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RESEARCH ARTICLE

Application of carrot powder in preparation of low-fat frozen yoghurt

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Abstract: Low-fat frozen yoghurt was prepared using carrot powder as one of the ingredients. Response surface methodology (RSM) was used to optimize the level of carrot powder, stabilizer-emulsifier mixture and sugar. The responses were sensory attributes such as flavour, body and texture, melting quality, colour and appearance and total score as well as physical attributes like melted quantity and overrun. Based on the output, RSM suggested the rate of addition of carrot powder, stabilizer-emulsifier mixture and sugar to be 3.93%, 0.41% and 14.30% respectively. The experimental frozen yoghurt was prepared as per the suggestions from RSM and compared with control low-fat frozen yoghurt where carrot powder was replaced with vanilla flavour. 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.

Keywords: Carrot, Frozen yoghurt, Response surface methodology, Sensory

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 with addition of colouring and flavouring material. Frozen yoghurt contains the live strains of *Lactobacillus delbrueckii* subsp. *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 every age group (Tamime and Robinson, 2007).

Carrot is a root vegetable which is produced, exported and consumed in different parts of the world. Carrot is most valuable member of the apiaceae family due to its nutritional quality, phytochemical content, antioxidant capacity, and health advantages (Leja et al. 2013; Hassan and Barakat, 2018). Carrot roots may be extensively processed into nutrient-rich finished products such as juice, dry powder, concentrate, tinned, candy and pickle in addition to the traditional uses for salad and sweet dishes like carrot *halwaa*, which is the most well-known variant in north India. The acceptability of carrot is significantly influenced by peel to core ratio, total soluble content, carotenoid concentration, and fibre content (Sharma et al. 2012).

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 carrot 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.

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Therefore, in current investigation, low-fat frozen yoghurt has been developed with incorporation of carrot 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. Carrots (*Daucus* carota subsp. Sativus) were purchased from local vegetable market. Starter cultures *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* were obtained from Dairy Microbiology department of the institute. Sodium alginate, guar gum, carrageenan and pectin were supplied by HiMedia, Mumbai. Glycerol monostearate (GMS) was supplied by Loba Chemical, Mumbai. Vanilla flavour (International Flavours & Fragrances India Pvt. Ltd., Chennai) was used to prepare control frozen yoghurt.

Preparation of carrot powder

The carrot fruits were washed in portable water, peeled and shredded; the shredded carrots were blanched for 3 minutes in hot water containing sodium metabisulphite to prevent browning and discoloration. The sulphited carrots were immediately cooled by exposing to air and dried in a vacuum tray drier at 50°C for 12 hours. The dried carrot was ground to fine powder and sieved with a 0.150 µ sieve and was packaged in black polythene bag for further uses (Phebean et al. 2017).

Preparation of stabilizer-emulsifier blend

A blend of stabilizers (such as sodium alginate, guar gum, carrageenan and pectin) and emulsifier (such as 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.

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, carrot powder and stabilizer-emulsifier blend 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* subsp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* at the rate of 2% (w/w) of the quantity of mix followed by incubation at 42±2°C till the acidity reaches to 0.6% LA. 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 carrot incorporated low-fat frozen yoghurt

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, titratable acidity and overrun as per the method described by FSSAI (2015). Carbohydrates were calculated by difference. Viscosity of yoghurt mix was analysed by the method suggested by Muse and Hartel (2004) using Brookfield viscometer. Melting resistance of frozen yoghurt was analysed using the method given 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 carrot incorporated low-fat frozen yoghurt

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

The minimum and maximum levels of carrot powder, stabilizer-emulsifier blend and sugar were selected as 2 and 6%, 0.2 and 0.5% as well as 12 and 16% respectively, on the basis of preliminary trials. A central composite rotatable design (CCRD) of the response surface methodology (RSM) technique was adopted for the optimization of carrot powder, stabilizer-emulsifier blend and sugar. The CCRD of three factors contained 20 combinations, including lower and upper limits, along with their responses for sensory parameters as well as hardness and melting time are displayed in Table 1. The data generated for different responses were analyzed 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 carrot 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<0.01 and 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 carrot incorporated low-fat frozen yoghurt samples was analysed using independent t-test.

Results and discussion

The optimization of the rate of addition of carrot powder, stabilizer-emulsifier blend and sugar was carried out on the basis of sensory properties of carrot incorporated low-fat frozen yoghurt such as flavour, body & texture, meting characteristics, colour & appearance and total score as well as quantity of frozen yoghurt melted in specific time and firmness in terms of penetration in cone penetrometer. Experimental design matrix showing factors and their responses is displayed in Table 1. 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 87 per cent to 93 per cent (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 6.81 to 12.09. All these results firmly recommended that the model could be used to develop carrot incorporated low-fat frozen yoghurt. Regression equation for predicting sensory score, melted quantity and firmness of carrot incorporated low-fat frozen yoghurt is indicated in Table 3.

Effect of variables on colour and appearance: Colour and appearance is the first sensory parameter that is observed while carrying out sensory evaluation. The colour and appearance score of the frozen yoghurt was ranged between 3.13 and 4.63. The product obtained minimum score for colour and appearance when carrot powder, stabilizer-emulsifier mixture and sugar were added at the rate of 7.36%, 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 carrot powder significantly (P<0.05) improved colour and appearance of the frozen yoghurt at linear level as the judges liked the light reddish orange colour given by carrot powder but significantly (P<0.05) deteriorated colour and appearance at quadratic level due to high intensity of the colour which was disliked by the judges. The appearance score was increased from 6.66 to 7.90 with increase in rate of addition of carrot pulp from 2.0 to 4.0 per cent followed by reduction to 7.80 when carrot pulp was added at the rate of 5.0 per cent which is attributed to formation of gel like coagulum and reduction in wheying off (Agarwal and Prasad, 2013). Ateteallah et al. (2019) and Pandey et al.

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

Std Run	A: Carrot powder (% w/w)	B: S+E@ (% w/w)	C: Sugar (% w/w)	Response 1: Flavour	Response 2: Body & Texture	Response 3: Melting character-ristics	Response 4: C&A#	Response 5: Total score*	Response 6: Melted quantity, %	Response 7: Overrun, %
1	2.00	0.20	12.00	36.88	24.63	4.38	3.88	84.77	68.35	72.15
2	2.00	0.50	16.00	43.88	25.88	4.50	3.88	93.14	54.39	98.66
3	4.00	0.35	14.00	44.12	28.50	4.25	4.50	96.37	46.94	90.35
4	6.00	0.20	16.00	35.75	25.25	4.00	3.50	83.50	69.35	84.26
5	6.00	0.20	12.00	36.63	24.50	3.50	3.88	83.51	61.88	76.19
6	2.00	0.20	16.00	43.63	26.63	4.00	3.88	93.14	73.45	77.81
7	4.00	0.10	14.00	35.88	24.50	3.88	4.13	83.39	67.89	73.16
8	4.00	0.35	14.00	43.63	28.88	4.63	4.63	96.77	47.05	91.12
9	4.00	0.60	14.00	36.88	27.88	4.25	3.50	87.51	42.16	81.62
10	2.00	0.50	12.00	38.63	26.50	4.50	4.50	89.13	48.65	84.18
11	6.00	0.50	12.00	36.88	24.25	3.63	3.63	83.39	45.37	86.63
12	4.00	0.35	17.36	39.50	26.14	4.25	3.50	88.39	58.98	98.99
13	4.00	0.35	14.00	43.88	28.00	4.25	4.50	95.63	46.99	89.98
14	6.00	0.50	16.00	37.88	25.38	4.25	3.63	86.14	56.18	79.44
15	4.00	0.35	14.00	44.25	28.00	4.50	4.63	96.25	47.11	90.51
16	7.36	0.35	14.00	35.88	22.63	3.00	3.13	79.64	49.12	85.32
17	4.00	0.35	10.64	35.88	23.88	4.13	4.00	82.89	48.63	86.95
18	4.00	0.35	14.00	44.00	28.88	4.25	4.50	96.63	47.01	90.94
19	4.00	0.35	14.00	43.88	28.63	4.50	4.50	96.51	46.96	90.32
20	0.64	0.35	14.00	37.13	24.88	3.13	3.88	84.02	54.18	82.81

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

(2019) also observed initial improvement in colour and appearance followed by deterioration at higher level.

Effect of variables on flavour

Flavour 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 flavour score of the frozen yoghurt between 35.85 and 44.15. The minimum flavour score for the frozen yoghurt was obtained when carrot powder, stabilizer-emulsifier blend and sugar were added at the rate of 6%, 0.2% and 16% respectively while maximum flavour score was obtained when carrot powder, stabilizer-emulsifier blend and sugar were added at the rate of 4%, 0.35% and 14% respectively (Table 1). Carrot powder and sugar significantly ($P<0.05$) improved flavour of the final product at linear level. Similarly, the interaction of both of them also significantly ($P<0.05$) improved the flavour while all the three variables significantly deteriorated flavour at quadratic level because high intensity of carrot flavour and very sweet taste were disliked by the judges. Flavour release was also reported to be slow by the experts when stabilizer-emulsifier mixture was added in higher amount. Agarwal and Prasad (2013) also observed improvement in flavour profile of low-fat frozen yoghurt prepared using carrot pulp. The flavour score increased from 6.76 to 7.90 with increase in rate of carrot pulp addition from 2.0 per cent to 5.0 per cent while increase in rate of addition of stabilizer from 0.5 per cent to 3.0 per cent also increased flavour score from 7.02 to 7.62. Moeenfard and Tehrani (2008) reported non-significant influence of rate of addition of stabilizers on flavour. The flavour score of ice-cream prepared using carrot pulp increased initially with increase in addition of carrot pulp followed by decrease at higher level (Dias et al. 2015; Ateteallah et al. 2019; Pandey et al. 2019).

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 carrot was ranged from 22.63 to 28.88. The frozen yoghurt

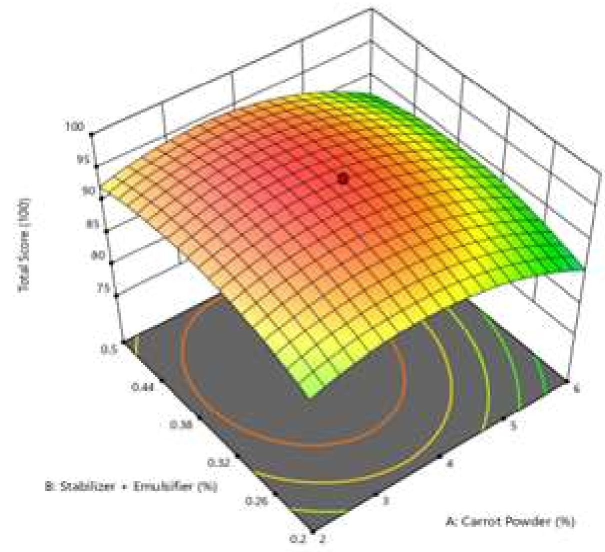
Table 2 Regression coefficients and ANOVA fitted quadratic model for the responses of carrot incorporated low-fat frozen yoghurt

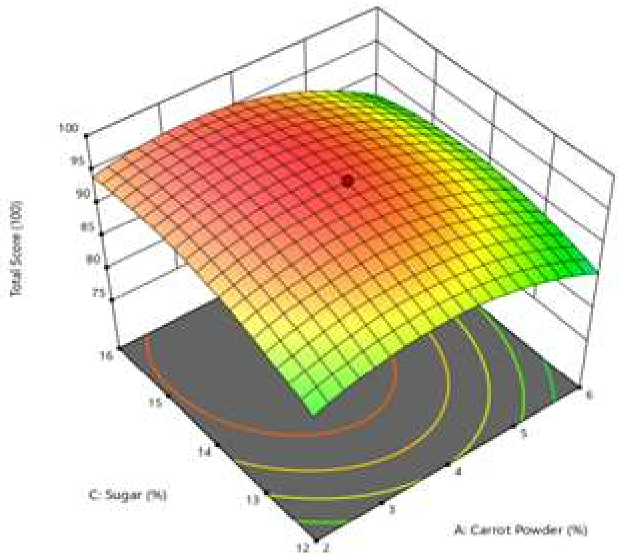
Partial coefficients	Flavour	Body & texture	Melting characteristics	Colour & appearance	Total score	Melted quantity, %	Overrun, %
Intercept	43.86	28.46	4.37	4.53	96.23	46.81	92.16
A-Carrot powder	1.31*	-0.59*	-0.15	0.20*	2.24*	-1.51	-0.28
B-S+E#	0.44	0.48*	0.21*	-0.04	1.10	-8.21*	2.16*
C-Sugar	1.32*	0.51*	0.16*	-0.06	1.86*	3.43*	0.83*
AB	0.03	-0.16	-0.03	-0.09	-0.25	1.14	0.26
AC	1.47*	0.06	0.19	0.03	-1.19	0.93	0.24
BC	0.03	-0.28	0.06	-0.03	-0.22	0.50	0.15
A^2	-2.12*	-1.54*	-0.46*	-0.32*	-4.46*	2.86*	0.52
B^2	-2.20*	-0.69*	-0.55*	-0.09	-3.06*	4.15*	-1.38*
C^2	-1.69*	-1.09*	-0.39*	0.07	-2.92*	3.59*	0.80*
			Model fit statistics				
Lack of fit	< 0.0001	0.0313	0.0455	0.0022	0.0001	< 0.0001	< 0.0001
Model F value	8.22	11.72	9.43	7.49	12.81	16.00	8.35
R^2	0.88	0.91	0.89	0.87	0.92	0.93	0.88
APV	6.81	9.81	12.09	7.87	10.09	11.96	9.51

#Stabilizer-emulsifier blend; *significant effect at 5% level

Table 3 Regression equation for predicting sensory score, melted quantity and firmness of carrot incorporated low-fat frozen yoghurt

Property	Equation
Flavour	$43.86 + 1.31A + 0.44B + 1.32C + 0.03AB + 1.47AC + 0.03BC - 2.12A^2 - 2.2B^2 - 1.69C^2$
Body & texture	$28.46 - 0.59A + 0.48B + 0.51C - 0.16AB + 0.06AC - 0.28BC - 1.54A^2 - 0.69B^2 - 1.09C^2$
Melting characteristics	$4.37 - 0.15A + 0.21B + 0.16C - 0.03AB + 0.19AC + 0.06BC - 0.46A^2 - 0.55B^2 - 0.39C^2$
Colour & appearance	$4.53 - 0.2A - 0.04B - 0.06C - 0.09AB + 0.03AC - 0.03AC - 0.32A^2 - 0.09B^2 + 0.07C^2$
Total score	$96.23 - 2.24A + 1.10B + 1.86C - 0.25AB - 1.19AC - 0.22BC - 4.46A^2 - 3.06B^2 - 2.92C^2$
Melted quantity	$46.81 - 1.51A - 8.21B + 3.43C + 1.14AB + 0.93AC + 0.50BC + 2.86A^2 + 4.15B^2 + 3.59C^2$
Overrun	$92.16 - 0.28A + 2.16B + 0.83C + 0.26AB + 0.24C + 0.15BC + 0.52A^2 + 1.38B^2 + 0.80C^2$





displayed minimum body and texture score when it contained 7.36% carrot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar while maximum body and texture score was observed when it contained 4% carrot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar (Table 1). At linear level, carrot powder significantly (P<0.05) reduced body and texture score while stabilizer-emulsifier mixture and sugar significantly (P<0.05) increased it. Addition of carrot powder led to slight crumbly body addition of stabilizer-emulsifier mixture and sugar increased viscosity and assisted to get proper overrun resulting in smooth 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. Carrot pulp when increased from 2.0 to 5.0 per cent showed minor increase in body and texture score from 6.93 to 7.03 (Agarwal and Prasad, 2013; Ateteallah et al. 2019; Pandey et al. 2019). Body and texture score also increased with increase in rate of addition of stabilizers (Moeenfard and Tehrani, 2008; Agarwal and Prasad, 2013). 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.

Effect of variables on melting characteristics: The behaviour of frozen product upon melting has utmost importance. The sensory score for melting quality ranged between 3 and 4.5 The minimum score for melting quality was obtained when the product contained 7.36% carrot powder, 0.35% stabilizer-emulsifier mixture and 14% sugar while maximum body and texture score was observed when it contained 4% carrot 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. Ateteallh et al. (2019) observed

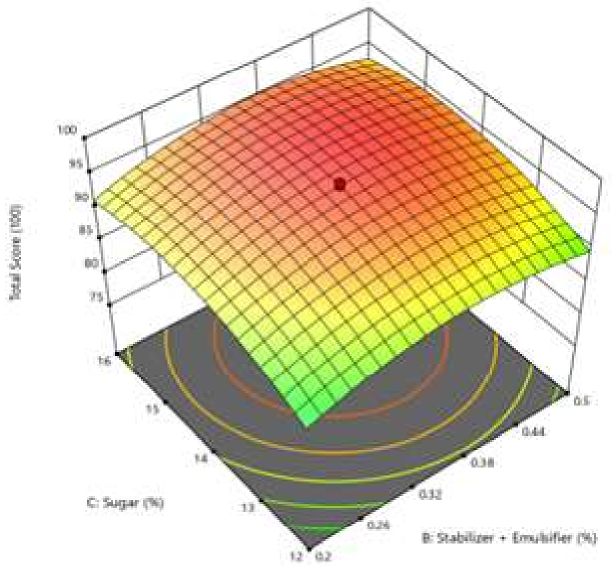


Fig. 1 Effect of different variables on total score of carrot-incorporated low-fat frozen yoghurt

improvement in melting characteristics with increase in carrot pulp initially followed by reduction at higher level while in current investigation carrot powder failed to impact melting quality which could be due to use of different stabilizer.

Effect of variables on total score

Total score is sum of the scores of all the sensory attributes. The total score ranged from 79.64 to 96.63. The frozen yoghurt containing 7.36% carrot 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. The rate of addition of carrot powder and sugar significantly (P<0.05) increased total score while all the three variables significantly (P<0.05) reduced total score. The impact of different factors on total score is shown in Figure 1. Agarwal and Prasad (2013) also reported similar results in low-fat frozen yoghurt prepared using carrot pulp. The frozen yoghurt containing 0.1 per cent carrageenan was rated better than the ones containing 0.05 and 0.15 per cent while in case of corn starch sensory properties improved with increasing corn starch from 1 per cent to 3 per cent (Skryplonek et al. 2018). Ateteallah et al. (2019) and Pandey et al. (2019) also reported similar results.

Effect of variables on melted quantity

Frozen product should have optimum melting time. Rapid or slow melting causes inconvenience for the consumer. Melting time is inversely related to melted quantity. The melted quantity of the frozen yoghurt ranged between 42.16% and 73.45%. The frozen yoghurt containing 4% carrot powder, 0.6% stabilizer-emulsifier mixture and 14% sugar showed minimum melting while the one containing 2% carrot powder, 0.2% stabilizer-emulsifier mixture and 16% 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, all the three variables resulted in significantly (P<0.05) higher melting rate due to higher viscosity resulting in lower overrun and higher freezing point depression. Moeenfard and Tehrani (2008) also observed increase in melting resistance of frozen yoghurt with increase in stabilizer and emulsifier content. Increase in carrageenan content from 0.05 to 0.15 per cent reduced melting rate by almost 13 per cent while increasing corn starch from 2.0 to 3.0 per cent reduced melting rate by 4 per cent (Skryplonek et al. 2018).

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 ceam while too little overrun produces soggy and heavy body (Patel et al. 2015). Overrun (%) of the frozen yoghurt ranged between 72.15 per cent and 98.99 per cent. 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. Overrun increased from 41.16 per cent to 45.46 per cent with increase in rate of addition of stabilizer-emulsifier mixture from 0.144 per cent to 0.254 per cent (Moeenfard and Tehrani, 2008). The rate of addition of stabilizer-emulsifier mixture was quite lower by Moennfard and Tehrani (2008) than current investigation where rate of addition varied from 0.10 to 0.60 per cent. Increase in carrageenan content from 0.05 to 0.15 per cent reduced overrun by almost 5.0 per cent while increasing corn starch

Table 4 Goals set for constraints to optimize the carrot incorporated low-fat frozen yoghurt

Constraint	Goal	Lower limit	Upper limit
Carrot powder, %	Maximize	2	6
S+E*, %	In range	0.2	0.5
Sugar, %	In range	12	16
Flavour	Maximize	35.75	44.25
Body & texture	Maximize	22.63	28.88
Melting characteristics	Maximize	3.00	4.63
Colour & appearance	Maximize	3.13	4.63
Total score	Maximize	79.64	96.77
Melted quantity, %	Target – 50	42.16	73.45
Overrun, %	Target - 90	72.15	98.99

*Stabilizer-emulsifier blend

Table 5 Comparison of predicted values and observed values for carrot incorporated low-fat frozen yoghurt

Attribute	Predicted value	Observed value	t-value
Flavour	43.29	43.27	NS
Body & texture	27.47	27.43	NS
Melting characteristics	4.43	4.42	NS
Colour & appearance	4.45	4.46	NS
Total score	94.66	94.58	NS
Melted quantity, %	50.13	50.14	NS
Overrun, %	90.05	90.12	NS

Table 6 Comparison of carrot 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	64.51±0.09	0.11
Fat, %	2.47±0.07	2.44±0.08	NS
Protein, %	5.18±0.10	5.15±0.12	NS
Ash, %	1.09±0.05	1.13±0.07	NS
Carbohydrates, %	23.10±0.18	26.67±0.20	0.20
Physical charactеirstics			
Melted quantity, %	50.62±0.42	50.14±0.37	NS
Overrun, %	91.45±1.15	90.12±1.13	NS
Sensory characteristics			
Flavour	40.85±0.51	43.27±0.62	0.35
Body & texture	25.54±0.69	27.43±0.55	0.26
Melting characteristics	4.23±0.16	4.42±0.22	0.13
Colour & appearance	4.49±0.14	4.46±0.20	NS
Total Score*	90.11±0.64	94.58±0.71	1.07
Microbial analysis			
APC (log_{10}cfu/g)	9.04 ± 1.24	8.97 ± 1.37	NS
Coliform	Absent in 1 g		
Y&M	Absent in 1 g		

from 2.0 to 3.0 per cent reduced overrun rate by 6.0 per cent (Skryplonek et al. 2018).

Optimization of variables for preparation of low-fat frozen yoghurt

The optimization of different variables such as carrot 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, carrot 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 target of 50% and 90% respectively for the optimization process. RSM suggested the rate of addition of carrot powder, stabilizer-emulsifier mixture and sugar to be 3.93 per cent, 0.41 per cent and 14.30 per cent respectively with desirability of 0.90. Carrot-based low-fat frozen yoghurt was prepared by adding carrot powder, stabilizer-emulsifier mixture and sugar as suggested by RSM. The predicted values for flavour, body and texture, melting quality, colour and appearance, total score, melted quantity and overrun for the frozen yoghurt were 43.29, 27.47, 4.43, 4.45, 94.66, 50.13% and 90.05% respectively. It is evident from the Table 5 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 carrot powder, stabilizer-emulsifier mixture and sugar is most suitable for the preparation of carrot-based low-fat frozen yoghurt with optimum sensory and physico-chemical attributes.

Analysis of carrot incorporated low-fat frozen yoghurt

Carrot-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 ($P<0.05$) due to addition of carrot powder. Sensory attributes flavour, 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

Carrot-based low-fat frozen yoghurt was prepared using response surface methodology and the rate of addition of carrot powder, stabilizer-emulsifier mixture and sugar were optimized to obtain sensorially acceptable product and similar physical characteristics to those of control. At linear level, carrot powder improved flavour as well as colour and appearance of the frozen yoghurt while stabilizer-emulsifier mixture improved body and texture, melting quality as well as overrun. It also reduced melted quantity of frozen yoghurt. Sugar also improved flavour, body and texture, melting quality as well as overrun. At quadratic level, all the variables had negative impact on sensory attributes and rate of melting was also increased. Stabilizer-emulsifier mixture reduced overrun while sugar had opposite effect. On the basis of the outcomes, RSM suggested to prepare frozen yoghurt using 3.93 per cent carrot powder, 0.41 per cent stabilizer-emulsifier mixture and 14.30 per cent sugar. The final product was highly acceptable. Hence, acceptable quality carrot-based low-fat frozen yoghurt can be developed by using response surface methodology.

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