Advances in Research

Volume 25, Issue 3, Page 122-127, 2024; Article no.AIR.115291
ISSN: 2348-0394, NLM ID: 101666096

Influence of Heat Treatment on Flow Behaviour Index of Dairy Cream

Yogeshkumar Vekariya [a*], Santosh Chopde [b], Mital Kathiriya [c] and Kumaresh Halder [d]

[a] Department of Dairy Engineering, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India.
[b] Department of Dairy Engineering, College of Dairy Technology, Udgir, Mahrashtra, India.
[c] Department of Dairy Microbiology, SMC College of Dairy Science, Kamdhenu University, Anand, Gujarat, India.
[d] Department of Dairy Engineering, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2024/v25i31057

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/115291

Original Research Article

Received: 26/01/2024
Accepted: 01/04/2024
Published: 04/04/2024

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 with fat content of 10%, 20%, 30%, 40%, 50% & 60% was subjected to different heat treatments i.e., 80°C/No hold, 85°C/No hold, 90°C/No hold & 95C°/No hold. The flow behaviour index of such heat-treated samples was evaluated at every 10°C upon cooling from 80°C or 70°C as the case may be till 10°C at 250 S-1 shear rate using rheometer. It was observed that at 10°C, 20°C, 30°C and 40°C temperature of measurement, 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 sample temperature between 50°C to 80°C,

**Corresponding author: E-mail: vekariyayv@gmail.com, yogeshvekariya@kamdhenuuni.edu.in;*

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 ($p>0.05$). These data are useful to dairy equipment designer for selection of proper sizing of equipment.

Keywords: Dairy cream; flow behaviour index; rheology; cream fat; cream temperature; dairy equipment; dairy industry; cultured milk.

1. 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 [1]. Cream exhibit non-Newtonian flow behaviour Velez-Ruiz et al., [2] when sheared. Cooling of cream results in increase in thickness of cream [3]. 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, [4], Bylund, [5]. 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., [6], Börjesson et al., [7], Moens et al., [8], Edén et al., [9], Phan et al., [10], Jakubczyk and Niranjan, [11], Hotrum et al., [12], Van Aken, [13]. Hussain et al., [14] 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.

2. MATERIALS AND METHODS

Mixed milk was separated into cream and skim milk. Cream was standardised using Pearson Square technique to different fat content i.e., 10%, 20%, 30%, 40%, 50% & 60% by adding skim milk into cream. Each cream sample was then subjected to heat treatment for 80/85/90/95^{o}C for no hold. Samples were evaluated for their flow behaviour using rheometer. The samples were analysed for their fat content (%) using Gerber method mentioned in FSSAI Lab manual 1 (2015). Methodology followed is shown in Fig 1.

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.

2.1 Statistical Analysis

All the data were analysed statistically by following analysis of variance (F-test) at 5% levels of significance using two factor experiment

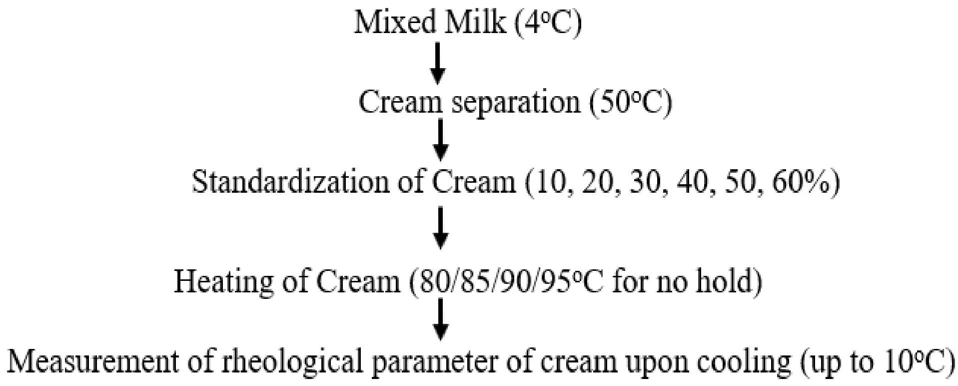

Fig. 1. Flow chart for heat treatment given to cream

with completely randomized design with equal replications. Significant F-test assures that the observed difference among the treatment means is real and not due to chance. All these calculations including standard deviation were done using Microsoft Excel 2019 (Microsoft Corp., USA).

3. 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 [15].

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

Heat treatment	Cream fat (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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 (%)						
	10	**20**	**30**	**40**	**50**	**60**	**Mean**
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
90°C/ No hold	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
95°C/ No hold	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
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

4. 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. Further, only few researchers have endeavoured to assess the flow behaviour property of the dairy product they have developed, with the primary goal being its formulation and development. Nevertheless, there was an absence of organized data specifically for dairy cream that could be inputted into design software to compute the necessary heat transfer size and area for the design and selection of diverse dairy processing equipment, including heat exchangers, agitation and mixing power requirements, and pump selection. Consequently, these data could be employed by software designers to establish a comprehensive database for dairy cream and integrate it into the design process of dairy equipment, particularly heat exchangers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Prentice JH. Dairy rheology: a concise guide. Food science and technology (USA); 1992.
2. Velez-Ruiz JF, Barbosa Canovas GV, Peleg M. Rheological properties of selected dairy products. Critical Reviews in Food Science & Nutrition. 1997;37(4):311-359.
3. Prentice JH, Chapman HR. Some effects of process treatment on the body of cream. Journal of Dairy Research. 1969; 36(2):269-278.
4. Macias-Rodriguez BA, Marangoni AG. Rheology and texture of cream, milk fat, butter and dairy fat spreads. Dairy Fat products and functionality: Fundamental Science and Technology. 2020;245-275.
5. Bylund G. Rheology In: Dairy processing handbook (2nd rev. ed.), Tetrapak Dairy processing Systems. 2003;37-44.
6. Amiri A, Mousakhani-Ganjeh A, Torbati S, Ghaffarinejhad G, Kenari RE. Impact of high-intensity ultrasound duration and intensity on the structural properties of whipped cream. International Dairy Journal. 2018;78:152-158.
7. Borjesson J, Dejmek P, Löfgren R, Paulsson M, Glantz M. The influence of serum phase on the whipping time of unhomogenised cream. International Dairy Journal, 2015;49:56-61.
8. Moens K, Masum AKM, Dewettinck K. Tempering of dairy emulsions: Partial coalescence and whipping properties. International Dairy Journal. 2016;56:92-100.
9. Eden J, Dejmek P, Lofgren R, Paulsson M, Glantz M. Native milk fat globule size and its influence on whipping properties. International Dairy Journal. 2016;61:176-181.
10. Phan TTQ, Moens K, Le TT, Van der Meeren P, Dewettinck K. Potential of milk fat globule membrane enriched materials to improve the whipping properties of recombined cream. International Dairy Journal. 2014;39(1):16-23.

11. Jakubczyk E, Niranjan K. Transient development of whipped cream properties. J Food Eng. 2006;77(1):79–83.
12. Hotrum NE, Stuart MAC, van Vliet T, Avino SF, van Aken GA. Elucidating the relationship between the spreading coefficient, surface-mediated partial coalescence and the whipping time of artificial cream. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2005;260(1-3) 71-78.
13. Van Aken GA. Aeration of emulsions by whipping. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2001;190(3):333-354.
14. Hussain H, Truong T, Bansal N, Bhandari B. The effect of manipulating fat globule size on the stability and rheological properties of dairy creams. Food Biophysics. 2017;12: 1-10.
15. FSSAI Lab manual 1. Manual of methods of analysis of food – Milk and milk products, Ministry of health and family welfare, Government of India, New Delhi; 2015.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/115291