Impact of heat treatment on consistency coefficient of dairy cream

Abstract

The experiment aimed to collect consistency coefficient data for dairy cream subjected to various heat treatments and subsequent temperature variations. Each sample of dairy cream 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 consistency 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°Cat 250 S^{-1}shear rate using rheometer. At a specified measurement temperature, the fat content of cream exhibited a notable ($p<0.05$) impact on the consistency coefficient. However, the heat treatment applied to the cream and their interaction displayed no significant ($p>0.05$) variation in the consistency coefficient. Both the fat content of the cream and the heat treatment demonstrated a positive correlation with the consistency coefficient, whereas the measurement temperature showed a negative correlation. These data are useful to dairy equipment designer for selection of proper sizing of equipment.

Keywords: Dairy cream,consistency coefficient, rheology, cream fat

Introduction

Dairy cream, which can be separated mechanically, is a yellowish component of milk, rich in fat globules, that rises to the surface naturally if milk is allowed to stand(Prentice, 1992). Consistency is the resistance offered by the liquid to flow (Kessler, 1981). Cream exhibit non-Newtonian flow behaviour (Velez-Ruiz et al., 1997) when sheared.Cooling of cream results in increase in thickness ofcream (Prentice and Chapman, 1969).When planning food processing plants, it's crucial to take various factors into account to ensure the high quality of the final products. Among these factors is rheology, which relates to how products flow. Especially in the dairy sector, products like cream and cultured milk can suffer from diminished quality if their flow properties are not properly understood or managed.

Rheology is used in food science to define the consistency of different products. Rheologically, the consistency is described by two components, the viscosity (thickness, lack of slipperiness) and the elasticity ('stickiness', structure). In practice, therefore, rheology stands for *viscosity measurements, characterisation of flow behaviour and determination of material structure*(Macias-Rodriguez & Marangoni, 2020; Bylund, 2003). Basic knowledge of these subjects is essential in process design and product quality evaluation.For the adaptation of viscosity measurement data to process design calculations some kind of mathematical description of the flow behaviour is required. For that purpose, several models are available for mathematical description of the flow behaviour of non-Newtonian systems. For measurement of consistency of dairy products, different types of instruments are used depending on the type of product. Dairy cream like products can be evaluated for its consistency using rotational viscometer. Further, pumpable consistency depends on the shear rate of the product during measurement. It is important to evaluate the product at several different shear rate such that process conditions can be simulated in the measurement. Amongst the factors affecting the viscosity of cream, fat percentage and heat treatment play a major role. Trinh et al., 2007 reported that as the total solids content of milk products increases, the rheological behavior of milk concentrates changes from Newtonian to time-dependent shear thinning (Trinh, et al., 2007). FSSAI has defined different types of cream such as pre-packaged liquid cream, whipping cream, *malai*, etc., in which the base material used is cream.

Rheological data of cream is important, especially when designing and fabricating equipment where cream is used as one of the products. However, no such systematic data is available in the literature. Hence, the study was conducted to assess the effect of varying fat percentages and heat treatments of dairy cream on consistency coefficient.

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 consistency coefficient using rheometer.The samples were analysed for their fat content (%) using Gerber method mentioned inFSSAI Lab manual 1 (2015). Methodology followed is shown in Figure 1.

Mixed Milk (4^{o}C)

↓

Cream separation (50^{o}C)

↓

Standardization of Cream (10, 20, 30, 40, 50, 60%)

↓

Heating of Cream (80/85/90/95^{o}C for no hold)

↓

Measurement of rheological parameter of cream upon cooling (up to 10^{o}C)

Figure 1 Flow chart for heat treatment to cream

The rheological parameter of cream viz., consistency coefficient was analysed using Rheometer (Make: AntoPaar, Model: RheolabQC, Spindle: CC27). The instrument was calibrated before the measurement of required parameter.

Statistical analysis

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

Results and discussion

The consistency coefficient of cream from 10°C to 80°C is shown in Table 1 to 8. At a given temperature of measurement, Consistency coefficient of cream increased significantly ($p<0.05$) as the fat content of cream increased from 10% to 60%. With respect to heat treatment given to cream, there was non-significant increase in consistency coefficient of cream at given temperature of measurement. At a given temperature of measurement, the interaction of fat content of cream & heat treatment showed non-significant ($p>0.05$) difference in consistency coefficient

Table 1: Consistency coefficient (mPa.s^n) 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	3.76±0.01	5.83±0.01	17.47±1.04	44.40±1.13	152.48±1.30	418.70±8.91	107.11
85°C/ No hold	3.82±0.01	5.98±0.01	17.81±1.12	45.36±1.62	153.73±2.37	417.75±6.01	107.41
90°C/ No hold	3.94±0.01	6.18±0.04	19.33±1.23	45.93±1.51	156.19±4.97	419.80±5.94	108.56
95°C/ No hold	4.10±0.03	6.33±0.02	20.22±1.40	47.28±2.30	157.49±5.82	426.25±10.96	110.28
Mean	3.90	6.08	18.71	45.74	154.97	420.63	

CD (0.05) Cream fat=3.96, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=3.55

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 2: Consistency coefficient (mPa.s^n) 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	3.40±0.07	4.20±0.13	13.21±0.63	42.10±1.27	127.17±1.65	374.35±5.16	94.07
85°C/ No hold	3.50±0.08	4.33±0.16	13.55±0.64	43.05±1.34	127.92±1.02	379.40±7.92	95.29
90°C/ No hold	3.61±0.06	4.42±0.15	14.04±0.67	44.65±1.91	129.15±1.20	378.95±4.31	95.80
95°C/ No hold	3.79±0.11	4.92±0.07	14.90±0.47	45.10±1.27	129.95±1.48	384.20±8.20	97.14
Mean	3.58	4.47	13.92	43.73	128.55	379.23	

CD (0.05) Cream fat=2.93, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=2.97

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 3: Consistency coefficient (mPa.s^n) 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	2.73±0.01	3.90±0.07	8.19±0.05	33.06±2.13	99.44±3.90	225.75±6.01	62.18
85°C/ No hold	2.95±0.02	3.99±0.04	8.28±0.40	33.74±2.64	98.52±2.10	228.80±8.77	62.71
90°C/ No hold	3.13±0.05	4.37±0.04	9.11±0.48	33.88±2.44	99.01±1.40	230.25±9.55	63.29
95°C/ No hold	3.18±0.02	4.63±0.08	8.94±1.32	34.48±2.16	100.60±1.98	231.30±9.48	63.85

Mean	2.99	4.22	8.63	33.79	99.39	229.03	

CD (0.05) Cream fat=3.90, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=6.01

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 4: Consistency coefficient (mPa.s^n) 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	2.08±0.11	3.29±0.15	5.22±0.12	17.04±0.27	76.61±0.40	188.30±0.99	48.75
85°C/ No hold	2.18±0.07	3.50±0.12	5.45±0.16	17.49±0.54	77.28±0.87	190.85±3.75	49.46
90°C/ No hold	2.41±0.07	3.62±0.08	5.81±0.23	17.87±0.64	77.80±0.42	192.23±3.92	49.96
95°C/ No hold	2.52±0.06	3.93±0.07	6.11±0.30	18.44±0.33	78.65±0.78	194.16±5.44	50.63
Mean	2.30	3.58	5.65	17.71	77.58	191.38	

CD (0.05) Cream fat=1.67, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=3.26

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 5: Consistency coefficient (mPa.s^n) 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	1.57±0.03	3.02±0.20	4.74±0.22	14.73±0.25	54.05±1.63	155.05±5.87	38.86
85°C/ No hold	1.68±0.08	3.20±0.36	4.88±0.35	15.24±0.35	54.80±1.98	156.20±7.08	39.33
90°C/ No hold	1.84±0.08	3.41±0.36	5.00±0.33	15.51±0.52	55.65±2.05	157.88±7.52	39.88
95°C/ No hold	2.22±0.35	3.50±0.37	5.13±0.21	15.64±0.52	57.15±2.47	158.95±7.42	40.43
Mean	1.82	3.28	4.93	15.28	55.41	157.02	

CD (0.05) Cream fat=3.09, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=7.75

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 6: Consistency coefficient (mPa.s^n) 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	1.17±0.08	2.15±0.06	3.94±0.07	12.82±0.23	41.71±0.69	139.20±1.98	33.50
85°C/ No hold	1.26±0.04	2.18±0.06	4.16±0.26	13.03±0.25	42.19±0.58	140.80±3.11	33.94
90°C/ No hold	1.40±0.08	2.42±0.06	4.31±0.20	13.74±0.12	42.82±0.26	142.85±4.88	34.59
95°C/ No hold	1.55±0.14	2.55±0.14	4.50±0.25	14.03±0.25	43.67±0.33	144.35±4.88	35.11
Mean	1.34	2.32	4.22	13.40	42.60	141.80	

CD (0.05) Cream fat=1.67, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=4.71

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 7: Consistency coefficient (mPa.s^{n}) 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	0.88±0.02	2.13±0.25	3.81±0.26	11.83±0.54	29.70±0.71	125.70±2.12	29.01
85°C/ No hold	1.02±0.13	2.20±0.25	3.95±0.24	12.10±0.76	30.77±1.32	129.60±5.94	29.94
90°C/ No hold	1.16±0.25	2.34±0.16	4.11±0.14	12.49±0.54	31.51±1.83	130.20±4.67	30.30
95°C/ No hold	1.22±0.28	2.64±0.35	4.25±0.18	12.78±0.45	32.66±1.20	131.05±4.88	30.76
Mean	1.07	2.33	4.03	12.30	31.16	129.14	

CD (0.05) Cream fat=2.05, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=6.61

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

Table 8: Consistency coefficient (mPa.s^{n}) 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	0.72±0.05	1.85±0.18	2.77±0.27	9.96±0.48	22.87±0.33	96.25±2.76	22.40
85°C/ No hold	0.78±0.01	1.98±0.33	3.12±0.14	10.12±0.40	23.00±0.29	96.50±2.40	22.58
90°C/ No hold	0.95±0.06	2.06±0.40	3.29±0.24	10.36±0.63	23.55±0.21	97.55±2.47	22.96
95°C/ No hold	1.19±0.10	2.18±0.40	3.74±0.11	10.80±0.14	24.65±0.64	99.00±3.25	23.59
Mean	0.91	2.02	3.23	10.31	23.51	97.33	

CD (0.05) Cream fat=1.19, Heat treatment=NS, Cream fat × Heat treatment=NS; CV%=5.06

Values are mean±SD, n=3, *NS* non-significant at 5% level of significance

As seen from the table data, dairy cream exhibits pseudoplastic behaviour when sheared. Similar results have been reported by Walstra et al., 2006 and Hussain et al., 2017.It implies that less power is required at higher flow rate of cream that at less flow rate. This trend is similar to other dairy products i.e., Condensed milk of medium consistency. Data as such are useful in design by directly selecting the value among the different fat content and heat treatment given to cream. However, consistency of cream as affected by fat content of cream and heat treatment given to it has been shown for the cream sample evaluated at different sample temperatures representing different processing and handling temperature of cream.Biglarian and co-workers (2022) evaluated similar parameter for the whipped cream.

Conclusions

At a given temperature of measurement, fat content of cream showed significant ($p<0.05$) effect on consistency coefficient whereas, heat treatment given to cream and their interaction showed non-significant ($p>0.05$) difference in consistency coefficient. Fat content of cream and heat treatment showed positive correlation with consistency coefficient whereas temperature of measurement showed negative correlation. The empirical formula to predict consistency coefficient for cream of 10% to 60% fat content for temperature range of 10°C to 80°C using following equation: $\log_e$ (consistency coefficient) = –0.31+ [1.0 ×cream fat (%)] - [0.02×temperature of measurement (°C)]. Many researchers have tried to evaluate the consistency of the dairy product developed by them in which the primary objective was to develop and formulate the product. However, no systematic data were available for dairy cream which can be fed into design software for calculating the size and area of heat transfer required for design and selection of various dairy processing equipment such as heat exchanger, power required for agitation and mixing and selection of pump. Hence, these data can be used by software designer to create library of data for dairy cream and utilise it in design of dairy equipment such as heat exchanger.

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