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RESEARCH ARTICLE

Development of low-fat frozen yoghurt incorporated with strawberry and beetroot powder

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Abstract: Low-fat frozen yoghurt was prepared using a blend of strawberry and beetroot powder as one of the ingredients. Response Surface Methodology (RSM) was used to optimize the level of strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar. The responses were sensory attributes such as flavor, body and texture, melting characteristics, color and appearance and total score as well as physical attributes like melting rate and overrun. Based on the output, RSM suggested the rate of addition of strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar to be 4.06 per cent, 0.21 per cent and 15.45 per cent respectively. The experimental frozen yoghurt was prepared as per the suggestions from RSM and compared with control low-fat frozen yoghurt where strawberry and beetroot powder were replaced with strawberry flavor and matching color. The experimental frozen yoghurt was statistically similar in terms of compositional parameters except moisture and carbohydrate content while the experimental sample was superior to control sample in terms of sensory attributes. Aerobic plate count of both the samples were statistically similar while coliform as well as yeast and mold were absent in the product.

Key words: Frozen yoghurt; Strawberry; Beetroot; Response Surface Methodology; Sensory, Overrun

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Introduction

Frozen yoghurt is a frozen fermented milk product manufactured by freezing of either stirred yoghurt prepared by fermentation of ice-cream mix or a mixture of stirred yoghurt and ice-cream mix or partially fermented ice-cream mix with addition of coloring and flavoring material. Frozen yoghurt contains the live strains of *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus*. Hence, it contains the nutritional benefits of yoghurt and sensory benefits of ice-cream and therefore, it is enjoyed by the people of age group (Tamime and Robinson, 2007).

Strawberry (*Fragaria ananassa*) is the most economically valuable berry fruit, owing to its high nutritional value and pleasant flavor. (Hummer and Hancock, 2009). Strawberries possess appreciable amounts of minerals such as potassium, calcium and magnesium as well as vitamins such as ascorbic acid and folic acid (Beattie et al. 2005). Strawberries are an excellent source of phytochemicals, mainly phenolic compounds and biologically active non-nutrients with considerable biological functions (Häkkinen & Törrönen, 2000). Strawberry phenolics are well recognised for their anti-inflammatory, anti-hypertensive and antioxidant characteristics as well as anti-allergy capabilities and the potential to block the actions of certain physiological enzymes, preventing oxidative stress-related disorders (Giampieri et al. 2014). Beetroot (*Beta vulgaris* L.) is high in a variety of biologically active phytochemicals such as betalains (betacyanins and betaxanthins), polyphenols, flavonoids, and nitrate (NO_3); as well as high in minerals like calcium, magnesium, potassium, sodium, phosphorus, zinc, manganese and iron (Mirmiran et al. 2020) as well as a minor quantity of vitamin C and vitamin E, which have been demonstrated to have good antioxidant capacity (Apak et al. 2004). Beetroot is a rich source of anthocyanins (1.44 to 8.45 mg/100 g) and carotenoids (1.9 to 2.3 mg/100 g) (Rebecca et al. 2014). According to studies, it also reduced low-density lipoprotein (LDL) by 50 percent and blood glucose by 40 percent after beetroot consumption (Ceclu and Nistor, 2020). Hence, beetroot is an excellent nutritional supplement.

Response Surface Methodology (RSM) has been widely used in recent years for the development of new products as well as improvement in existing products. RSM delineates the effect of the independent variables on responses of importance and is regarded as an effective method to optimize the new product formulations. It is a robust tool for data analysis that focuses on an adequate approximation relationship between input and output variables and determines the best operating circumstances for a system (Myers et al. 2004).

With a changing lifestyle and increasing awareness towards health and nutrition, consumers are moving towards low-fat diet to reduce the risk of obesity, coronary heart disease, atherosclerosis and hypertension (Dharaiya et al. 2021). High fat diet is also linked with psychiatric disorders (Jeong et al. 2019). Fat, being a costliest constituent in milk, increases the cost of final product and make the product unaffordable by low-income group people. However, reduction in fat content of frozen yoghurt influences sensory and rheological characteristics of the product. Incorporation of strawberry and beetroot will make up for the deterioration taken place in the quality of frozen yoghurt by reduction of fat along with improvement in the nutritional quality of the final product. Therefore, in current investigation, low-fat frozen yoghurt has been developed with incorporation of strawberry and beetroot powder.

Materials and Methods

Whole milk and skimmed milk were obtained from nearby commercial dairy plant. Skimmed milk powder of *Sagar* brand, marketed by Gujarat Cooperative Milk Marketing Federation (GCMMF) Ltd., Anand was used for standardization. Commercial grade cane sugar of *Madhur* brand was obtained from local market. Fresh beetroots were purchased from local vegetable market. Strawberry powder (Holy Natural brand, Earth Expo Company, Bhavnagar, India) was purchased online. Starter cultures *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* were obtained from Dairy Microbiology Division of the institute. Sodium alginate, guar gum, carrageenan and pectin were supplied by HiMedia, Mumbai. Glycerol Monostearate (GMS) was supplied by Loba Chemical, Mumbai. Strawberry flavor (International Flavors & Fragrances India Pvt. Ltd., Chennai) and erythrosine supra color (AB Enterprises, Mumbai, India) was used to prepare control frozen yoghurt.

Preparation of beetroot powder

Raw beetroot was brought from the local market and cleaned properly to remove foreign materials. Then trimmed properly and was sliced into thin pieces (3 mm) with the help of slicer. Sliced beetroot was blanched at 80°C, followed by drying at 55°C for 4 h by a cabinet drier. Dried beetroot was ground to a fine powder (65 mesh size sieve) and packed in airtight colored glass bottles for further use (Srivastava and Singh, 2016).

Preparation of stabilizer-emulsifier blend

A blend of stabilizers (i.e., sodium alginate, guar gum, carrageenan and pectin) and emulsifier (i.e., glycerol monostearate) was prepared and used in frozen yoghurt at a level suggested by RSM. The blend contained sodium alginate, guar gum, carrageenan, pectin and GMS in the ratio of 2:1:1:2:2. The ratio was decided on the basis of preliminary trials. A combination of different stabilizers has synergistic effect on the quality of frozen yoghurt which can ultimately reduce the use of stabilizers (Milani and Koocheki, 2011). Hence, a combination of stabilizers and emulsifiers has been used in current investigation.

Preparation of frozen yoghurt

Frozen yoghurt has been prepared using the method suggested by Agarwal and Prasad (2013) with minor modifications. The detailed method is illustrated hereafter:

Whole milk and skimmed milk are blended together and heated to 55°C. All the dry ingredients such as sugar, skimmed milk powder, a blend of strawberry powder and beetroot powder as well as stabilizer-emulsifier mixture were mixed together and added to whole milk and skimmed milk blend. The mixture was then homogenized at 65°C followed by heat treatment at 85°C/30 min. The heated mix was cooled to 42±2°C and inoculated with starter cultures *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* at the rate of 2 percent (w/w) of the quantity of mix followed by incubation at 42±2°C till the pH reached to 5.0. The yoghurt mix was then cooled to 4°C and stirred. The stirred mix was aged at 4°C for 6 h followed by freezing, packaging and hardening at -25°C for 24 h. The frozen yoghurt was stored at -18°C after hardening.

Analysis of low-fat frozen yoghurt incorporated with strawberry and beetroot powder

Whole milk and skimmed milk were analysed for fat, total solids and acidity as per the method described by FSSAI (2015). The prepared frozen yoghurt was analysed for fat, protein, ash, total solids and pH as per the method described by FSSAI (2015). Carbohydrates are calculated by difference. Viscosity of yoghurt mix, using Brookfield viscometer, as well as melting rate of frozen yoghurt was analysed by the method suggested by Muse and Hartel (2004). Overrun of frozen yoghurt was calculated as per the formulae used by Ilansuriyan and Shanmugam (2018). Aerobic plate count, coliform count and yeast and Mold count were analysed using the method given by FSSAI (2012).

Sensory evaluation of low-fat frozen yoghurt incorporated with strawberry and beetroot powder

The frozen yoghurt samples were stored at -13±2°C for 24 h before serving to the semi-trained judges (n=12). The judges were from the faculty of the institute who have basic idea about the product. Sensory analysis of the product was performed in isolated sensory booths illuminated with incandescent light maintained at 22±2°C. The well-labelled samples were presented in polystyrene cups in completely randomized order. The frozen yoghurt samples were evaluated using 100-point score card (Marshall et al. 2013).

Statistical analysis

A Central Composite Rotatable Design (CCRD) of the Response Surface Methodology (RSM) technique was adopted for the optimization of strawberry and beetroot powder, stabilizer-emulsifier blend and sugar. The minimum and maximum levels of the blend of strawberry powder and beetroot powder, stabilizer-emulsifier blend and sugar were selected as 2 and 6 percent, 0.2 and 0.5 percent as well as 12 and 16 percent respectively, on the basis of preliminary trials. The CCRD of three factors contained 20 combinations, including lower and upper limits, along with their responses for sensory parameters as well as melting rate and overrun are displayed in Table 1. The data generated for different responses were analysed using Design Expert® software (13.0.2 version) (Stat-Ease, Inc., 2021 E. Hennepin Avenue, Minnepolis, USA). A general polynomial equation given below was fitted for each response.

$$Y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_{11}x_{12} + a_{22}x_{22} + a_{33}x_{32} + a_{12}x_1x_2 + a_{23}x_2x_3 + a_{13}x_1x_3 + \text{Error term}$$

where Y represents the predicted response; a_0 the constant coefficient; a_{11}, a_{22} and a_{33} denote quadratic coefficients; a_{12}, a_{23} and a_{13} denote interaction coefficients; x_1, x_2 and x_3 denote rate of addition of strawberry and beetroot powder, stabilizer-emulsifier blend and sugar respectively.

Adequacy of the model was evaluated using coefficient of determination (R^2) and statistical significance was examined by F value. The effect of independent variables and individual responses was described at $P<0.05$. t-test for two samples assuming equal variance was applied using Microsoft Excel for comparison of predicted values with the actual values of the responses. The variation between control and strawberry and beetroot incorporated low-fat frozen yoghurt samples was analysed using independent t-test.

Results and Discussion

The optimization of the rate of addition of the blend of strawberry and beetroot powder, stabilizer-emulsifier blend and sugar were carried out on the basis of sensory properties of the low-fat frozen yoghurt such as flavor, body & texture, melting characteristics, color & appearance and total score as well as quantity of frozen yoghurt melted in specific time and overrun. The successive regression analysis of the responses produced the quadratic models for each response. The variation in experimental data of fitted quadratic model was given by coefficient of determination (R^2) which ranged from 88 percent to 92 percent (Table 2). The model F-value of the fitted quadratic model for all responses was found to be significant. The sufficient accuracy for predicting all response variables of the frozen yoghurt prepared from any combinations of variables within the range was evaluated by non-significant lack of fit. These indicate that the obtained quadratic model fitted the data strongly. The signal to noise ratio called *Adequate Precision Value (APV)* for a well fitted model should be above four. This measure also fulfilled for the obtained mode with APVs ranging from 8.12 to 11.27. All these results firmly recommended that the model could be used to develop strawberry and beetroot incorporated low-fat frozen yoghurt.

Effect of variables on flavour

Flavor is an amalgamation of taste, odour and mouthfeel. It is a major factor in sensory evaluation and consumer acceptance for majority of the dairy products. The flavor score of the frozen yoghurt between 34.87 and 43.12. The minimum flavor score for the frozen yoghurt was obtained when strawberry and beetroot powder, stabilizer-emulsifier blend and sugar were added at the rate of 7.36%, 0.35% and 14% respectively while maximum flavor score was obtained when strawberry and beetroot powder, stabilizer-emulsifier blend and sugar were added at the rate of 4%, 0.35% and 14% respectively (Table 1). Strawberry and beetroot powder and sugar significantly ($P<0.05$) improved flavor of the final product at linear level. Similarly, the interaction of both of them also significantly ($P<0.05$) improved the flavor while all the three variables significantly deteriorated flavor at quadratic level because high intensity of beetroot flavor and very sweet taste were disliked by the judges. Flavor release was also reported to be slow by the experts when stabilizer-emulsifier mixture was added in higher amount. Incorporation of beetroot juice up to 4 percent level improved flavor followed by deterioration (Manoharan et al. 2013). Sudha and Madhvi (2015) incorporated beetroot pulp in ice-cream and observed improvement in flavor up to the addition of 6 percent beetroot pulp followed by deterioration at higher level. Similarly, Ateteallah et al. (2019) also reported improvement in flavor of ice-cream with addition of beetroot juice up to the level of 3 percent followed by deterioration. Moeenfard and Tehrani (2008) reported non-significant influence of rate of addition of stabilizers on flavor when added between 0.15 to 0.25 percent.

Effect of variables on body and texture

Body and texture is an important sensory characteristic for frozen yoghurt. The body and texture score of the low-fat frozen yoghurt containing strawberry and beetroot was ranged from 23 to 28.87. The frozen yoghurt displayed minimum body and texture score when it contained 7.36% strawberry and beetroot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar while maximum body and texture score was observed when it contained 4% strawberry and beetroot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar (Table 1). At linear level, all the three variables significantly ($P<0.05$) improved body and texture of the frozen yoghurt. Addition of strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar increased total solids, which led to improvement water binding and increase in viscosity which assisted to get proper overrun resulting in smooth and firm body. At quadratic level, all the three variables reduced body and texture score which could be attributed to heavy and soggy body of the final product. Similar results were reported by different researchers when beetroot pulp (Sudha and Madhvi, 2015) and beetroot juice (Manoharan et al. 2013; Ateteallah et al. 2019) were added in ice-cream. Body and texture score also increased with increase in rate of addition of stabilizers (Moeenfard and Tehrani, 2008; Agarwal and Prasad, 2013).

Effect of variables on melting characteristics

The behaviour of frozen product upon melting has an utmost importance. The sensory score for melting quality ranged between 3 and 4.67 The minimum score for melting quality was obtained when the product contained 0.64% strawberry and beetroot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar while maximum melting characteristics score was observed when it contained 4% strawberry and beetroot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar (Table 1). Stabilizer-emulsifier mixture and sugar significantly ($P<0.05$) improved melting quality of the product at linear level which could be attributed to uniform melting at optimum rate. The addition of all the three variables at higher level resulted in very slow melting as well as presence of visible curd particles on melting, leading to lower score. Dabija et al. (2019) showed improvement in water holding capacity and therefore, reduction in syneresis in yoghurt. Melting characteristics of ice-cream improved by the addition of beetroot juice up to 3 percent followed by deterioration (Ateteallah et al. 2019). Addition of beetroot pulp in oat milk-based ice-cream improved melting characteristics of ice-cream (Butt et al. 2023). Similar results were reported by Manoharan et al (2013) in ice-cream.

Effect of variables on color and appearance

Color and appearance is the first sensory parameter that is observed while carrying out sensory evaluation. The color and appearance score of the frozen yoghurt was ranged between 2.50 and 4.62. The product obtained minimum score for color and appearance when strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar were added at the rate of 0.64%, 0.35% and 14% respectively while maximum score was obtained when the variables were added at the rate of 4%, 0.35% and 14% respectively. The rate of addition of strawberry and beetroot powder significantly ($P<0.05$) improved color and appearance of the frozen yoghurt at linear level as the judges liked the red color given by strawberry and beetroot powder but significantly ($P<0.05$) deteriorated color and appearance at quadratic level due to high intensity of the color which was disliked by the judges. The color and appearance score of ice-creams incorporated with beetroot pulp increased up to the level of 6 percent followed by reduction at higher level (Manoharan et al. 2013; Sudha and Madhvi, 2015).

Effect of variables on total score

Table 1: Experimental design matrix showing factors and their responses for the development of strawberry and beetroot incorporated low-fat frozen yoghurt

Std Run	A: SBP** (% w/w)	B: S+E@ (% w/w)	C: Sugar (% w/w)	Response 1: Flavor	Response 2: Body & Texture	Response 3: Melting character-ristics	Response 4: C&A#	Response 5: Total score*	Response 6: Melting rate, %	Response 7: Overrun, %
1	4.00	0.35	14.00	42.87	28.12	4.37	4.42	94.78	47.16	90.62
2	4.00	0.35	14.00	42.62	28.52	4.52	4.62	95.28	46.98	89.84
3	6.00	0.20	12.00	35.00	24.87	3.52	3.50	81.89	63.04	77.26
4	4.00	0.35	14.00	42.67	28.62	4.67	4.42	95.38	47.25	91.25
5	4.00	0.60	14.00	36.25	28.00	4.40	4.08	87.73	43.48	82.26
6	7.36	0.35	14.00	34.87	23.00	4.12	3.12	80.11	48.14	84.76
7	4.00	0.35	17.36	39.75	26.12	4.52	4.32	89.71	59.61	97.88
8	4.00	0.35	14.00	42.82	28.87	4.50	4.38	95.57	48.23	90.16
9	2.00	0.20	16.00	42.12	26.87	3.82	3.87	91.68	72.64	72.45
10	6.00	0.50	12.00	35.25	25.37	3.87	4.32	83.81	46.01	86.14
11	6.00	0.20	16.00	36.25	25.12	4.18	4.28	84.83	70.14	85.05
12	2.00	0.50	12.00	38.25	26.52	4.43	3.50	87.70	48.92	84.95
13	4.00	0.10	14.00	35.50	24.37	3.37	3.62	81.86	68.34	72.88
14	4.00	0.35	14.00	43.12	28.50	4.31	4.62	95.55	47.65	88.98
15	0.64	0.35	14.00	35.50	25.25	3.00	2.50	81.25	55.14	83.12
16	2.00	0.50	16.00	42.37	26.50	4.22	3.87	91.96	54.69	97.16
17	4.00	0.35	10.64	35.87	23.52	4.06	3.57	82.02	48.25	87.02
18	2.00	0.20	12.00	35.12	24.00	3.00	3.42	80.54	68.96	78.38
19	6.00	0.50	16.00	36.25	25.12	4.00	4.06	84.43	57.31	80.18
20	4.00	0.35	14.00	43.00	28.37	4.38	4.32	95.07	48.05	91.52

*Score for bacteria (15) was added in the Total score; @ Stabilizer-emulsifier blend; #Color and appearance; **Strawberry and beetroot powder

Total score is sum of the scores of all the sensory attributes. The total score ranged from 80.11 to 95.57. The frozen yoghurt containing 7.36% strawberry and beetroot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar showed minimum total score while one containing 4% carrot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar showed maximum total score. All the three variables significantly (P<0.05) increased total score at linear level while all the three variables significantly (P<0.05) reduced total score at quadratic level. Several researchers observed similar trend in ice-cream (Manoharan et al. 2013; Sudha and Madhvi, 2015; Ateteallah et al. 2019, Butt et al. 2023).

Effect of variables on melting rate

Frozen product should have optimum melting time. Rapid or slow melting causes inconvenience to the consumer. Melting time is inversely related to melting rate. The melting rate of the frozen yoghurt ranged between 43.48 per cent and 72.64 percent. The frozen yoghurt containing 4 percent strawberry and beetroot powder, 0.6 percent stabilizer-emulsifier mixture and 14 percent sugar showed minimum melting while the one containing 2 percent strawberry and beetroot powder, 0.2 percent stabilizer-emulsifier mixture and 16 percent sugar showed maximum melting. At linear level, melting rate was significantly (P<0.05) reduced with increase in stabilizer-emulsifier quantity which could be attributed to increase in amount of bound water with addition of stabilizer and increased overrun while was significantly (P<0.05) increased with increase in sugar quantity leading to higher freezing point depression. At quadratic level, strawberry and beetroot powder as well as sugar resulted in significantly (P<0.05) higher melting rate due to higher freezing point depression while stabilizer-emulsifier blend reduced melting significantly by increasing the amount of bound water. Incorporation of beetroot pulp in strawberry flavored frozen yoghurt reduced melting rate (Chhikara et al. 2019). The deviation from the current

Table 2: Regression coefficients and ANOVA fitted quadratic model for the responses of strawberry and beetroot incorporated low-fat frozen yoghurt

Partial coefficients	Flavor	Body & texture	Melting characteristics	Color & appearance	Total score	Melting rate, %	Overrun, %
Intercept	42.77	28.24	4.29	4.45	94.16	47.29	91.89
A-SBP@	1.33*	0.52*	0.14*	0.18*	1.46*	-0.71	-0.42
B-S+E#	0.35	0.64*	0.33*	0.10	1.43*	-2.21*	1.78*
C-Sugar	1.60*	0.58*	0.18*	0.12	2.50*	1.43*	0.75*
AB	0.39	0.20	0.20*	0.06	0.49	1.14	0.32
AC	0.98*	-0.35	0.02	-0.03	-1.48	0.86	0.29
BC	0.39	0.42	0.19*	-0.14	-0.90	0.65	0.22
A^2	-1.64*	-1.39*	-0.33*	-0.50*	-1.89*	1.86*	0.74
B^2	-0.40	-1.66*	-0.63*	-0.13	-1.26*	-3.15*	-1.56*
C^2	-1.71*	-1.15*	-0.03	-0.10	-1.93*	2.59*	0.91*
Model fit statistics							
Lack of fit	< 0.0001	0.0286	0.0394	0.0026	0.0001	< 0.0001	< 0.0001
Model F value	8.82	9.63	9.85	8.21	11.76	14.26	9.02
R^2	0.90	0.92	0.88	0.89	0.91	0.92	0.89
APV	8.12	9.43	10.24	9.74	11.27	10.56	9.12

@ Strawberry and beetroot powder; #Stabilizer-emulsifier blend; *significant effect at 5% level

Table 3: Regression equation for predicting sensory score, melted quantity and overrun of strawberry and beetroot incorporated low-fat frozen yoghurt

Property	Equation
Flavor	$42.77+1.33A+0.35B+1.60C+0.39AB+0.98AC+0.39BC-1.64A^2-0.40B^2-1.71C^2$
Body & texture	$28.24+0.52A+0.64B+0.58C+0.20AB-0.35AC+0.42BC-1.39A^2-1.66B^2-1.15C^2$
Melting characteristics	$4.29+0.14A+0.33B+0.18C+0.20AB+0.02AC+0.19BC-0.33A^2-0.63B^2-0.03C^2$
Color & appearance	$4.45+0.18A+0.10B+0.12C+0.06AB-0.03AC-0.14BC-0.50A^2-0.13B^2-0.10C^2$
Total score	$94.16+1.46A+1.43B+2.50C+0.49AB-1.48AC-0.90BC-1.89A^2-1.26B^2-1.93C^2$
Melting rate	$47.29-0.71A-2.21B+1.43C+1.14AB+0.86AC+0.65BC+1.86A^2-3.15B^2+2.59C^2$
Overrun	$91.89-0.42A+1.78B+0.75C+0.32AB+0.29AC+0.22BC+0.74A^2-1.56B^2+0.91C^2$

investigation may be due to addition of strawberry flavor instead of strawberry powder.

Effect of variables on overrun

Overrun, directly related to amount of air incorporated in ice cream, is an important characteristic as it influences product quality and profit of the producer as well as is also involved in meeting legal standards. Too high overrun results in fluffy ice cream while too little overrun produces soggy and heavy body (Patel et al. 2015). Overrun (%) of the frozen yoghurt ranged between 72.45 percent and 97.88 percent. The frozen yoghurt samples containing 2% strawberry and beetroot powder, 0.2% stabilizer-emulsifier blend and 16% sugar showed minimum overrun while the one containing 4% strawberry and beetroot powder, 0.35% stabilizer-emulsifier blend and 17.36% sugar showed maximum overrun. At linear level, the rate of addition of stabilizer-emulsifier mixture and sugar significantly ($P<0.05$) increased overrun due to increased water binding and thus viscosity while at quadratic level stabilizer-emulsifier mixture had significantly ($P<0.05$) negative impact on overrun due to drastic increase in viscosity leading to poor air incorporation (Syed and Shah, 2016). Sugar had significantly ($P<0.05$) positive impact even at quadratic level. Moeenfard and Tehrani (2008) reported increase in overrun up to the level of 0.25 per cent. Though the combination of stabilizers and emulsifiers was different as well as the process of preparation of frozen yoghurt was also different. Increase in carrageenan content from 0.05 to 0.15 percent reduced overrun by almost 5.0 percent while increasing corn starch from 2.0 to 3.0 percent reduced overrun rate by 6.0 percent (Skryplonek et al. 2018).

Optimization of variables for preparation of low-fat frozen yoghurt

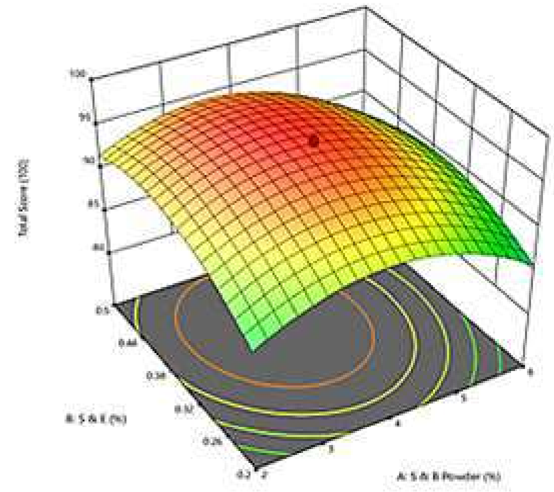
The optimization of different variables such as strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar was carried out using numerical optimization technique. The criteria used for optimization are summarized in Table 4. Among the variables, strawberry and beetroot powder was maximized while stabilizer-emulsifier mixture and sugar were kept in range. Among the responses, the sensory parameters were maximized while melted quantity and overrun were set to the target of 50% and 90% respectively for the optimization process. RSM suggested the rate of addition of strawberry and beetroot powder, stabilizer-

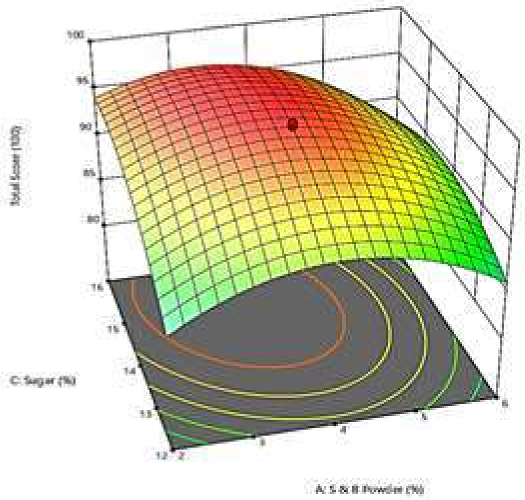
Table 5: Comparison of predicted values and observed values for strawberry and beetroot incorporated low-fat frozen yoghurt

Attribute	Predicted value	Observed value	t-value
Flavor	43.14	43.05	NS
Body & texture	28.02	27.81	NS
Melting characteristics	4.41	4.34	NS
Color & appearance	4.48	4.44	NS
Total score	94.23	94.14	NS
Melting rate, %	50.05	50.15	NS
Overrun, %	90.07	90.20	NS

Table 6: Comparison of strawberry and beetroot incorporated low-fat frozen yoghurt with control frozen yoghurt

Parameter	Control frozen yoghurt	Carrot incorporated low-fat frozen yoghurt	t-value
Chemical composition			
Moisture, %	68.18±0.11	64.12±0.15	0.15
Fat, %	2.47±0.07	2.41±0.09	NS
Protein, %	5.18±0.10	5.08±0.15	NS
Ash, %	1.09±0.05	1.19±0.08	NS
Carbohydrates, %	23.10±0.18	27.18±0.23	0.22
Physical characteirstics			
Melting rate, %	50.62±0.42	50.15±0.26	NS
Overrun, %	91.45±1.15	90.20±1.18	NS
Sensory characteristics			
Flavor	40.85±0.51	43.05±0.78	0.32
Body & texture	25.54±0.69	27.81±0.64	0.29
Melting characteristics	4.23±0.16	4.34±0.32	0.15
Color & appearance	4.49±0.14	4.44±0.26	NS
Total Score*	90.11±0.64	94.14±0.54	1.09
Microbial analysis			
APC (log_{10}cfu/g)	9.04 ± 1.24	9.15 ± 1.29	NS
Coliform	Absent in 1 g		
Y&M	Absent in 1 g		





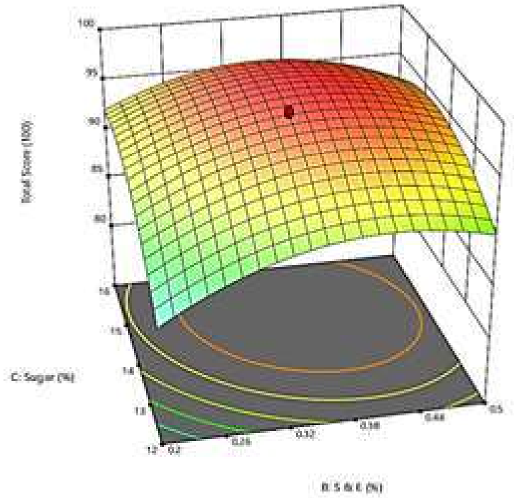


Fig. 1: Effect of different variables on total score of strawberry and beetroot incorporated low-fat frozen yoghurt

emulsifier mixture and sugar to be 4.06 percent, 0.21 percent and 15.45 percent respectively with desirability of 0.96. Strawberry and beetroot-based low-fat frozen yoghurt was prepared by adding strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar as suggested by RSM. The predicted values for flavor, body and texture, melting quality, color and appearance, total score, melted quantity and overrun for the frozen yoghurt were 43.14, 28.02, 4.41, 4.48, 94.23, 50.05% and 90.07% respectively. It is evident from the table that the observed values were not significantly ($P>0.05$) different from predicted values with respect to all attributes. Hence, it was confirmed that the selected level of addition of strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar is most suitable for the preparation of strawberry and beetroot-based low-fat frozen yoghurt with optimum sensory and physio-chemical attributes.

Analysis of strawberry and beetroot incorporated low-fat frozen yoghurt

strawberry and beetroot-based low-fat frozen yoghurt was analysed and compared with control frozen yogurt for its compositional parameters, physical characteristics as well as sensory attributes and analysed statistically using t-test. Moisture content of experimental frozen yoghurt was significantly ($P<0.05$) lower while carbohydrates content was significantly ($P<0.05$) higher due to addition of strawberry and beetroot powder. Sensory attributes such as flavor, body and texture, melting quality and total score of experimental frozen yoghurt were significantly ($P<0.05$) higher than those of control frozen yoghurt. Aerobic plate count of the experimental and control frozen yoghurt were statistically at par. Both the yoghurt samples were free from coliform as well as yeast and Mold (Table 6).

Conclusion

Strawberry and beetroot-based low-fat frozen yoghurt was prepared using response surface methodology and the rate of addition of strawberry and beetroot powder, stabilizer-emulsifier mixture and sugar were optimized to obtain sensorially acceptable product and similar physical characteristics to those of control. At linear level, strawberry and beetroot powder improved flavor, body and texture, color and appearance as well as total score of the frozen yoghurt while stabilizer-emulsifier mixture improved body and texture, melting characteristics, total score and overrun. It also reduced melted quantity of frozen yoghurt. Sugar improved flavor, body and texture, melting characteristics, total score, melted quantity as well as overrun. At quadratic level, all the variables had negative impact on sensory attributes while strawberry and beetroot powder increased melted quality, stabilizer-emulsifier blend reduced melted quality and overrun while sugar increased both of them. On the basis of the results, RSM suggested to prepare frozen yoghurt using 4.06 percent strawberry and beetroot powder, 0.21 percent stabilizer-emulsifier mixture and 15.45 percent sugar. The standardized frozen yoghurt was highly acceptable. Hence, an acceptable quality carrot-based low-fat frozen yoghurt can be developed by using response surface methodology.

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