

Original Research Article

Influence of Heat Treatment on Flow Behaviour Index of Dairy Cream

Abstract

The objective of the experiment was to gather data on the flow behaviour index of dairy cream under different heat treatments and subsequent temperature changes. Dairy cream samples containing fat percentages ranging from 10% to 80% were exposed to varying heat treatments, including 80°C with no hold, 85°C with no hold, 90°C with no hold, and 95°C with no hold. The flow behaviour index of such heat-treated samples was evaluated at every 10°C upon cooling from 90°C or 80°C as the case may be till 10°C at 250 S⁻¹ shear rate using rheometer. At temperatures of measurement including 10°C, 20°C, 30°C, and 40°C, both the fat content of cream and the heat treatment applied to the cream demonstrated a significant impact ($p < 0.05$) on the flow behavior index, while their interaction effect was found to be not significant ($p > 0.05$). Conversely, at temperatures of measurement ranging from 50°C to 80°C, the fat content of the cream exhibited a significant ($p < 0.05$) effect on the flow behavior index, while the heat treatment applied to the cream and the interaction effect were not significant ($p > 0.05$). Fat content of cream, heat treatment and temperature of measurement showed negative correlation with flow behaviour index. These data are valuable for dairy equipment designers in determining the appropriate sizing of equipment.

Keywords: Dairy cream, flow behaviour index, rheology, cream fat, cream temperature

Introduction

Dairy cream, a yellowish portion of milk abundant in fat globules, can naturally rise to the surface if milk is left to settle and can be mechanically separated (Prentice, 1992). Cream exhibit non-Newtonian flow behaviour (Velez-Ruiz et al., 1997) when sheared. Cooling of cream results in increase in thickness of cream (Prentice and Chapman, 1969). When designing food processing facilities, it's essential to consider numerous factors to guarantee the excellence of the end products. One of these factors is rheology, which pertains to the flow characteristics of products. Particularly in the dairy industry, items such as cream and cultured milk may experience a decline in quality if their flow characteristics are not adequately comprehended or controlled.

Rheology, the study of flow and deformation of materials, is essential in understanding how dairy cream behaves under different processing conditions (Macias-Rodriguez & Marangoni,

2020; Bylund, 2003). Dairy cream typically consists of fat globules dispersed in a continuous aqueous phase. The rheological behaviour of cream is influenced by factors such as fat content, particle size distribution, protein content, and the presence of emulsifiers. Various factors influencing the whipability of creams have been reported, such as their composition, tempering, fat globule size, ultrasound treatment, and homogenization (Amiri et al., 2018; Börjesson et al., 2015; Moens et al., 2016; Edén et al., 2016; Phan et al., 2014; Jakubczyk and Niranjana, 2006; Hotrum et al., 2005; Van Aken, 2001). Hussain et al., (2017) reported that the fat globule size had a significant effect on rheological characteristics of dairy creams.

Heat treatment affects the fat globules in dairy cream. When cream is subjected to heat, fat globules begin to melt and coalesce, leading to changes in the cream's microstructure. This process alters the interaction between fat globules and the continuous phase, which in turn affects the flow behaviour. Proteins present in dairy cream undergo denaturation upon heating. Denaturation alters the protein's structure, leading to changes in its functional properties, including its ability to interact with other components in the cream. This can influence the cream's rheological behaviour by affecting its flow characteristics. The flow behaviour index of dairy cream is often determined using rheological measurement techniques such as rotational viscometry or rheometry. These techniques allow for the quantification of the cream's flow behaviour under various conditions, providing valuable insights into the effects of heat treatment.

In short, heat treatment significantly influences the flow behaviour index of dairy cream by altering its microstructure, phase transitions, protein functionality, emulsion stability and thermal history. Understanding these effects is crucial for optimizing the processing parameters to achieve desired rheological properties in dairy cream products. Hence this experiment was conducted with an aim to investigate the effect of heat treatment on flow behaviour index of dairy cream with varying fat percentage.

Materials and method

Fresh cream samples of different fat content were procured from Vidya Dairy, Anand. The samples were analysed for their fat content (%) using Gerber method mentioned in FSSAI Lab manual 1 (2015) and acidity (%LA) using titration (AOAC 1995). Methodology followed is shown in Figure 1.

Mixed Milk (4°C)



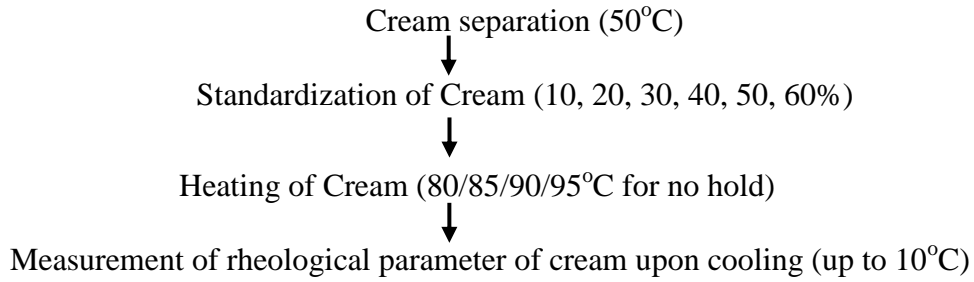


Figure 1 Flow chart for heat treatment to cream

The rheological parameter of cream viz., flow behaviour index was analysed using Rheometer (Make: Anto Paar, Model: RheolabQC, Spindle: CC27). The instrument was calibrated before the measurement of required parameter. The data recorded by the instrument were subjected to completely randomized design and regression analysis.

Results and discussion

The flow behaviour index of cream from 10°C to 80°C is shown in Table 1 to 8. At 10°C, 20°C, 30°C and 40°C temperature of measurement, cream fat and heat treatment given to cream showed significant ($p < 0.05$) effect on flow behaviour index, whereas their interaction effect was non-significant ($p > 0.05$) difference in flow behaviour index. At 50°C, 60°C, 70°C and 80°C temperature of measurement, cream fat showed significant ($p < 0.05$) effect on flow behaviour index, whereas the heat treatment given to cream and interaction effect was non-significant ($p > 0.05$) difference in flow behaviour index. Fat content of cream, heat treatment and temperature of measurement showed negative correlation with flow behaviour index.

Table 1: Flow behaviour Index of cream at 10°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.99±0.01	0.96±0.05	0.90±0.01	0.85±0.02	0.80±0.02	0.72±0.04	0.87
85°C/ No hold	0.99±0.01	0.94±0.04	0.88±0.02	0.83±0.07	0.79±0.04	0.71±0.01	0.85
90°C/ No hold	0.98±0.01	0.92±0.01	0.87±0.02	0.81±0.04	0.78±0.01	0.70±0.01	0.84
95°C/ No hold	0.97±0.01	0.90±0.03	0.87±0.01	0.80±0.03	0.77±0.01	0.70±0.01	0.83
Mean	0.98	0.93	0.88	0.82	0.78	0.70	

CD (0.05) Cream fat=0.03, Heat treatment=0.02, Cream fat × Heat treatment=NS;
CV%=3.18

Values are mean±SD, n=3

Table 2: Flow behaviour Index of cream at 20°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	

80°C/ No hold	0.87±0.01	0.83±0.02	0.80±0.01	0.73±0.05	0.66±0.04	0.61±0.01	0.75
85°C/ No hold	0.86±0.01	0.81±0.01	0.79±0.01	0.71±0.03	0.64±0.01	0.60±0.01	0.73
90°C/ No hold	0.86±0.01	0.81±0.01	0.78±0.01	0.70±0.03	0.63±0.01	0.61±0.02	0.73
95°C/ No hold	0.84±0.01	0.81±0.01	0.78±0.01	0.68±0.01	0.63±0.01	0.54±0.06	0.71
Mean	0.85	0.81	0.79	0.70	0.64	0.59	
CD (0.05) Cream fat=0.02, Heat treatment=0.02, Cream fat × Heat treatment=NS; CV%=3.01							

Values are mean±SD, n=3

Table 3: Flow behaviour Index of cream at 30°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.84±0.02	0.78±0.02	0.74±0.02	0.67±0.03	0.61±0.02	0.53±0.03	0.69
85°C/ No hold	0.83±0.02	0.77±0.01	0.73±0.01	0.67±0.02	0.60±0.02	0.52±0.01	0.69
90°C/ No hold	0.81±0.01	0.76±0.02	0.72±0.04	0.65±0.01	0.59±0.01	0.49±0.01	0.67
95°C/ No hold	0.80±0.02	0.75±0.05	0.70±0.01	0.63±0.02	0.57±0.02	0.47±0.04	0.65
Mean	0.82	0.76	0.72	0.65	0.59	0.50	
CD (0.05) Cream fat=0.02, Heat treatment=0.02, Cream fat × Heat treatment=NS; CV%=3.49							

Values are mean±SD, n=3

Table 4: Flow behaviour Index of cream at 40°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.81±0.03	0.74±0.04	0.66±0.04	0.59±0.01	0.54±0.06	0.51±0.03	0.64
85°C/ No hold	0.80±0.01	0.72±0.02	0.64±0.02	0.58±0.03	0.54±0.05	0.49±0.01	0.63
90°C/ No hold	0.80±0.02	0.71±0.01	0.63±0.01	0.56±0.02	0.53±0.01	0.46±0.02	0.61
95°C/ No hold	0.78±0.04	0.68±0.01	0.61±0.05	0.55±0.04	0.53±0.04	0.43±0.04	0.60
Mean	0.80	0.71	0.63	0.57	0.53	0.47	
CD (0.05) Cream fat=0.03, Heat treatment=0.03, Cream fat × Heat treatment=NS; CV%=5.15							

Values are mean±SD, n=3

Table 5: Flow behaviour Index of cream at 50°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.75±0.02	0.70±0.02	0.62±0.04	0.56±0.04	0.54±0.04	0.48±0.02	0.61

hold							
85°C/ No hold	0.74±0.02	0.69±0.03	0.60±0.02	0.56±0.04	0.53±0.03	0.48±0.03	0.60
90°C/ No hold	0.73±0.03	0.68±0.03	0.61±0.03	0.56±0.04	0.53±0.02	0.48±0.01	0.60
95°C/ No hold	0.72±0.01	0.68±0.03	0.60±0.04	0.56±0.04	0.54±0.02	0.48±0.01	0.60
Mean	0.73	0.69	0.61	0.56	0.53	0.48	
CD (0.05) Cream fat=0.03, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=4.86							
Values are mean±SD, n=3							

Table 6: Flow behaviour Index of cream at 60°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.70±0.04	0.66±0.04	0.58±0.06	0.52±0.04	0.47±0.06	0.44±0.04	0.56
85°C/ No hold	0.69±0.03	0.66±0.04	0.58±0.05	0.50±0.01	0.46±0.04	0.43±0.04	0.55
90°C/ No hold	0.69±0.02	0.65±0.02	0.57±0.06	0.50±0.04	0.45±0.04	0.42±0.03	0.54
95°C/ No hold	0.68±0.02	0.64±0.02	0.56±0.05	0.49±0.03	0.44±0.04	0.42±0.03	0.54
Mean	0.69	0.65	0.57	0.50	0.45	0.43	
CD (0.05) Cream fat=0.04, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=6.81							
Values are mean±SD, n=3							

Table 7: Flow behaviour Index of cream at 70°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.64±0.04	0.62±0.04	0.53±0.03	0.48±0.04	0.44±0.05	0.39±0.03	0.51
85°C/ No hold	0.64±0.04	0.62±0.04	0.52±0.02	0.48±0.04	0.43±0.04	0.39±0.03	0.51
90°C/ No hold	0.64±0.04	0.61±0.03	0.51±0.03	0.48±0.04	0.43±0.04	0.39±0.02	0.51
95°C/ No hold	0.64±0.04	0.61±0.04	0.51±0.02	0.47±0.04	0.42±0.04	0.39±0.02	0.50
Mean	0.64	0.61	0.52	0.47	0.43	0.39	
CD (0.05) Cream fat=0.03, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=6.58							
Values are mean±SD, n=3							

Table 8: Flow behaviour Index of cream at 80°C as affected by cream fat and heat treatment

Heat treatment	Cream fat (%)						Mean
	10	20	30	40	50	60	
80°C/ No hold	0.61±0.05	0.55±0.06	0.50±0.01	0.43±0.02	0.38±0.03	0.33±0.02	0.46
85°C/ No hold	0.61±0.05	0.55±0.06	0.50±0.01	0.44±0.04	0.38±0.02	0.33±0.02	0.46

hold							
90°C/ No	0.60±0.04	0.51±0.01	0.50±0.01	0.42±0.02	0.36±0.01	0.33±0.02	0.45
hold							
95°C/ No	0.59±0.04	0.51±0.01	0.49±0.01	0.40±0.01	0.36±0.01	0.32±0.02	0.44
hold							
Mean	0.60	0.53	0.49	0.42	0.37	0.32	
CD (0.05) Cream fat=0.03, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=6.48							
Values are mean±SD, n=3							

The multiple linear regression analysis of consistency coefficient was carried out to obtain equation for prediction of consistency coefficient with respect to fat content of cream and temperature of measurement.

Conclusion

At 10°C, 20°C, 30°C and 40°C temperature of measurement, cream fat and heat treatment given to cream showed significant ($p < 0.05$) effect on flow behaviour index, whereas their interaction effect was non-significant ($p > 0.05$) difference in flow behaviour index. At 50°C, 60°C, 70°C and 80°C temperature of measurement, cream fat showed significant ($p < 0.05$) effect on flow behaviour index, whereas the heat treatment given to cream and interaction effect was non-significant ($p > 0.05$) difference in flow behaviour index. Fat content of cream, heat treatment and temperature of measurement showed negative correlation with flow behaviour index.

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