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RESEARCH PAPER

Studies on Rheological Characteristics of Guava Powder based Ice-cream

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ABSTRACT

The rheological behaviour of guava based ice-cream was studied for treatment combination guava powder (%): jackfruit seed starch (%) i.e. 8:2; 6:4; 4:6; 2:8; and 0:10 (w/$_w$) at various mixing time 15 minutes, 25 minutes and 35 minutes respectively. The share rate (Pa) V_S share stress data (1/s) for ice-cream was obtained by using Brookfield Viscometer RVDV II + pro using spindle S_4 with different speed 20, 30, 50, 60, 100 rpm. The guava based ice-cream indicated that the flow behaviours index (η) lies 0.0331 – 0.0785 and consistency coefficient (K) lies 15.705-39.513 (Pas) ($R^2 \geq 0.7274$) indicating that icecream are non-newtonian ($n < 1$) and pseudoplastic in nature the consistency coefficient decreases from 39.513 – 20.640; 25.560 – 19.533 and 18.443-15.705(pas) as the mixing time increases from 15 minutes, 25 minutes 35 minutes respectively.

Keywords: Guava ice-cream, rheological properties of ice-cream, flow behaviour index, consistency coefficient

Ice cream can be considered as an aerated suspension of fat and water in a concentrated sugar solution including stabilizers, casein micelles and proteins. It is prepared with milk, sweeteners, emulsifiers, stabilizers and flavoring agents (Koxholt *et al*. 2001). The two important factors affecting the ice cream texture and acceptability are stabilizers and emulsifiers. Stabilizers are ingredients which are used in small amounts in ice cream formulations and impart specific and important functions to the finished product Bahramparvar and Mazaheri-Tehrani, (2011). Rheology concerns with the flow and deformation of a substance under applied forces; and attempts to define a relationship between the stress acting on a given material and the resulting deformation and/or flow that takes place. These rheological properties have several applications in the field of food acceptability, food processing and food handling Dak *et al*. (2006).

Understanding the rheological properties of food products is important for product development. In particular these properties influence design and evaluation of process equipment such as pumps, piping, heat exchangers, evaporators, sterilizers and mixers. Knowledge of the fundamental rheological properties of any food can be an indication of how the food is going to behave under various processing conditions such as pasteurization concentration and dehydration (Kampf *et al*. 2003). The viscosity of a mix is affected by composition (mainly fat and stabilizer), kind and quality of ingredients, processing and handling of the mix, and concentration (total solid content). As the viscosity increases, resistance to

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melting and smoothness of the body increases, but the rate of whipping decreases. So, the desirable viscosity can be assured by controlling the mix composition (Arbuckle, 1972).

Many researchers studied about the rheological characterization of the ice cream mix are reported in literature Karaoca *et al*. (2009) studied the functional rheological and sensory characteristics of ice cream, Akalin *et al.* (2007) stud ied rheological properties of reduced fat and low fat ice cream containing whey protein isolute and insulin. Pon *et al*. (2015) reported the rheological properties of stevia ice cream.

A mathematical equation between apparent viscosity and shear rate has been described which can be related to the power-law model Heikal and Hinnan, (1990). The power-law equation has been widely used in analyzing viscosity, shear rate data. In general, commercial instant food thickeners consist of modified starches and gums as their base materials and they are becoming more popular because of low cost, convenience, and easy preparation (Garcia *et al*. 2005). The commercial production of ice cream depends on knowledge of the product's flow and textural behavior during and after processing.

In this paper effect of guava powder (%) and mixing time (min) on the rheological behaviour i.e. flow behaviour index, and consistency coefficient (Pa) of the Guava powder ice cream was studied.

MATERIALS AND METHODS

Sample preparation

The Guava powder prepared by drying guava slices at 45°C was used for the development of ice cream mixes. The jackfruit seed starch produced through the wet process reported by Hundekari (2017) was used for the development of ice cream mixes. The guava powder: jackfruit seed starch ($w/_w$) i.e. 8:2; 6:4; 4:6; 2:8 and 0:10 were used for the preparation of ice cream mixes. The other ingredients were sugar 32%, milk solid not fat 55%, emulsifier (GMS powder) 2%, stabilizer (CMC powder) 1% were used to develop the ice cream mixes. 100 g of ice cream mixes as per above levels was added with 100 ml of whole milk in the proportion (1:1). The mixture was heated at 70°C for 30 minutes in a open pan, the mixture was agitated periodically by SS Spatula and was cooled at room temperature. The mixture was stored in the refrigerator at 4°C in 4 hours for aging process to complete. After aging process the ice cream was prepared with various mixing time 15 minutes, 25 minutes, 35 minutes by using hand operated with 34 RPM after aging the mixture at 4°C, the mixture (150 ml) from each treatment. The experiment 5 no. treatments and 3 no. mixing time resulted 15 no of experiments. The experiments was repeated three times and average data was repeated.

Rheological Properties of Guava powder ice cream

The Share rate-shear stress data for Guava powder ice cream was measured by using a Brookfield Viscometer RVDV II + Pro (M/s Brookfield's Engineering Lab., USA) and spindle number S4 with different speeds 20, 30, 50, 60, 100 rpm at ambient temperature. The reading at each spindle speed was taken after three minutes of revolution at that speed until constant reading was observed. Separate ice cream as per each treatment combination was used for each test. All the rheological measurements were conducted at room temperature and repeated thrice. The readings of the viscometer were converted into average shear stress (Pa) and average share rate (s^{-1}) values using equation Briggs and Steffe, (1997); Mitschka, (1982).

Power law model provides the mathematical rheological relationship between shear rate and shear stress which is used to verify the flow behaviour of Guava powder ice cream is given as follows. Mitschka (1982) has developed a simple technique to determine rheological parameters of power law fluids using a Brookfield viscometer Briggs and Steffe, (1997).

$$\sigma = K \cdot \gamma^n \qquad \ldots(1)$$

Where,

σ = Shear stress, Pa; k = Consistancy coefficient, Pa.s^n

γ = Shear rate, s^{-1}; n = Flow behavior index

Briggs and Steffe (1997) have improved the method by modelling the Mitschka data, the flow behaviour index (n) and the consistency index (K) of power law fluids was obtained using the following procedure:

Shear stress (σ) of the Guava powder ice cream was obtained using the spring torque (obtained by reading the instrument dial) and factors related with Brookfield model and spindle;

$$\sigma_a = K_{a\sigma}\,(C.\ Dial\ reading) \quad \ldots(2)$$

Where,

σ_a = Average shear stress, Pa

$K_{a\sigma}$ = Shear stress conversion factor, Pa

= function of spindle No. RV 4 (0.539)

C = dimension less (sprig constant i.e. 1)

The logarithm of shear stress was plotted versus the logarithm of rotational speed (N); the flow behavior index (n) was obtained as the slope of the graphic (Mitschka, 1982);

$$n = \frac{d\left(\log_{10}\sigma_a\right)}{d\left(\log_{10}N\right)} \quad \ldots(3)$$

Where,

σ_a = Average shear stress, Pa

N = Rotational speed, rpm

Average shear rate (γ) is then obtained by Equation (7), empirically determined by Briggs and Steffe (1997):

$$\gamma_a = \left(0.263\left(n\right)^{-0.771}\right)N \quad \ldots(4)$$

Where,

γ_a = Shear rate, (1/s)

n = Flow behaviour index

N = Rotational speed, rpm

RESULTS AND DISCUSSION

Fig. 1 shows the shear rate verses shear stress data at various guava powder incorporation i.e. 0%, 2%, 4%, 6% and 8% and at mixing time i.e. 15 minutes. In all these three graph as the shear rate increases from 20 rpm (0.5(1/s)) to 100 rpm (3.0(1/s)) the shear stress (pa) increases. It was from 25.98 to 28.244 for 0%; from 26.519 to 30.454 for 2%; from 27.22 to 29.699 for 4%; from 37.604 to 41.916 for 6%; and 38. 539 to 41.755 for 8% guava powder incorporation. It can also be seen from the graph that as the guava powder increases from 0 to 8% the shear stress values are increases. The data for shear rate (1/s) versus shear stress (Pa) at 15 minutes mixing time was fitted to the power law equation. Table 1 (a) shows the parameters of the power law models fitted to the ice cream prepared at varied guava power composition 0, 2, 4, 6 and 8 at 15 minutes mixing time. It indicates that the 0.0785 ≤ K ≥ 0.0459 and 39.513 ≤ K ≥ 20.640 the ice cream fluid is a non Newtonian pseudoplastic in nature. Power law model is well fitted to the experimental data with $R^2 \geq 0.7274$. as the guava powder increases from 0 to 8% consistency coefficient (K) increases. The flow behaviour index doesnot show any trend.

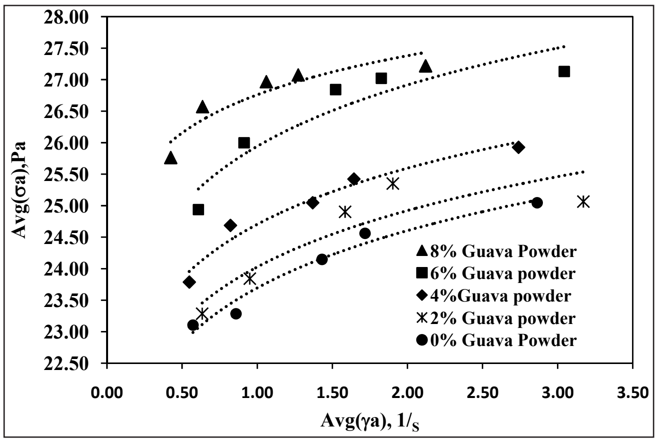

Fig. 1: Shear rate verses shear stress data showing the effect of addition of guava powder in mix from guava powder at 15 min mixing time

Fig. 2 shows the shear rate verses shear stress data at various guava powder incorporation i.e. 0%, 2%, 4%, 6% and 8% and at mixing time i.e. 15 minutes. In all these three graph as the shear rate increases from 20 rpm (0.5(1/s)) to 100 rpm (3.0(1/s)) the shear stress (pa) increases. It was from 23.105 to 25.046 for 0%; from 23.285 to 25.064 for 2%; from 23.788 to 25.926 for 4%; from 24.938 to 27.13 for 6%; and 25.764 to 27.22 for

8% guava powder incorporation. It can also be seen from the graph that as the guava powder increases from 0 to 8% the shear stress values are increases. The data for shear rate (1/s) versus shear stress (Pa) at 15 minutes mixing time was fitted to the power law equation. Table 1 (b) shows the parameters of the power law models fitted to the icecream prepared at varied guava power composition 0, 2, 4, 6 and 8 at 15 minutes mixing time. It indicates that the 0.0544 ≤ η ≥ 0.0331 and 25.560 ≤ K ≥ 19.533 the icecream fluid is a non Newtonian pseudoplastic in nature. Power law model is well fitted to the experimental data with R^2 ≥ 0.8203. As the guava powder increases from 0 to 8% consistency coefficient (K) increases. The flow behaviour index doesnot show any trend.

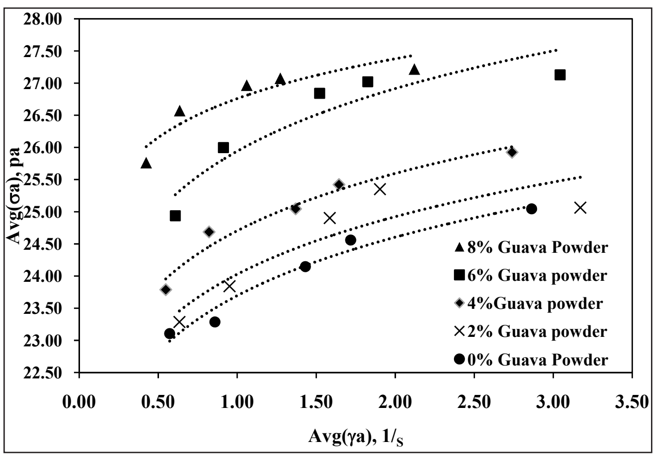

Fig. 2: Shear rate verses shear stress data showing the effect of addition of guava powder in mix from guava powder at 25 min mixing time

Fig. 3 shows the shear rate verses shear stress data at various guava powder incorporation i.e. 0%, 2%, 4%, 6% and 8% and at mixing time i.e. 15 minutes. In all these three graph as the shear rate increases from 20 rpm (0.5(1/s)) to 100 rpm (3.0 (1/s)) the shear stress (pa) increases. It was from 19.620 to 21.955 for 0%; from 20.051 to 22.225 for 2%; from 20.859 to 22.207 for 4%; from 21.291` to 23.195 for 6%; and 22.422 to 24.956 for 8% guava powder incorporation. It can also be seen from the graph that as the guava powder increases from 0 to 8% the shear stress values are increases. The data for shear rate (1/s) versus shear stress (Pa) at 15 minutes mixing time was fitted to the power law equation. Table 1 (c) shows the parameters of the power law models fitted to the icecream prepared at varied guava power composition 0, 2, 4, 6 and 8 at 15 minutes mixing time. It indicates that the 0.0746 ≤ n ≥ 0.0470 and 18.443 ≤ K ≥ 15.705 the icecream fluid is a non Newtonian pseudoplastic in nature. Power law model is well fitted to the experimental data with R^2 ≥ 0.7315. As the guava powder increases from 0 to 8% consistency coefficient (K) increases. The flow behaviour index doesnot show any trend.

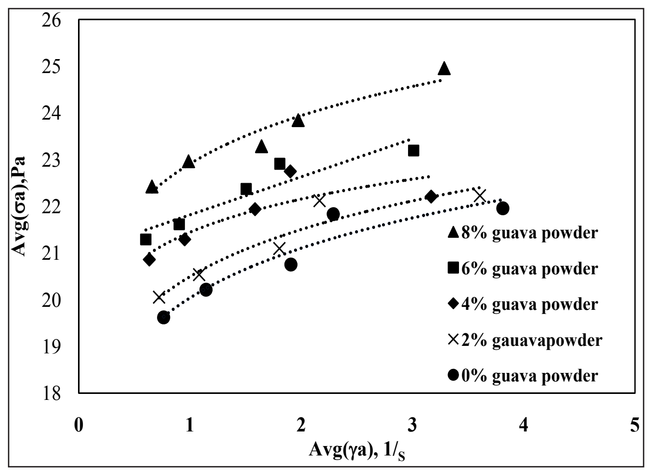

Fig. 3: Shear rate verses shear stress data showing the effect of addition of guava powder in of mix from guava powder at 35 min mixing time

The flow behavior index is reported to be around 0.7 for ice-cream mixes Goff and Davidson,(1994), Cotrell *et al.* (1980) reported n values of the icecream mix to be in the range of 0.98-0.68 and 0.88-0.48 for the natural stabilizers guar gum and locust bean gum (at 0.05-0.40% stabilizer content).

Aime *et al.* (2001) reported the increases consistency coefficient of their ice creams between 0.0733 and 1.260 Pas. Minhas *et al.* (2002) concluded that the consistency coefficient of the ice cream mixes ranged between 0.29 and1.19 Pas.

From the Table 1 (a), (b), (c) it can be seen that as the guava powder composition (%) increases the consistency coefficient increases from 20.640-39.513 pas, 19.533- 25.560 pas and 15.705 – 18.443 pas. at 15 minutes, 25 minutes 35 minutes mixing time respectively. It indicated that, as mixing time

Table 1: Model parameters of power law equation at different treatments P_1T_1 to P_5T_3 (concentrations) and at varied mixing time (15, 25 and 35 Min) of instant ice cream mixes from guava powder

Sl. No.	Mixing Time (Min)	Guava Powder (%)	Flow behaviour index (*n*)	Consistency coefficient (k), Pa.s	R^2
(a)	15 Min	8	0.0459	39.513	0.909
		6	0.0601	30.899	0.727
		4	0.0526	23.171	0.977
		2	0.0785	20.640	0.832
		0	0.0495	22.492	0.959
(b)	25 Min	8	0.0331	25.560	0.865
		6	0.0532	21.544	0.872
		4	0.0511	20.552	0.961
		2	0.0528	20.027	0.820
		0	0.0544	19.533	0.967
(c)	35 Min	8	0.0635	18.443	0.942
		6	0.0577	17.876	0.960
		4	0.047	18.231	0.731
		2	0.0692	16.289	0.910
		0	0.0746	15.705	0.913

increases from 15 minutes to 35 the consistency coefficient decreases.

CONCLUSION

The rheological behaviour of icecream mixes from guava powder indicated that the fluid is non-newtonian and pseudoplastic in nature (n<1). The consistency coefficient increases from 20.640 to 39.513; 19.533 - 25.560; and 15.705 to 18.443. As the guava powder increase ice-cream from 0-8% at mixing time 15 minutes, 25 minutes, 35 minutes. The power law model was well fitted to the data on shear rate and shear stress of ice-cream from guava powder at $R^2 \geq 0.7274$. As the mixing time increase the consistency coefficient decreases.

GENERATIVE AI DECLARATION

The author(s) confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI. The authors developed and verified all scientific content, data analysis, interpretation of results, and conclusions. The authors take full responsibility for the accuracy, integrity, and originality of the work presented, and no AI tool was listed as an author.

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