at 50°C, 60°C, 70°C, 80°C, and 90°C for 60 mins with continuous stirring. The stirring action was facilitated by the paddle agitator, operating at a speed of 300 rpm. The range of temperature and time was chosen based on several preliminary experiments and by comparing the physicochemical properties of SCFM to a commercial sample, which was used as the control. After the heating process, the SCFM was rapidly cooled, aseptically filled into sterile cans and hermetically sealed using a double seamer machine (Metal Box Co.). The canned SCFM was then stored at room temperature (28±2°C) and was analysed within three days of storage.

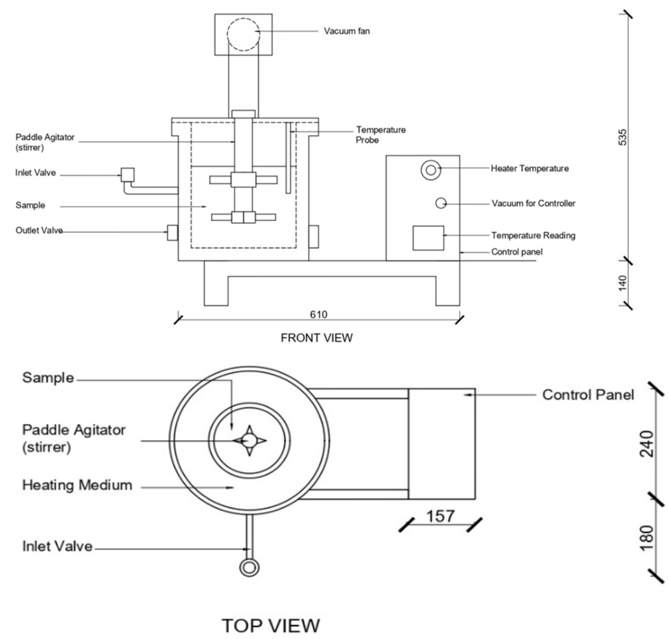

Figure 1. Schematic diagram of double boiler designed by Zul Design Autotronic.

2.3 Analysis

2.3.1 pH

The pH value of SCFM was determined using a calibrated pH meter (Delta 320) following the method by Geetha *et al.* (2015). The pH meter was calibrated against a standard buffer solution of pH 7.0 and 4.0 (Systerm) before use. About 10.0 g of SCFM sample was thoroughly mixed with 10 mL distilled water in a 50 mL beaker. The electrode was placed in the solution, and the pH value was recorded at room temperature (28±2°C).

2.3.2 Total soluble solids

Total soluble solid was determined by using a hand refractometer (Atago Brix ˚N1 Model, USA). A drop of sample was placed on the prism, and the TSS was read directly.

2.3.3 Crude Protein

The crude protein content of the sample was determined according to the AOAC Official Method 991.20 (AOAC INTERNATIONAL, 2016). First, 1.000 g of the sample was transferred to a 250 mL digestion tube. Two catalyst tablets and 12 mL of sulphuric acid were added to the tube. The tube was then placed in a tube rack and heated until the digestor reached 420°C for 45 mins, or until the mixture became clear. The tube was cooled to room temperature prior to distillation. Next, the digestion tube containing the digested sample was attached to the distillation unit. To start the distillation process, 50-75 mL of distilled water and 50 mL of NaOH (40%) were dispensed from the unit. Steam distillation was then initiated. The volume of 0.1 N HCl required for the distillate was recorded. A blank sample was also analysed. Protein percentage was calculated as follows:

$$\% \, Protein = \frac{(\text{mL sample} - \text{mL blank}) \times \text{Concentration of HCl} \times 1.4007 \times \text{Factor}}{\text{Sample weight}} \quad (1)$$

2.3.4 Colour

The colour parameters were measured using a chromameter (CR-410, Konica Minolta Sensing, Inc., Japan). The instrument was calibrated against a standard white tile before measurements. The colour was expressed in terms of L*(lightness, 0 = black, 100 = white), a* (+a* = red, -a* = green) and b* (+b* = yellow, -b* = blue) (Pathare *et al.*, 2013). Chromaticity (*C**, Eq. (1)) and Hue angle (*h**, Eq.(2)) were calculated based on Pathare *et al.* (2013).

$$C* = (a*^2 + b*^2)^{1/2} \quad (2)$$

$$h* = \tan -1\left(\frac{b*}{a*}\right) \quad (3)$$

2.3.5 Water activity

Water activity was determined using the Aqualab Model Series 3 TE at 25°C (Pullman, USA). The sample was filled to half a cup and placed into the sample container of the water activity meter. The reading was read directly.

2.3.6 Moisture content

The moisture content was determined using the vacuum oven method based on Nielsen (2010), with minor modifications. A 3.000 g sample was weighed in a clean aluminium dish (W1), placed in a vacuum oven at 70°C, and dried until a constant weight was obtained (W2). The moisture content of the sample was calculated using the following formula:

$$\% \text{ Moisture} = (W1 - W2) \times 100 / \text{sample weight (g)} \quad (4)$$

where, *W1* = Initial weight of aluminium dish + sample in g; and *W2* = Final weight of aluminium dish + sample in g.

2.3.7 Particle size analysis

The particle size of SCFM was measured using the Malvern Mastersizer 2000 (Malvern Instruments Ltd., UK). Approximately 1.0 to 2.0 g of SCFM sample was dispersed in distilled water until the laser obscuration value was within the acceptable range. The refractive indices of particles and dispersant (distilled water) were set at 1.520 and 1.330, respectively (Mercan *et al.*, 2018). The results were expressed as: D [4,3] volume weighted mean diameter; D [3,2] surface weighted mean diameter; span, which measures the width of the distribution; and uniformity, which measures absolute deviation from the mean.

2.3.8 Viscosity

A rheometer (MCR 72, Austria) was used to determine the rheological properties of the SCFM. Measurements were conducted using CP 25-1 cone plate geometry at 1.004° cone angle with cone truncation of 47 µm. The gap was set at 0.047 mm for each run. The shear rate applied was 1 to 1,000 s^{-1} for 45 s.

2.3.9 Carbohydrates

The analysis of carbohydrates (lactose, sucrose, and glucose) was performed using high-performance liquid chromatography (HPLC) following the AOAC Official Method 977.20. Firstly, 5.000 g of SCFM was weighed in a small beaker and transferred to a 50 mL volumetric flask. The flask was filled up to volume with distilled water. The solution was diluted by adding 50 mL of acetonitrile (ACN). Then, the solution was filtered through a 0.45µm filter using a clarification kit. The filtered samples were injected (10 µL) into the liquid chromatograph (Jasco LC-Net II/ADC), with the detector ELSD variant 385-LC using a 4.6 × 250 mm column (Zorbax Carbohydrate, Agilent, USA). The mobile phase was deionised water (75% ACN: 25% deionised water) at a flow rate of 1.5 mL/min (isocratic). HPLC chromatograms were obtained using LC Solution software (Agilent, USA). Quantitation was performed by an external standard method using lactose, glucose, and sucrose (Sigma–Aldrich, USA) as standards. Then, 10 µL standard solution was injected into the chromatograph. The retention times and peak heights were recorded, and the reproducibility was checked. Concentration of lactose, glucose, and sucrose was calculated from integrator values of peak heights as follows:

$$\text{Weight of sugar (\%)} = 100 \times (PH/PH') \times (V/V') \times (W'/W) \quad (5)$$

where *PH* and *PH'* are the peak heights of the test solution, respectively. *V* and *V'* are mL of test and standard (50 and 100) solutions, respectively. *W* and *W'* are g test portion (5.000) and standard, respectively.

2.4 Statistical analysis

The means of three replicates of each reading were used to analyse the data. Analysis of variance and Tukey

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Pairwise comparison were used to detect differences between samples for all analyses except for total soluble solids, with significant differences valued at P < 0.05. Data were analysed using Minitab 18.

3. Results and discussion

3.1 pH, total soluble solids and protein content

The pH value serves as an important indicator of SCFM quality, exerting influence on the viscosity of milk during the heating process (Anema *et al.*, 2003). Figure 2 illustrates the pH variations in SCFM following heat treatment at different temperatures. The results demonstrate a significant ($p < 0.05$) increase in SCFM pH with the rising temperatures, similar to the observation of Haq *et al.* (2014) in their study of skimmed milk. Elevated heating temperatures led to a reduction in lactic acid, thereby causing an increase in pH. Notably, this experiment did not observe a decline in pH due to thermal degradation of lactose, which can occur under more severe heat treatments (Fox *et al.*, 2015). The control sample exhibited a higher pH, but the reason for this difference is unknown since factors affecting pH, such as processing time and temperature, and formulations for the control sample were unavailable for comparison (Aydogdu *et al.*, 2023).

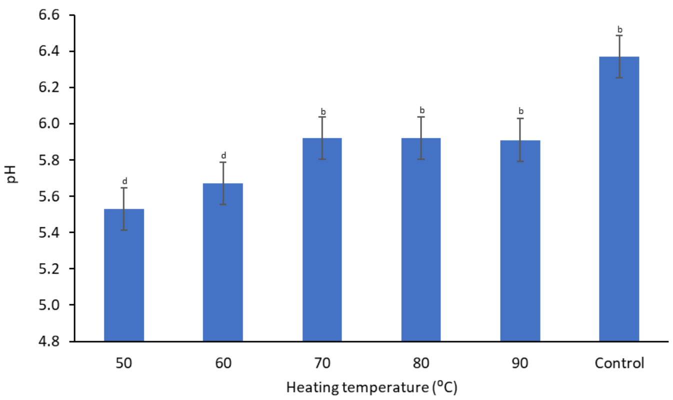

Figure 2. Effect of heating temperature on pH of SCFM. Bars with different notations are significantly different ($p<0.05$).

The concentration of total soluble solids (TSS) in SCFM increased as the temperature was increased, as illustrated in Figure 3. This rise in concentration can be attributed to the phenomenon of water loss during the heating process. As the sample undergoes heating, the reduction in available space within the sample for water content contributes to a more concentrated solution (Reh and Gerber, 2003). In this case, the increase in concentration primarily accounts for the rise in total solids, with sucrose being a major component of these solids. Therefore, the higher temperatures during heating lead to a reduction in water content, resulting in an increase in the total soluble solids of SCFM.

The results from Figure 4 show that increasing the heating temperature had a significant effect on the protein content of SCFM. As the temperature increases, there is a discernible rise in protein concentration within the sample. This observed increase in protein content is probably attributed to the thermal effects on the composition of SCFM. Higher temperatures intensify molecular motion, leading to the disruption of hydrogen bonds that maintain water molecules' structure in SCFM. Consequently, the water vapour is released, reducing the overall moisture content in the sample. Since protein content is measured on a weight basis, the decrease in water content concentrates the protein within the remaining mass, resulted in an increase in protein concentration. Concurrently, the increase in the TSS of SCFM as depicted in Figure 3 supports the proposition that the observed rise in protein concentration is, in part, a consequence of reduced moisture content due to the applied heating treatment.

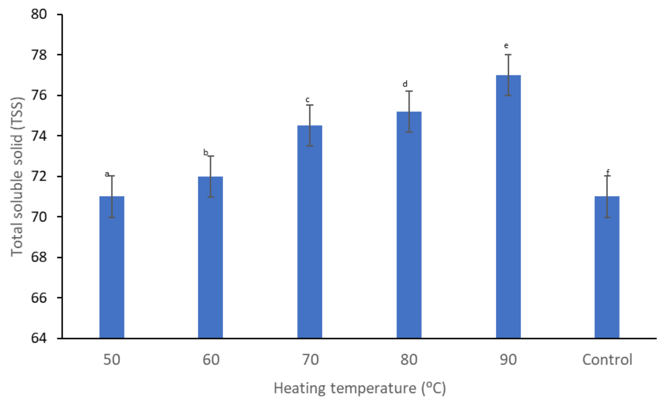

Figure 3. Effect of heating temperature on total soluble solid of SCFM. Bars with different notations are significantly different ($p<0.05$).

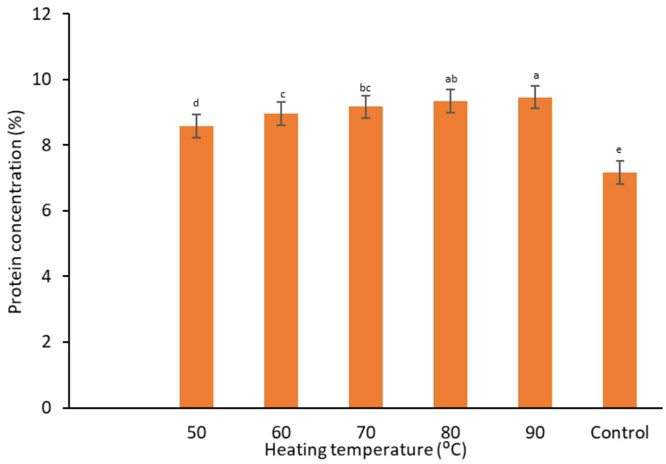

Figure 4. Effect of heating temperature on protein concentration (%) of SCFM. Bars with different notations are significantly different ($p<0.05$).

3.2 Colour

Colour is an essential quality parameter for SCFM. Notably, there were significant differences in L* values at various temperatures ($p < 0.05$), as illustrated in Figure 5. As the temperature increases, the L* values of

SCFM decrease (indicating darker colours), the a* values become more negative (indicating a shift towards greenness), while the b* values increase, suggesting more yellowness. This observation implies that at higher processing temperatures, the SCFM changes to more intense colours, increased greenness, and higher yellowness. The commercial sample has distinct colour characteristics; being darker, redder, and slightly more yellow compared to all the heated samples.

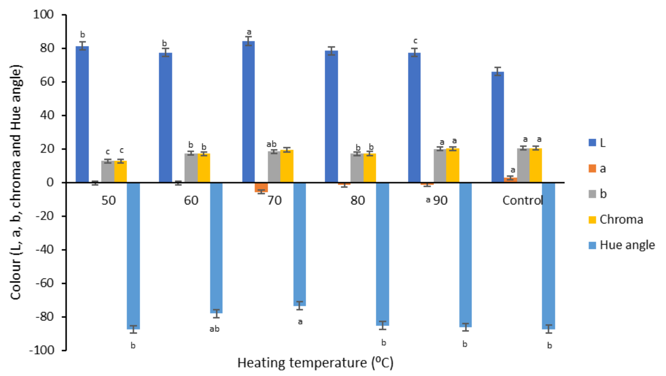

Figure 5. Effect of heating temperature on colour characteristics of SCFM. Bars with different notations are significantly different ($p<0.05$).

Meanwhile, the chroma values of SCFM showed an increment at higher heating temperatures, indicating an increase in colour intensity or saturation. While the hue angle of all the samples changes with temperature, indicating the shifts in the dominant colour. This observation suggests that as the heating temperature increases, there is an increase in colour intensity (chroma values) of SCFM. The hue angle remains relatively stable, indicating a consistent dominant colour, with a subtle shift observed at 90°C. The commercial sample shows a slightly higher chroma value and a hue angle, similar to the SCFM at 80°C and 90°C, but with a slight difference. The observed variations in colour parameters of SCFM may be attributed to the intricate dynamics of the Maillard reaction, a non-enzymatic browning process implicated in the development of colour in thermally treated foods (Starowicz and Zieliński, 2019). The Maillard reaction ensues when reducing sugars react with amino acids, culminating in the formation of melanoidin as the final product. In the context of the current study, the impact of heating temperature on the Maillard reaction is evident through alterations in luminosity (L*), redness (a*), and yellowness (b*) of the SCFM. A similar observation was reported by Barrios-Rodríguez *et al.* (2021), in their study on dulce de leche. Furthermore, the intricate relationship between temperature and the progression of the Maillard reaction is well-established in the literature (Yanez *et al.*, 2018). In summary, the colour characteristics of the SCFM vary with temperature, showing trends towards increased intensity, shifts in dominant colours, and changes in darkness and hue. However, even at higher temperatures, there are differences compared to the commercial sample, which remains generally more intense with a unique colour profile.

3.3 Water activity and moisture content

Water activity and moisture content are important parameters in assessing the safety and quality of food products. In this study, the effect of heat treatment on water activity and moisture content of SCFM was investigated. The results presented in Figure 6 illustrate a noticeable decline in water activity as the heat temperature increases from 70°C to 80°C. This parameter holds significant importance in anticipating the proliferation of microorganisms in food, as it delineates the availability of free water crucial for microbial growth (Chirife and Fontana, 2020). Notably, Figure 6 reveals that the average water activity of both the SCFM and control samples ranged from 0.80 to 0.83, which falls within the reported recommended range. Besides the effect of heat treatment, the inclusion of sucrose as the primary component in SCFM, along with the presence of milk salts and lactose, contributes to the product's relatively low water activity (Nieuwenhuijse, 2016). Essentially, within this water activity range, food products are generally safe from certain pathogenic bacteria, such as Staphylococcus aureus (Tan, 2009; Ross, 2020). However, it is crucial to note that at this water activity level, osmophilic yeasts and moulds, which exhibit greater tolerance, may still survive.

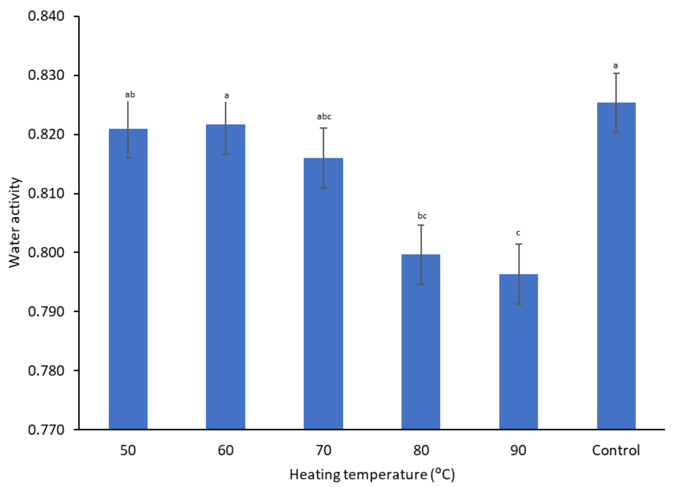

Figure 6. Effect of heating temperature on water activity of SCFM. Bars with different notations are significantly different ($p<0.05$).

The moisture content of food refers to the amount of water present in a given food product. Figure 7 shows that the moisture content of SCFM decreased with increasing heat temperature. This decrease is likely due to the increase in evaporation rate caused by the higher temperature, which leads to a declining trend in moisture

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content (Abasi *et al.*, 2009). The reduction in moisture content can also affect the physical and sensory properties of the food, such as texture and taste (Kanavouras *et al.*, 2020). Therefore, it is important to consider the effects of heat treatment on water activity and moisture content when evaluating the safety and quality of SCFM.

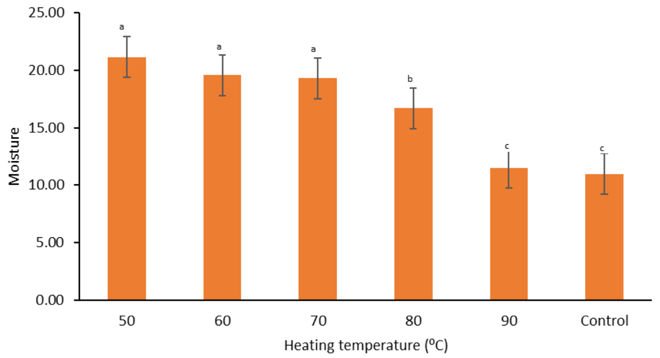

Figure 7. Effect of heating temperature on moisture content of SCFM. Bars with different notations are significantly different (p<0.05).

3.4 Particle size analysis

Particle size analysis is a crucial method in evaluating the stability of food emulsions. The results in Figure 8 illustrate the effect of different heating temperatures on the particle size of SCFM. The D [3, 2] and D [4,3] values indicate the surface mean diameter and volume mean diameter of particle size, respectively. The findings demonstrate that increasing the heating temperature results in an increase in particle size. This phenomenon can be attributed to the denaturation of whey protein, which leads to the formation of aggregates and an increase in the casein micelle size (Nguyen and Anema, 2010; Leong *et al.*, 2018; Markoska *et al.*, 2019).

Bienvenue *et al.* (2003) noted that whey protein denatures at a temperature of 70°C, explaining the observed increase in particle size values at heating temperatures ranging from 80°C to 90°C in Figure 8. Additionally, Tangsuphoom and Coupland (2005) reported that heating temperatures above 70°C can induce the flocculation of SCFM emulsion droplets, resulting in an increase in particle size.

The span value and uniformity are important indicators of the particle size distribution, and their values provide useful insights into the stability and homogeneity of food emulsions. A narrower distribution with a lower span value indicates a more uniform particle size distribution. Figure 9 shows the particle size distribution of SCFM samples, with different heating temperatures and a control sample. The control sample exhibited a bimodal distribution and a higher span value, wider peak, indicating a high distribution of particle sizes and a less homogeneous particle size distribution. In contrast, the samples treated at different heating temperatures exhibited a unimodal distribution, suggesting a more homogeneous particle size distribution. The bimodal distribution observed in the control sample was caused by coalescence (McClements, 2007).

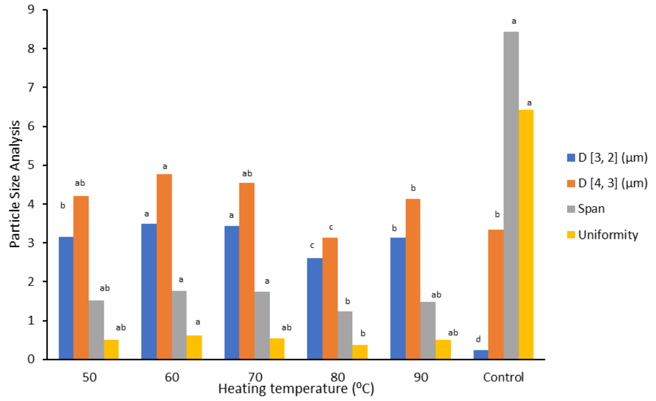

Figure 8. Effect of heating temperature on particle size analysis of SCFM. Bars with different notations are significantly different (p<0.05).

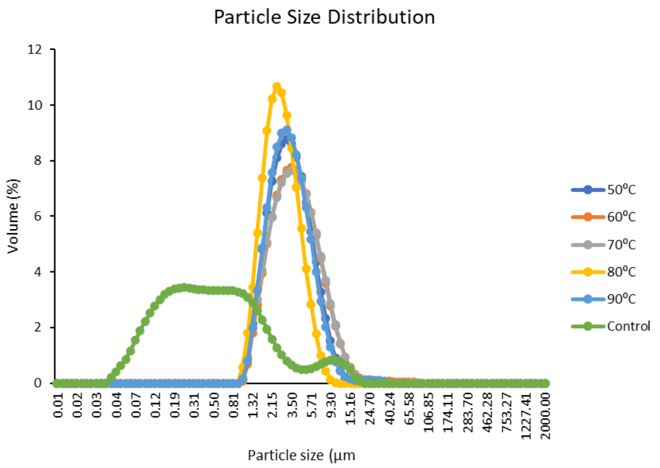

Figure 9. Volume (%) against particle size (μm) on SCFM at different temperature (°C)

The absence of coalescence observed in all treated SCFM samples indicates that the droplets did not remain in contact for prolonged periods. In contrast to the control, which exhibited coalescence, the treated SCFM samples were analysed within one week of production. On the other hand, the control was analysed after purchasing from the supermarket, with an unknown manufacturing date, likely having been stored for a more extended period. Coalescence is acknowledged as one of the mechanisms leading to emulsion destabilization (Tcholakova *et al.*, 2006). Consequently, these findings suggest that the heating treatment conditions applied in this study effectively prevented coalescence and maintained the stability of SCFM emulsions.

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3.5 Viscosity

Flow curves were quantified based on the Casson model since this model fitted well with the experimental data (correlation coefficients of > 0.98). The yield stress and correlation coefficient were calculated using RheoCompass software (Mezger, 2011).

$$(\sigma)^{0.5} = (\kappa_1)^{0.5}(\gamma)^{0.5} + (\sigma_0)^{0.5} \quad (6)$$

where, σ is shear stress (Pa); γ is shear rate (s^{-1}); μ_0 is plastic viscosity ($Pa.s^{-1}$); σ_0 is yield stress (Pa); κ_1 is Casson plastic viscosity ($Pa.s^{-1}$);

As depicted in Figure 10, the viscosity of SCFM demonstrates an upward trend with higher heating temperatures across all shear rates, except for the sample heated at 90°C. Interestingly, this particular sample exhibited lower viscosity than the one heated at 80°C, specifically within shear rates ranging from 63.1 s^{-1} to 1,000 s^{-1}. It is noteworthy that skim milk is rich in casein micelles, constituting 80% of the total milk protein (Walstra *et al.*, 2006; Chandan and Kilara, 2011). The enlargement of casein micelles resulting from heating can be attributed to the interaction between denatured whey proteins and the casein micelles (Anema and Li, 2003). This increase in micelle size, coupled with alterations in micelle-micelle interaction and whey protein denaturation due to heating, contributes to increase in protein voluminosity, consequently leading to increased viscosity (Bienvenue *et al.*, 2003).

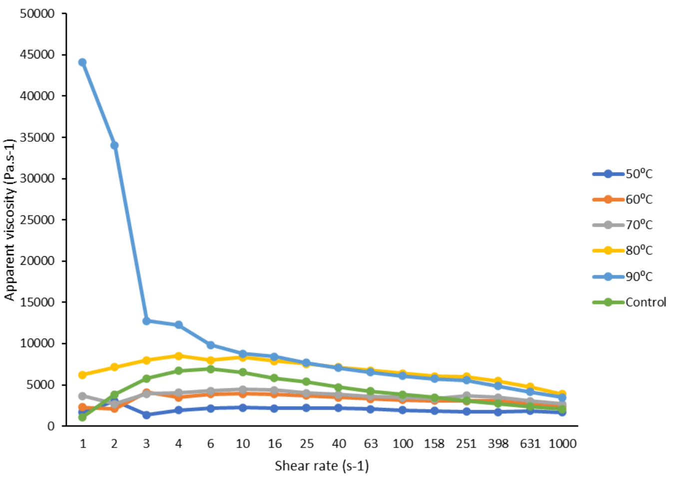

Figure 10. Viscosity (Pa. s^{-1}) of SCFM at different temperature (°C)

Furthermore, the yield stress, representing the minimum stress required for the sample to flow, consistently rises with increasing heating temperature as shown in Figure 11. This suggests heightened interaction forces between casein micelles in the samples, contributing to stronger structure formation (Foegeding *et al.*, 2011). The presence of sugars further enhances the molecular interactions between casein molecules, amplifying the viscosity of SCFM (Dickinson and Matia Merino, 2002). It was clear that the SCFM sample heated at 90ºC exhibited an exceptionally high yield stress, demonstrating a substantial difference when compared to samples treated at lower heating temperatures. This remarkable increase in yield stress at 90ºC suggests the occurrence of exceptionally strong interactions between casein particles and the heat-aggregated whey proteins, as emphasised by Chever *et al.* (2014). These intensified interactions are likely to result in the formation of a highly structured network, contributing to the exceptionally high yield stress observed in the sample heated at 90°C.

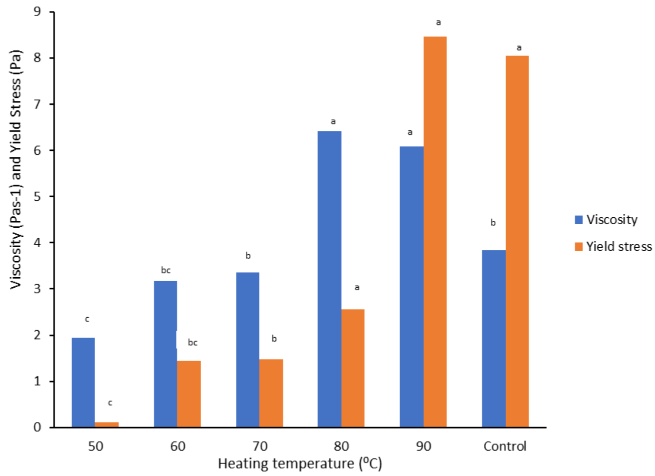

Figure 11. Effect of heating temperature on viscosity and yield stress of SCFM. Bars with different notations are significantly different ($p<0.05$).

3.6 Carbohydrates

High concentrations of sucrose and lactose in SCFM can increase the susceptibility to non-enzymatic browning reactions and lactose crystallisation, which can affect the quality of the product (Gaze *et al.*, 2015). Non-enzymatic browning is a series of chemical reactions between sugars and proteins, and the Maillard reaction is one of the four reactions that occur during non-enzymatic browning (Xiang *et al.*, 2021). In addition, lactose from skim milk can crystallise during the cooling of SCFM, but this process needs to be controlled to prevent the formation of a gritty texture (Tan, 2009). The concentrations of lactose, sucrose, and glucose in SCFM heated at different temperatures were analysed, and Figure 12 demonstrated that only samples treated at 50°C and 70°C and the control showed the presence of glucose. However, no significant differences among all treated samples were observed, indicating that the heating temperature did not affect the levels of sucrose, glucose, and lactose in the samples. This result is supported by Bezie (2019), who stated that carbohydrates are not affected by heat treatment. The presence of glucose can inhibit sucrose crystallisation by adsorbing to the sugar crystal surface (Laos *et al.*, 2007). Lactose is added during the cooling stage to control the

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sandiness effect of the sample, preventing the formation of larger lactose crystals (Nieuwenhuijse, 2016).

The selection of 70°C as a suitable temperature for processing of SCFM was based on considerations of viscosity across shear rates, with the overall readings lower than those of the control sample. Maintaining an appropriate viscosity is critical for SCFM quality, as high viscosity can lead to age-thickening, a phenomenon involving increased viscosity in concentrated dairy products over time (Trinh *et al.*, 2007). Heating of SCFM at 60°C was not recommended due to its larger moisture content and particle size compared to the sample treated at 70°C. Conversely, the viscosity of the sample treated at 50°C was deemed too low, causing it to flow very easily because of its low viscosity.

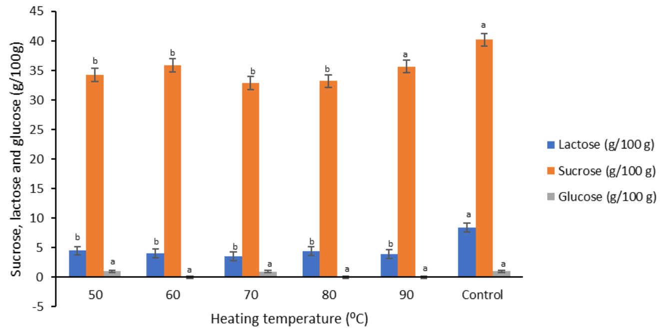

Figure 12. Effect of heating temperature on lactose, sucrose and glucose concentration of SCFM. Bars with different notations are significantly different ($p<0.05$).

In summary, ensuring the quality of SCFM involves not only controlling the concentrations of lactose, sucrose, and glucose but also selecting the right heating temperature. The optimal temperature, in this case, is 70°C, balancing viscosity considerations and avoiding issues related to moisture content and particle size. This careful control contributes to the overall quality and shelf stability of SCFM.

4. Conclusion

In conclusion, this study highlights the substantial impact of heat treatment on the physicochemical characteristics of SCFM. The efficacy of the newly developed double boiler as a tool for heating the sample at various temperatures was demonstrated. Heating temperature emerged as a key factor influencing the moisture content, protein levels, viscosity, colour, and particle size of SCFM. The observed decrease in moisture content at elevated temperatures holds promise for enhancing the stability and shelf life of the product. Furthermore, the rise in protein content and viscosity with increasing heating temperatures presents potential advantages for the textural and sensory qualities of SCFM.

Based on the results of this study, it can be deduced that heating SCFM at 70°C using the newly designed double boiler is the most favourable temperature for SCFM production. This temperature selection resulted in a sample with a viscosity level deemed acceptable, a crucial parameter in assessing SCFM quality. The knowledge derived from this research provides valuable guidance to the dairy industry, facilitating the optimisation of SCFM production with desired physicochemical properties.

Conflict of interest

The authors declare no conflict of interest.

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