

RESEARCH ARTICLE

Replacement of sugar with common salt and black pepper in low-fat frozen yoghurt

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Abstract: Common salt, black pepper and maltodextrin were used to replace milk fat and sugar in low-fat frozen yoghurt. Response Surface Methodology (RSM) was used to optimize the level of maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture. The responses in RSM were sensory attributes of frozen yoghurt such as flavour, body & texture, melting characteristics, colour & appearance and total score as well as physical properties such as melting rate and overrun. Based on the output, RSM suggested the rate of addition of maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture to be 6.12, 0.65 and 0.45 per cent respectively. The experimental frozen yoghurt was prepared as per the suggestion of RSM and compared with control low-fat frozen yoghurt which was prepared using vanilla flavour. The experimental frozen yoghurt was statistically similar with control sample for compositional parameters, physical properties, sensory attributes and microbiological quality.

Keywords: common salt, black pepper, frozen yoghurt, response surface methodology, sensory, overrun

Introduction

Frozen yoghurt is a frozen and fermented dairy dessert which possesses the characteristics of ice-cream and yoghurt both. Hence, it displays sensory characteristics of ice-cream and nutritive benefits of yoghurt. Frozen yoghurt is prepared by three different methods. Traditionally, ice-cream mix was fermented with

yoghurt starter culture *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus*. The set yoghurt was stirred and frozen. In another method, ice-cream and yoghurt were prepared separately followed by mixing in specific proportion. The mixture was frozen in ice-cream freezer. In third method, ice-cream mix is partially fermented with yoghurt culture followed by freezing (Granato et al. 2018).

From time immemorial, spices have played a vital role in world trade due to their varied properties and applications. We primarily depend on spices for flavour, colour, preservation and inherent medicinal qualities. One of the major spices, black pepper (*Piper nigrum*), king of spices, contains an array of phenolic components which are a mixture of the glycosides of phenolic acids and flavonol glycosides. Black pepper has found therapeutic applications in curing atherosclerosis, gangrene, earache, abdominal tumors, constipation, tooth decay, liver disorders, joint pain, lung diseases, insect bites etc. (Sharif et al. 2018).

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 (Dean et al. 2017).

Around 5 per cent people worldwide and 11 per cent in India are suffering from diabetes and increasing at the rate of 4 per cent annually (WHO, 2023). Sugar has been replaced by artificial intense sweeteners in variety of products but with the development of science, artificial sweeteners are now being linked with several diseases from mild headache to cancer (More et al. 2021). Therefore, replacement of sugar with natural ingredients is need of the hour. In addition, 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

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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 salt and black pepper 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. Hence, in current investigation, sugar has been replaced by salt and black pepper in low-fat frozen yoghurt.

Materials and Methods

Fresh, raw mixed (cow and buffalo) milk was procured from Livestock Research Station (LRS) of the University and calculated quantity of whole milk was subjected to cream separation to obtain skimmed milk. Skimmed milk powder (Sagar brand, marketed by Gujarat Cooperative Milk Marketing Federation Ltd., Anand, India), Cane sugar (Madhur brand, Karnataka), black pepper (Keya Foods International Pvt. Ltd., Kerala) and common salt (Tata Chemicals Ltd., Mumbai) was purchased from local market. Maltodextrin was supplied by Cargill India Pvt. Ltd., New Delhi. Stabilizers such as pectin, sodium alginate, guar gum and carrageenan were obtained from HiMedia, Mumbai. Emulsifier Glyceromonostearate (GMS) of Loba Chemicals, Mumbai was used. Starter cultures for yoghurt making such as *Streptococcus salivarius* ssp. *thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* were obtained from Dairy Microbiology Division of the institute. Vanilla flavour for control sample was obtained from International Flavors and Fragrances (IFF), Mumbai.

Preparation of stabilizer-emulsifier blend: A blend of stabilizers (such as sodium alginate, guar gum, carrageenan and pectin) as well as emulsifier (such as glyceromonostearate) was used in preparation of frozen yoghurt as per the suggestion of Response Surface Methodology (RSM). The blend contained sodium alginate, guar gum, carrageenan, pectin and GMS in the ratio of 2:2:1:2:2 on the basis of preliminary trials. A combination of different stabilizers has synergistic effect on the quality of frozen yoghurt and can reduce their use (Kugashiya et al. 2023). Hence, a combination of stabilizers and emulsifiers has been used in current investigation.

Preparation of salt and black pepper blend: Salt and black pepper were mixed in the ratio of 1:1 based on preliminary trials and used in preparation of frozen yoghurt.

Preparation of frozen yoghurt: Frozen yoghurt has been prepared using the method suggested by Kugashiya et al (2023) with minor modifications. The detailed method is illustrated hereunder:

Calculated quantity of whole milk and skimmed milk were mixed at 45°C followed by heating to 55°C. All the dry ingredients such as skimmed milk powder, maltodextrin, sugar, salt and black pepper blend as well as stabilizer-emulsifier mixture were blended together before addition to whole milk and skimmed milk blend. The mixture

was then homogenized at 65°C. The homogenization pressures used were 2000 and 500 psi in first and second stage respectively. It was then heat treated at 85°C for 30 min followed by cooling to 42±2°C and inoculation of starter cultures *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* at the rate of 2 per cent (w/w) of the quantity of yoghurt mix and incubated till the acidity reached to 0.6 per cent LA. The yoghurt mix was then cooled to 4°C and stirred. The stirred yoghurt 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 milk and experimental 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 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 Shahein et al. (2022). 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 Shahein et al. (2022).

Sensory evaluation of experimental 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 (Hussein et al. 2023).

Statistical analysis: A Central Composite Rotatable Design (CCRD) of the Response Surface Methodology (RSM) technique was adopted for the optimization of maltodextrin, salt and black pepper blend as well as stabilizer-emulsifier blend. The minimum and maximum levels of maltodextrin, salt and black pepper blend as well as stabilizer-emulsifier blend were selected as 4 and 8 per cent, 0.5 and 1.0 per cent as well as 0.25 and 0.75 per cent 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, Minneapolis, 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 maltodextrin, salt and black pepper blend as well as stabilizer-emulsifier blend 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 sample prepared using vanilla flavour and low-fat frozen yoghurt added with salt and black pepper was analysed using independent t-test.

Results and Discussion

The optimization of rate of addition of maltodextrin, salt and black pepper blend as well as stabilizer-emulsifier blend were carried out on the basis of sensory attributes such as flavour, body & texture, melting characteristics, colour & appearance and total score as well as melting rate 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 82 to 91 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 8.16 to 13.78. All these results firmly recommended that the model could be used to develop low-fat frozen yoghurt added with salt and black pepper. Regression equation for predicting sensory score, melting rate and overrun of the experimental frozen yoghurt is depicted in Table 3.

Effect of variables on flavour: Flavour is the most important sensory characteristics for majority of dairy products which includes taste, odour and mouthfeel. The flavour score for the frozen yoghurt ranged from 35.14 to 40.57. The minimum flavour score was obtained when maltodextrin, salt & black pepper blend and stabilizer-emulsifier blend were added at the rate of 6.00, 1.17 and 0.50 per cent respectively. Similarly, the maximum flavour score was obtained when maltodextrin, salt & black pepper blend and stabilizer-emulsifier blend were added at the rate of 4.00, 0.50 and 0.75 per cent respectively (Table 1). Salt and black pepper blend significantly ($P < 0.05$) improved flavour of the frozen yoghurt at linear level which could be attributed to

Table 1: Experimental design matrix showing factors and their responses for the development of low-fat frozen yoghurt added with salt and pepper

Std Run	A: Maltodextrin (% w/w)	B: S+P@ (% w/w)	C: S+E** (% w/w)	Response 1: Flavour	Response 2: Body & Texture	Response 3: Melting characteristics	Response 4: C&A#	Response 5: Total score*	Response 6: Melting rate, %	Response 7: Overrun, %
1	8.00	0.50	0.75	39.14	25.71	3.18	4.28	87.31	43.75	85.42
2	6.00	0.33	0.50	36.42	25.42	3.72	4.07	84.63	48.19	88.92
3	8.00	1.00	0.75	35.57	25.50	3.32	4.08	83.47	47.26	84.06
4	4.00	1.00	0.75	36.71	24.71	3.71	4.02	84.15	49.11	88.24
5	6.00	0.75	0.50	39.85	26.42	4.07	4.32	89.66	50.98	91.05
6	6.00	0.75	0.50	39.14	26.34	4.05	4.27	88.80	50.44	90.36
7	4.00	0.50	0.75	40.57	26.01	3.64	4.28	89.50	43.92	88.29
8	6.00	0.75	0.50	39.52	26.38	4.25	4.29	89.44	51.12	89.94
9	6.00	0.75	0.08	40.14	23.42	3.72	4.07	86.35	59.23	80.19
10	6.00	1.17	0.50	35.14	25.42	3.52	3.97	83.05	54.29	92.76
11	9.36	0.75	0.50	35.28	24.85	3.71	4.07	82.91	45.68	94.05
12	8.00	1.00	0.25	36.42	24.42	3.28	4.07	83.19	55.81	87.26
13	2.63	0.75	0.50	35.37	24.12	3.43	4.02	81.94	53.96	84.32
14	6.00	0.75	0.92	38.51	23.76	3.75	4.25	85.27	43.82	83.87
15	6.00	0.75	0.50	39.23	26.35	3.98	4.26	88.82	49.88	90.55
16	6.00	0.75	0.50	40.18	26.25	3.95	4.36	89.74	50.24	90.28
17	4.00	0.50	0.25	40.05	24.50	3.74	4.12	87.41	54.81	82.60
18	6.00	0.75	0.50	39.63	26.26	4.02	4.17	89.08	50.71	91.15
19	8.00	0.50	0.25	40.25	25.62	3.62	4.25	88.74	56.74	86.15
20	4.00	1.00	0.25	35.87	24.12	3.81	4.02	82.82	57.33	84.25

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

development of pleasant flavour due to salt and black pepper while at quadratic level, maltodextrin as well as salt and black pepper significantly ($P<0.05$) deteriorated the flavour. Maltodextrin produced typical bland flavour when added at higher level. Slow release of the flavour was also reported by the judges when maltodextrin was added at higher level. Addition of salt and black pepper blend in higher amount resulted in intense flavour which was not appreciated by the judges. Incorporation of maltodextrin in low-fat ice-cream improved flavour up to 5 per cent level followed by deterioration at higher level (Sonwane and Hembade, 2014). Solanki et al (2023) reported non-significant influence of rate of addition of stabilizers on flavor when added between 0.15 to 0.25 per cent. Incorporation of tulsi powder (Trivedi et al. 2014) in ice-cream improved flavour at initial level but deteriorated at higher level.

Effect of variables on body and texture: Body and texture is an important sensory characteristic for frozen products. The body and

texture score varied between 23.42 and 26.42. The frozen yoghurt samples added with 6.00 per cent maltodextrin, 0.75 per cent salt & black pepper blend and 0.08 per cent stabilizer-emulsifier blend obtained minimum score while the one containing 6.00 per cent maltodextrin, 0.75 per cent salt & black pepper blend and 0.50 per cent stabilizer-emulsifier blend scored maximum (Table 1). Maltodextrin and stabilizer-emulsifier blend had significant ($P<0.05$) positive impact on body and texture of the product at linear level which could be due to improvement in the firmness of the body and smooth texture but they had significant ($P<0.05$) negative impact at quadratic level due to development of heavy and soggy body which could be due to higher viscosity of the yoghurt mix. The interaction of maltodextrin and stabilizer-emulsifier blend also had significant ($P<0.05$) positive impact. Incorporation of maltodextrin in low-fat ice-cream improved body & texture when added up to 5 per cent level. Addition of maltodextrin at higher level resulted in heavy and soggy body (Sonwane and Hembade, 2014). Body and texture score

Table 2: Regression coefficients and ANOVA fitted quadratic model for the responses of low-fat frozen yoghurt added with salt and pepper

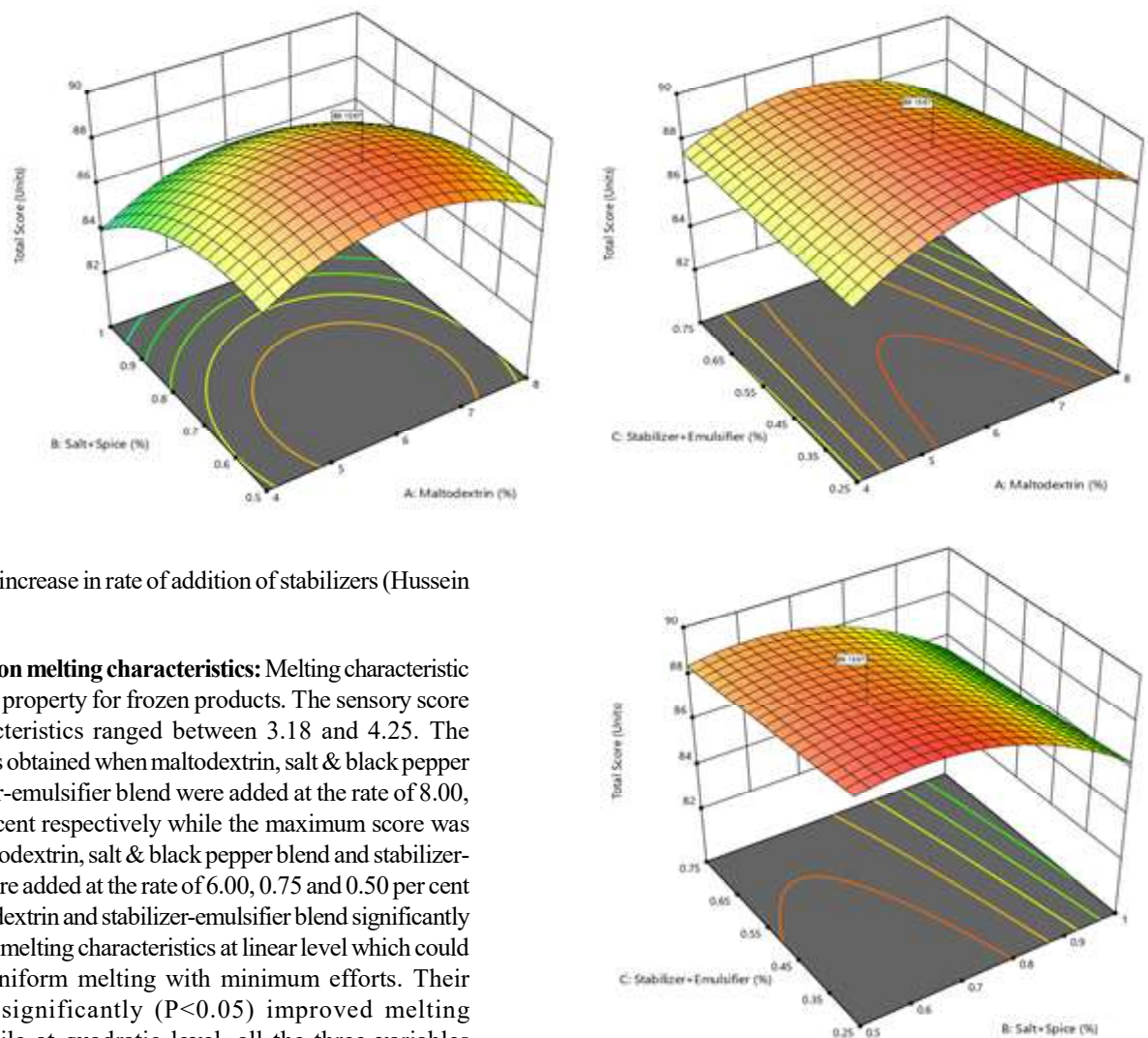
Partial coefficients	Flavour	Body & texture	Melting characteristics	Colour & appearance	Total score	Melting rate, %	Overrun, %
Intercept	39.54	25.84	3.99	4.28	88.67	51.12	89.76
A-Maltodextrin	-0.17	0.25*	0.20*	0.03	1.48*	-0.34	0.23
B-S+P [@]	1.26*	-0.17	-0.02	0.07	0.41*	0.25	0.16
C-S+E [#]	-0.27	0.34*	0.28*	0.06	0.44*	-1.14*	1.49*
AB	0.03	0.18	-0.04	-0.02	-0.51	-0.12	0.19
AC	-0.48	0.29*	0.24*	-0.01	0.08	-0.95*	0.41
BC	0.02	-0.09	0.06	0.02	0.61	0.21	0.36
A ²	-1.23*	-0.30*	-0.16*	-0.04	-1.74*	-0.96*	1.25*
B ²	-0.96*	-0.09	-0.14*	-0.19*	-1.29*	0.56*	0.26
C ²	0.18	-0.44*	-1.02*	-0.09	-1.20*	-2.34*	-2.13*
Model fit statistics							
Lack of fit	0.002	0.034	0.038	0.027	0.001	<0.0001	<0.0001
Model F value	8.16	9.52	9.46	8.36	11.48	13.78	9.58
R ²	0.82	0.84	0.87	0.87	0.85	0.89	0.91
APV	8.24	9.32	9.25	8.14	11.23	12.89	9.31

@ Salt and pepper blend; #Stabilizer-emulsifier blend; *significant effect at 5% level

Table 3: Regression equation for predicting sensory score, melting rate and overrun of low-fat frozen yoghurt added with salt and pepper

Property	Equation
Flavour	$39.54 - 0.17A + 1.26B - 0.27C + 0.03AB - 0.48AC + 0.02AB - 1.23A^2 - 0.96B^2 + 0.18C^2$
Body & texture	$25.84 + 0.25A - 0.17B + 0.34C + 0.18AB + 0.29AC - 0.09BC - 0.3A^2 - 0.09B^2 - 0.44C^2$
Melting characteristics	$3.99 + 0.2A - 0.02B + 0.28C - 0.04AB + 0.24AC + 0.06BC - 0.16A^2 - 0.14B^2 - 1.02C^2$
Colour & appearance	$4.28 + 0.03A + 0.07B + 0.06C - 0.02AB - 0.01AC + 0.02BC - 0.04A^2 - 0.19B^2 - 0.09C^2$
Total score	$88.67 + 1.48A + 0.41B + 0.14C - 0.51AB + 0.08AC + 0.61BC - 1.74A^2 - 1.29B^2 - 1.20C^2$
Melting rate	$51.12 - 0.34A + 0.25B - 1.14C - 0.12AB - 0.95AC + 0.21BC - 0.96A^2 + 0.56B^2 - 2.34C^2$
Overrun	$89.76 + 0.23A + 0.16B + 1.49C + 0.19AB + 0.41AC + 0.36BC + 1.25A^2 + 0.26B^2 - 2.13C^2$

Fig. 1 Effect of different variables on total score of low-fat frozen yoghurt added with salt and pepper



also increased with increase in rate of addition of stabilizers (Hussein et al. 2023).

Effect of variables on melting characteristics: Melting characteristic is a unique sensory property for frozen products. The sensory score for melting characteristics ranged between 3.18 and 4.25. The minimum score was obtained when maltodextrin, salt & black pepper blend and stabilizer-emulsifier blend were added at the rate of 8.00, 0.50 and 0.75 per cent respectively while the maximum score was obtained when maltodextrin, salt & black pepper blend and stabilizer-emulsifier blend were added at the rate of 6.00, 0.75 and 0.50 per cent respectively. Maltodextrin and stabilizer-emulsifier blend significantly ($P < 0.05$) improved melting characteristics at linear level which could be attributed to uniform melting with minimum efforts. Their interaction also significantly ($P < 0.05$) improved melting characteristics while at quadratic level, all the three variables significantly ($P < 0.05$) deteriorated melting characteristics. The product was criticized for very slow and uneven melting when maltodextrin and stabilizer-emulsifier blend were added at higher level while it melted very rapidly when salt & black pepper blend was added at higher level as addition of salt would result in freezing point depression yielding rapid melting. Addition of maltodextrin resulted in improvement in melting characteristics up to 3 per cent level followed by deterioration (Azari-anpar et al. 2017). Blassy et al. (2019) and Trivedi et al. (2014) also observed similar results in ginger ice-cream and basil ice-cream respectively.

Effect of variables on colour and appearance: Colour and appearance is first sensory attribute which is observed during sensory evaluation of a product. The colour and appearance score of the product ranged between 3.97 and 4.36. The minimum score was obtained by a product which contained 6.00 per cent maltodextrin, 1.17 per cent salt and black pepper blend and 0.50 per cent stabilizer-emulsifier mixture while the maximum score was obtained by the frozen yoghurt which contained 6.00 per cent maltodextrin, 0.75 per cent salt and black pepper blend and 0.50 per cent stabilizer-emulsifier mixture. Salt and

black pepper blend had significant ($P < 0.05$) negative effect at quadratic level which is majorly due to development of slight dark appearance because of the presence of black pepper. Maltodextrin and stabilizer-emulsifier blend failed to exert any impact on colour and appearance of low-fat frozen yoghurt added with salt and black pepper. Incorporation of black pepper in cottage cheese up to 1 per cent level improved colour and appearance followed by deterioration in it (Himabindu and Arunkumar, 2017). Addition of basil powder up to 3 per cent level improved colour and appearance of ice-cream followed by deterioration (Trivedi et al. 2014).

Effect of variables on total score: Total score is summation of the sensory score of all sensory attributes. Total score of the frozen yoghurt ranged from 81.94 to 89.74. The frozen yoghurt which obtained minimum score contained 2.63 per cent maltodextrin, 0.75 per cent salt and black pepper blend and 0.50 per cent stabilizer-emulsifier mixture while maximum score was obtained by a product

which contained 6.00 per cent maltodextrin, 0.75 per cent salt and black pepper blend and 0.50 per cent stabilizer-emulsifier mixture. All the three variables significantly ($P<0.05$) increased total score at linear level while they significantly ($P<0.05$) reduced it at quadratic level. Addition of maltodextrin up to 5 per cent level increased total sensory score of low-fat ice-creams followed by reduction at higher level (Sonwane and Hembade, 2014). Several other researchers observed similar trend in ice-cream (Trivedi et al. 2014; Ateteallah et al. 2019; Butt et al. 2023).

Effect of variables on melting rate: Melting rate is an important characteristic for frozen products. The melting should not be too rapid and too slow. The melting rate of the experimental frozen yoghurt varied between 43.75 and 59.23 per cent. The product containing 8.00 per cent maltodextrin, 0.50 per cent salt and black pepper blend and 0.75 per cent stabilizer-emulsifier mixture showed minimum melting while the one containing 6.00 per cent maltodextrin, 0.75 per cent salt and black pepper blend and 0.08 per cent stabilizer-emulsifier mixture showed maximum melting. Stabilizer-emulsifier mixture significantly ($P<0.05$) reduced melting of the product at linear as well as quadratic level which could be attributed to water binding by stabilizer and increased overrun by emulsifier. At quadratic level, maltodextrin significantly ($P<0.05$) decreased melting that could be ascribed to increased viscosity and overrun with the addition of maltodextrin while salt and black pepper blend significantly ($P<0.05$) increased it by increasing freezing point depression. The interaction of maltodextrin and stabilizer-emulsifier mixture significantly ($P<0.05$) reduced melting rate by increasing water binding, viscosity and

overrun. Increasing the rate of addition of stabilizer-emulsifier mixture from 0.144 to 0.198 per cent reduced melting rate of frozen yoghurt (Tawfek, 2021). Increasing κ -carrageenan from 0.05 to 0.15 per cent and corn starch from 1 to 3 per cent reduced melting rate of lactose-free frozen yoghurt (Skryplonek et al. 2019).

Effect of variables on overrun: Overrun is related to the amount of air incorporated during freezing. Frozen product should have optimum overrun. Higher overrun leads to fluffy body while lower overrun results in heavy and soggy body. The overrun of experimental frozen yoghurt varied from 80.19 to 94.05 per cent. The frozen yoghurt containing 6.00 per cent maltodextrin, 0.75 per cent salt and black pepper blend and 0.08 per cent stabilizer-emulsifier mixture had minimum overrun while the one containing 9.36 per cent maltodextrin, 0.75 per cent salt & black pepper blend and 0.50 per cent stabilizer-emulsifier mixture displayed maximum overrun. Stabilizer-emulsifier significantly ($P<0.05$) increased overrun at linear level by increasing water binding and thus viscosity. At quadratic level, maltodextrin significantly ($P<0.05$) increased overrun while stabilizer-emulsifier mixture significantly ($P<0.05$) reduced overrun by excessively increasing viscosity resulting in poor air incorporation (Syed and Shah, 2016). Swelam et al. (2021) 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 per cent reduced overrun by almost 5.0 per cent while increasing corn starch from 1 to 3 per cent reduced overrun rate by 6 per cent (Skryplonek et al. 2019).

Table 4: Goals set for constraints to optimize the low-fat frozen yoghurt added with salt and pepper

Constraint	Goal	Lower limit	Upper limit
Maltodextrin, %	Maximize	4.00	8.00
S+P [#] , %	In range	0.50	1.00
S+E*, %	In range	0.25	0.75
Flavour	Maximize	35.14	40.57
Body & texture	Maximize	23.42	26.42
Melting characteristics	Maximize	3.28	4.25
Colour & appearance	Maximize	3.97	4.36
Total score	Maximize	81.94	89.74
Melting rate, %	Target – 50	43.75	59.23
Overrun, %	Target - 90	80.19	94.05

Salt and pepper blend; *Stabilizer-emulsifier blend

Table 5: Comparison of predicted values and observed values for low-fat frozen yoghurt added with salt and pepper

Attribute	Predicted value	Observed value	t-value
Flavour	39.96	39.93	NS
Body & texture	25.94	25.98	NS
Melting characteristics	3.98	4.00	NS
Colour & appearance	4.27	4.26	NS
Total score	89.16	89.17	NS
Melting rate, %	49.99	50.05	NS
Overrun, %	89.99	90.14	NS

Table 6: Comparison of experimental frozen yoghurt with control frozen yoghurt

Parameter	Control frozen yoghurt	Low-fat frozen yoghurt added with salt and pepper	t-value
Chemical composition			
Moisture, %	73.83±0.94	73.86±0.82	NS
Fat, %	2.33±0.12	2.29±0.09	NS
Protein, %	4.16±0.16	4.19±0.02	NS
Ash, %	1.89±0.02	1.91±0.02	NS
Carbohydrates, %	17.79±0.32	17.76±0.38	NS
Physical characteristics			
Melting rate, %	53.19±0.55	50.07±0.17	NS
Overrun, %	92.61±0.87	90.11±0.21	NS
Sensory characteristics			
Flavour	39.45±0.97	39.93±0.83	NS
Body & texture	25.50±0.53	25.98±0.71	NS
Melting characteristics	3.90±0.18	4.00±0.16	NS
Colour & appearance	4.05±0.21	4.26±0.19	NS
Total Score*	87.90±1.33	89.17±1.54	NS
Microbial analysis			
APC (log ₁₀ cfu/g)	7.81±1.05	7.87±0.91	NS
Coliform	Absent in 1 g		
Y&M	Absent in 1 g		

*Score for bacteria (15) was added in the Total score

Optimization of variables for preparation of low-fat frozen yoghurt

The optimization of variables such as the rate of addition of maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture was carried out using numerical optimization technique. The criteria used for optimization are summarized in Table 4. Among the variables, the level of maltodextrin as well as salt and black pepper blend were maximized while stabilizer-emulsifier mixture was kept in range. Among the responses, sensory parameters were maximized while melting rate and overrun were set to target of 50 and 90 per cent respectively for the optimization process. RSM suggested the rate of addition of maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture to be 6.12, 0.65 and 0.45 per cent respectively with desirability of 0.86. The low-fat frozen yoghurt was prepared by adding maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture according to the suggestion of RSM. The predicted values for flavour, body & texture, melting characteristics, colour & appearance, total score, melting rate and overrun for the developed frozen yoghurt were 39.96, 25.94, 3.98, 4.27, 89.16, 49.99 and 89.99 respectively. The predicted values are not significantly ($P>0.05$) different from observed values for all the parameters (Table 5). Therefore, it was confirmed that the selected level of maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture is most suitable for preparation of low-fat frozen yoghurt with replacement of sugar with salt and black pepper.

Analysis of low-fat frozen yoghurt

The developed frozen yoghurt was analysed for its compositional parameters, physical characteristics, sensory attributes and microbiological quality and compared with control frozen yoghurt prepared using vanilla flavour. No significant ($P>0.05$) difference was observed between experimental and control sample for all the parameters (Table 6).

Conclusion

Low-fat frozen yoghurt was prepared by replacing sugar with salt & black pepper blend as well as maltodextrin. Stabilizer-emulsifier mixture was also modified accordingly. Maltodextrin, salt & black pepper blend and stabilizer-emulsifier mixture were optimized using response surface methodology. The optimized frozen yoghurt was highly acceptable.

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