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RESEARCH ARTICLE

Technology of protein fortified functional frozen yoghurt

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Abstract: The present study was aimed to fortify protein in frozen yoghurt by incorporating strained yoghurt (chakka). Effect of incorporation of chakka at 12%, 16%, 20% and 24% of ice cream mix base on compositional, physico-chemical properties and microbiological qualities was significant. Incremental level of addition of chakka resulted in significant increase in total solids and protein content, while fat content showed increase and later at higher level of chakka incorporation, showed decrease in fat content compared to control sample. Viscosity of control sample was 224.59 cp that increased significantly (718.42 cp) in sample containing 24% chakka. Similar increasing trend was noted for hardness and melting resistance, while over run decreased by approximately 10% compared to control frozen yoghurt, as level of protein increased (4.12 to 5.73 per cent) in form of chakka at 24% level. Flavour, body and texture and total score was highest in sample containing 20 per cent chakka. Lactic Acid Bacteria count increased as level of chakka increased. Overall 20% addition of chakka was considered best treatment to obtain protein fortified frozen yoghurt.

Keywords: Frozen yoghurt, protein enhancement, strained yoghurt, functional yoghurt

Introduction

Frozen yoghurt, also referred to as yoghurt ice cream, is a frozen dessert made from milk fermented with the use of yoghurt starter bacteria (*Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus*). As per Codex (2003), it should contain at least 2.70% milk protein and not more than 10.0% milk fat, and it has a titratable acidity of 0.30% Lactic Acid (LA), as minimum. The product may contain sweeteners, flavours, colorants, stabilizers and emulsifiers.

Frozen yoghurt is a complex fermented frozen dairy dessert that combines the physical characteristics of ice cream with the sensory and nutritional properties of fermented milk products. The four main variables in the composition of frozen yoghurt are fat, sugar, acid and total solids. Dairy fat and total solids are the main determinants to textural quality and sugar and acid are the main contributors to flavour (Syed et al. 2018).

Interest in frozen yoghurt consumption has been on the increase as it is an alternative to ice cream for people who suffer from obesity, cardiovascular disease and lactose intolerance because of its low fat and lactose content compared to ice cream. Frozen yoghurts as functional foods have been proposed as the most promising vehicles for the delivery of functional ingredients such as probiotic, prebiotics, proteins, vitamins and minerals, microspheres loaded with ascorbic acid and/or omega 3 (Akin and Ozcan, 2017; Summeye et al. 2024; Misturini et al. 2024).

Frozen yoghurt is a unique dairy product with physical properties related to ice cream and nutritional and sensory characteristics related to fermented milk products (Soukoulis and Tzia, 2008). High-protein yoghurts and fermented milks with a variety of names have existed for a long time in many countries. Labneh (Eastern Mediterranean), Torba (Turkey), Stragisto (Greece), Chakka (India), and Ymer (Denmark) are all examples of concentrated or strained fermented milks with different geographical origins (Jørgensen et al. 2019). The 'building blocks' of life, proteins are not only lacking in the Indian diet, but often overlooked (*Snetselaa* et al.2021; Kalapriya, 2024). Hence the present investigation was carried out To develop a technology and standard formulation using standard ice cream mix base to which different levels of chakka was added with the aim of fortifying protein in form of chakka (concentrated yoghurt) in manufacture of frozen yoghurt.

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Materials and Methods

To develop a technology and standard formulation, the study involved manufacture of standard ice cream mix base to which different levels of chakka was added to manufacture protein fortified frozen yoghurt. The frozen yoghurt samples thus manufactured were stored until analysed for their chemical composition, physico-chemical attributes, texture profile and sensory quality

Materials Used

The milk, skim milk and cream used in the manufacturing of ice cream mix and yoghurt was procured from Anubhav Dairy of AAU, Anand. Skim milk powder of 'Sagar' brand, cane sugar of 'Madhur' brand was procured from local market of Anand. 'Stamulcol', which is a blend of stabilizers and emulsifier, was procured from the Vidya Dairy, Anand. The starter culture which was used for manufacture of yoghurt was obtained from Delvo DSL (Direct set lyophilized starter cultures RST – 776 of DSM Food Specialties). The starter culture was composed of *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, 1:1 v/v.

Method for preparation

Yoghurt and Chakka

Set yoghurt was prepared from skim milk (9.2% Total Solids (TS), which was pasteurized at 90°C/10 min. cooled to 42±1°C and inoculated with starter culture (Yoghurt DVS starter) followed by incubation at 42±1°C, till acidity reached to 0.7 - 0.8 % LA. The set yoghurt (curd) was broken and hanged for 2 – 3 h in muslin cloth to separate whey and to get total solids of concentrated yoghurt/chakka around 18% and acidity was around 1.8 -1.9 % (LA).

Ice Cream Mix Base

The control and experimental ice cream mix base was formulated to contain 10.0 per cent milk fat, 11.0 % Milk Solids Not Fat (MSNF), 16.0% sugar, 0.40% of stabilizer and emulsifier (stamulcol) and processed. The mix was further heated to 68 °C and subjected to double-stage homogenization (2000 psi and 500 psi pressure in the first and second stage respectively, in M/s. Goma Engineering Pvt. Ltd., Mumbai) followed by pasteurization at a time-temperature combination of 85 °C for 5 min and cooled immediately to 4 °C and aged at the same temperature for 12 h.

Frozen yoghurt

In the manufacture of normal frozen yoghurt (control frozen yoghurt) the aged ice cream mix base was mixed with plain, unsweetened stirred yoghurt (i.e., 75:25, w/w) having 0.60 - 0.70 % LA acidity. In case of experimental frozen yoghurt samples, chakka (18% TS) at different rate (12%, 16%,20% and 24% w/w) was mixed with ice cream mix base just before freezing in batch freezer (Max Freezer, Ahmedabad, capacity-3 kg Ice-cream mix/ batch). After freezing of mix to semi-solid consistency (requiring 10.0–12.0 min.), as inferred from the load on beater, the product was drawn in cups and was immediately subjected to blast tunnel hardener (M/s. Pal Engineers, Ahmedabad) maintained at -25±2 ÚC for 2 h for hardening and subsequently stored in a deep freezer cabinet maintained at -18±2 ÚC.

The final product obtained as above was evaluated for its proximate composition, physico-chemical properties, and rheological attributes, microbiological and organoleptic characteristics.

Analysis

Compositional attributes

The TS of the frozen yoghurt samples was determined by standard procedure using Mojonnier Milk Tester Model-D). Fat content of frozen yoghurt was determined by standard method (BIS, 1989). Total nitrogen/protein was determined by Semi-Micro kjeldahl method using Kjel-plus digestion system (Model-KPS 006L) and Kjel-plus Semi-Automatic Distillation System (Model-Distil M) of M/s. Pelican Instruments, Chennai. The ash content was determined using 3.0 g of sample and following the standard method by FSSAI (2012). The total carbohydrate content was obtained by difference of other components like fat, protein, ash and moisture content.

Physico-chemical quality attributes

The pH readings were taken on Digital pH meter (M/s. Mettler Toledo AG, Schwerzenbach, Model No. CH-8603). The viscosity of frozen yoghurt mix was determined by the method of Muse and Hartel (2004) using a 'Brook field' viscometer (DV II + Pro Viscometer, Model- LVDV- II + P, USA). Overrun was determined according to the method described by Muse and Hartel (2004). The melting characteristics of frozen yoghurt were evaluated according to the method given by Muse and Hartel (2004). The hardness of the hardened frozen product was measured using cone penetrometer (Associated Instrument Manufacturers Pvt. Ltd., India) as per the method described by Hayakawa and Deman (1982).

Sensory Evaluation

All the four experimental samples along with the control sample of frozen yoghurt was subjected to sensory evaluation by a selected panel of judges using a 100-point scorecard as suggested by Salem *et al.* (1994). The product was evaluated for flavour score (Max. 45), Body and Texture score (Max. 30), Colour and Appearance score (Max. 10), melting quality score (Max. 5) as the product was frozen.

Microbiological quality

The Lactic Acid Bacteria (LAB) count of frozen yoghurt was determined adopting the process of Downes and Ito (2001). The MRS agar and M17 agar was used to enumerate viable cell count of *Lactobacillus* and *Streptococcus* respectively. Yeast and mold count (BIS, 1999) and coliform count was enumerated as per BIS (2012).

Results and Discussion

The control frozen yoghurt was prepared by addition of set yoghurt prepared from skim milk (set yoghurt: ice cream mix base. 25:75 w/w) in ice cream mix base, Skim milk yoghurt had 9.3% total solids, 0.05% fat, 3.65% protein and 4.9% carbohydrate content and acidity was 0.7% lactic acid. Chakka/Concentrated yoghurt was having 18.20% total solids, 0.80% fat, 12.60% protein, 3.60% carbohydrate and acidity was 1.9% lactic acid. Ice Cream mix as base used had 38.2% total solids, 10.1% fat, 4.36% protein, 21.0 % carbohydrate and acidity 0.17% lactic acid.

Effect of varying levels of chakka in frozen yoghurt on compositional attributes

All the frozen yoghurt samples i.e. one control (containing set yoghurt) and four experimental (having chakka @ 12.0, 16.0, 20.0 and 24.0 %) samples were analyzed for its proximate composition. The effect of addition of chakka on proximate composition of frozen yoghurt is depicted in Table 1.

It can be seen from the Table 1 that the TS content of experimental frozen yoghurt decreased significantly (P<0.05) with increase in the level of chakka. It was observed that the TS content of the control frozen yoghurt was significantly (P<0.05) lower and remained loweat compared to all the experimental frozen yoghurts. Among the experimental samples the highest TS was observed for the sample containing 12.0 per cent chakka and increasing level of addition of chakka led to significant (P<0.05) reduction in TS of experimental samples and thus the lowest TS was found in sample containing highest level (24.0 %) of chakka. Such significant decreasing trend in the TS was obvious because of the lower TS content containing ingredient (chakka, 18.01%, set yoghurt 9.2%) was incorporated in the ice cream mix base having TS content of 38.21 per cent. Singh et al. (2006) also reported a significant decrease in TS content of ice cream mix when yoghurt base was added to it. The similar decreasing trend in the TS content of the frozen yoghurts was also reported by Pratap *et al.* (2016), when the different levels of fruit pulps (i.e. apple, banana, grapes and mango) were added in frozen yoghurt.

Similar trend was observed for the fat content of the frozen yoghurt that also decreased significantly (P<0.05) with increase in the level of chakka. The fat content of the control sample (8.58%) was significantly (P<0.05) lower compared to the three experimental samples of frozen yoghurts, however it remained at par with C3 (20% chakka) level. Fat content reduced significantly (P<0.05) at each incremental level of addition of chakka in ice cream mix base. The decrease in fat content with increase in level of chakka was obviously understandable because to produce yoghurt and chakka skim milk was employed. Thus due to the lower fat content in the chakka (0.75%) and yoghurt (0.05%), as compared to the ice cream mix base (10.10%). The similar decreasing trend was also reported by Pratap et al. (2016) and Kiros *et al*. (2016) with the addition of different levels of fruit pulps and carrot juice respectively being lower fat contributor.

The protein content in the experimental samples increased significantly (P<0.05) with increase in the level of chakka in frozen yoghurt. The protein content of the frozen yoghurt containing 24 per cent chakka was significantly (P<0.05) higher (5.73%) and remained highest compared to all other experimental samples and control sample which had the lowest protein content (4.17%). The protein content of chakka (12.60%), which was higher compared to ice cream mix base (4.60%) that explains the reason for such significant increase in protein content in frozen yoghurts. Thus compared to control frozen yoghurt, experimental samples had 19.6 to 37.4 per cent increase in protein content. Yanni (2021) prepared frozen dessert by addition of Set yogurt and Greek yogurt each at 10, 15 and 20% w/w separately in ice cream mix. He reported increasing trend in protein content as the level of Greek yogurt increased in ice cream mix.

Table 1: Effect of varying levels of chakka on proximate composition of frozen yoghurts

Level of chakka	Parameters*(%)				
	Total Solids	Fat	Protein	Ash	Carbohydrates
C_0	$32.27^{e}\pm0.07$	$8.58^{c}\pm0.15$	$4.17^{e}\pm0.07$	1.21 ± 0.03	$18.21^{d}\pm0.20$
C_1	$35.18^{a}\pm0.19$	$9.22^{a}\pm0.17$	$4.99^{d}\pm0.06$	1.21 ± 0.04	$19.76^{a}\pm0.08$
C_2	$34.55^{b}\pm0.07$	$8.90^{b}\pm0.14$	$5.27^{c}\pm0.07$	1.20 ± 0.01	$19.18^{b}\pm0.18$
C_3	$34.06^{c}\pm0.17$	$8.60^{c}\pm0.09$	$5.51^{b}\pm0.13$	1.19 ± 0.02	$18.76^{c}\pm0.30$
C_4	$33.36^{d}\pm0.11$	$8.36^{d}\pm0.09$	$5.73^{a}\pm0.05$	1.18 ± 0.02	$18.09^{d}\pm0.16$

*Mean ± SD, (n = 4), NS – Non-significant, The values indicated column wise having same superscripted alphabet does not differ significantly (P>0.05) from each other, C_0 containing 25.0 % skim milk yoghurt and C_1, C_2, C_3 and C_4 are frozen yoghurts having 12.0, 16.0 20.0 and 24.0 % of chakka in the blend respectively.

A minor decrease in ash content was observed in the present study with increase in level of chakka, but such decrease was non-significant. Carbohydrate content followed the similar trend as is observed for TS and fat content. The total carbohydrates content was significantly ($P<0.05$) decreased with increase in the level of addition of chakka in ice cream mix base. The total carbohydrates content of the control frozen yoghurt was significantly ($P<0.05$) lower (18.21%) compared to all the experimental frozen yoghurts samples, however it remained statistically ($P<0.05$) at par with C4 level (24% chakka) which has lowest carbohydrate (18.09%) content.

Chemical properties of the frozen yoghurts as affected by addition of chakka

Chemical properties like acidity and pH has profound effect on physical and sensory properties of the product. During heat shock to the product, it may show higher rate of whey separation if the pH of the product is less and can lead to icy defect. More acidic product can affect the taste of the product and may impart tartness.

Raising the level of incorporation of chakka in frozen yoghurts, significantly ($P<0.05$) increased the acidity of final frozen yoghurt (Table 2). The acidity of frozen yoghurt containing 24 per cent chakka was significantly ($P<0.05$) higher (0.60 % LA) than all other experimental samples and control. The acidity of control and experimental frozen yoghurt containing 12.0 per cent chakka was statistically ($P>0.05$) at par with each other, however, at higher level of additions of chakka had significant increasing effect on the acidity values associated with frozen yoghurts containing 16.0, 20.0 and 24.0 per cent chakka. Chakka (1.9% LA) had higher acidity compared to ice cream mix (0.17 % LA) could be the reason for this increasing trend in acidity.

The values of pH have inverse relationship with acidity of foods. In the present study it showed the inverse trend for pH than that was observed for acidity parameter. The pH of the samples decreased with increase in the level of chakka in frozen yoghurt samples. The pH of control sample was significantly ($P<0.05$) higher (5.69) and that remained statistically ($P<0.05$) at par with C_1 level, however, pH values associated with frozen yoghurts containing 16.0, 20.0 and 24.0 per cent chakka were significantly ($P<0.05$) lower than the values observed for control sample. The trend observed for acidity and pH in the study was in line with the data reported by Yanni (2021) who prepared frozen yogurt by addition of Greek yogurt at 10, 15 and 20% level. Makawi and Razig (2016) also found that the addition of mango juice (25.0 to 75.0 % v/w) decreased the pH values (5.51 to 5.15) of frozen yoghurt samples. However, in the present study lowest pH was observed in C4 level (24% chakka) was 5.30 being higher than reported by Yanni (2021) (pH 4.27) and Makawi and Razig (2016) (pH 5.15).

Physical properties of the frozen yoghurts as affected by addition of chakka

The quantum of body building solids presents in ice cream mix, the type and amount of stabilizer used and the conditions of ageing will impact the viscosity of ice cream mixes; moreover, the viscosity of ice cream mix can in turn influence the hardness and determine the overrun that can be whipped into ice cream (Syed et al. 2018). In quality assurance, controlling the textural property of frozen yoghurt (i.e. hardness) could be one of the desired features for the frozen yoghurt industry. Hardness of frozen yoghurt is an important property since it can directly affect the scoop-ability, melting rate and overrun.

Viscosity increased significantly ($P<0.05$) with increase in each level of chakka in frozen yoghurt. The highest viscosity was observed for the sample containing 24 per cent chakka (718.42 cP). The control frozen yoghurt had lowest viscosity (224.59 cP) that increased significantly ($P<0.05$) with each significant increase in protein content (Table 1). As chakka contains higher amount of protein and lower pH compared to ice cream mix base, it was obvious to have impact of protein and pH content that directly affected viscosity of experimental frozen yoghurts. The trend observed in the present study was in line with the reports of Alvarez et al. (2005), who demonstrated that an increase in milk protein concentrate (MPC) content leads to significant viscosity enhancement of ice cream mixes. Ordonez et al. (2000) also observed increase in the viscosity of yoghurt ice cream (YIC) mixes from 0.63 to 4.4 Pa’”s in association with an increase in acidity from 0.25 to 0.50 per cent LA.

Overrun and the air cell structure of the ice cream product are the main factors that influence the melting of rate (Bahramparvar and Mazaheri Tehrani, 2011) rheological properties, and shape retention of the frozen dessert matrix.

The overrun in the control sample was higher (79.82%) and it decreased significantly ($P<0.05$) in all the experimental samples containing increased levels of chakka and C4 level had lowest (71.31%) overrun values. Such observed effect could be due to the higher viscosity of the experimental samples that might have impacted the efficient penetration and emulsification of the air in the base mix. Yanni (2021), Mahdian et al. (2012) and Guner et al. (2007) reported the similar trend in decreasing overrun with increasing the level of yoghurt in ice cream mix.

The hardness of the frozen yoghurt samples increased significantly ($P<0.05$) with increase in the level of chakka. The highest hardness was observed for the sample containing the highest level of chakka (24 per cent chakka) with the lowest penetration of 10.67 mm. The control sample remained statistically at par with experimental samples containing 12.0 and 16.0 per cent chakka, It is presumably explained with increasing protein content (Table 1) and decreasing pH (Table 2). Similar trend is reported by Yanni (2021) in frozen yogurt containing greek yogurt.

Increased resistance to heat might be related to how the pH greatly influences protein structure. The proteins present in the lower pH mixes may have denatured, allowing for the development of long structured protein aggregates and this would make it more difficult for the matrix to pass through the screen (Favaro-Trindade et al. 2007). The melt-down rate of ice cream/ frozen yoghurt is affected by many factors, including the amount of air incorporated (overrun), the nature of the ice crystals and the network of fat globules formed during freezing (Muse and Hartel, 2004).

The melting resistance was increased significantly ($P<0.05$) with increase in the level of chakka addition in frozen yoghurt. The highest melt down per cent value was observed in control sample (55.90%) that decreased significantly ($P<0.05$) in C1 level (54.61%), however further addition of chakka in frozen yoghurt decreased the melt down but non-significantly ($P>0.05$) in C2 level (53.80%). Further increase in level of addition of chakka in frozen yoghurt to 20.0 and 24.0 per cent level, the lowest quantity (highest melting resistance) of sample was melted in case of frozen yoghurt containing 24.0 per cent chakka (highest rate of addition).

The presumable reason for this increasing shift in melting resistance could be due to increase in the protein content of the samples with increase in the level of chakka that simultaneously led to increase in hardness of the samples.

The similar trend was reported by Dudhrejiya (2017), who revealed that an increase in level of moringa pulp increased the melting resistance significantly. The similar trend was also reported by Mahdian et al. (2012), who found that the increasing levels of addition of yoghurt fortified with soy flour in frozen yoghurt formulation led to improved melting resistance.

Overall, the physical properties of frozen yoghurts were affected significantly ($P<0.05$) with the addition of chakka. The viscosity, hardness and melting resistance increased significantly with an increase in level of chakka, whereas, percentage overrun decreased significantly at each incremental level of addition of chakka in experimental samples.

Sensory scores of the frozen yoghurts as affected by addition of chakka

Table 2: Effect of varying levels of chakka on physico-chemical properties of frozen yoghurts

Level of chakka	Parameters*	
	Acidity (% LA)	pH
C_0	$0.38^d \pm 0.02$	$5.69^a \pm 0.05$
C_1	$0.40^d \pm 0.01$	$5.65^a \pm 0.05$
C_2	$0.48^c \pm 0.01$	$5.53^b \pm 0.04$
C_3	$0.54^b \pm 0.02$	$5.42^c \pm 0.03$
C_4	$0.60^a \pm 0.01$	$5.30^d \pm 0.05$

*Mean ± SD, (n = 4), The values indicated column wise having same superscripted alphabet does not differ significantly ($P>0.05$) from each other, C_0 containing 25.0 % skim milk yoghurt and C_1, C_2, C_3 and C_4 are frozen yoghurts having 12.0, 16.0, 20.0 and 24.0 % of chakka in the blend respectively.

Table 3: Effect of varying levels of chakka on physical properties of frozen yoghurts

Level of chakka	Parameters*			
	Viscosity at 20 °C (cP)	Overrun (%)	Hardness (mm)	Melting resistance# (%)
C_0	$224.59^e \pm 15.47$	$79.82^a \pm 1.68$	$11.84^a \pm 0.23$	$55.90^a \pm 0.98$
C_1	$265.20^d \pm 15.75$	$77.50^b \pm 1.20$	$11.66^{ab} \pm 0.25$	$54.61^b \pm 0.42$
C_2	$371.75^c \pm 22.68$	$75.38^c \pm 1.0$	$11.39^b \pm 0.17$	$53.80^b \pm 0.50$
C_3	$595.47^b \pm 14.60$	$73.16^d \pm 0.36$	$11.06^c \pm 0.07$	$52.06^c \pm 0.90$
C_4	$718.42^a \pm 19.77$	$71.31^e \pm 0.97$	$10.67^d \pm 0.20$	$50.99^d \pm 0.35$

*Mean ± SD, (n = 4), The values indicated column wise having same superscripted alphabet does not differ significantly ($P>0.05$) from each other, C_0 containing 25.0 % skim milk yoghurt and C_1, C_2, C_3 and C_4 are frozen yoghurts having 12.0, 16.0, 20.0 and 24.0 % of chakka in the blend respectively. #- Quantity of sample melted in 20 min at 30 °C from 100 g.

The acceptability of any food product by the consumers is based on their sensory quality. Sensory evaluation of the frozen yoghurt samples was performed by the selected panel of judges to access the effect of addition of chakka on various sensory attributes (flavour, body & texture, colour & appearance and melting quality). The sensory scores for the frozen yoghurt samples are given in Table 4.

The flavour score received for frozen yoghurt containing 20.0 per cent chakka was highest among all samples. Increase in flavour score from control to C3 level and at higher level of addition of chakka (24%), a minor non-significant reduction in flavour score was observed. The observed effect could be due to an increase in acidity/decrease in pH up to certain level that might have provided refreshing taste to the product and also might be due to chakka that contains diacetyl flavour. An opposite, increasing trend for flavour upon increasing ice cream mix proportion and decreasing concentration of yoghurt has been reported by Olson et al. (2021) and Yanni and Ingolf (2023) for frozen dessert containing strained yoghurt.

The body and texture score for frozen yoghurts increased significantly at each incremental level of chakka and C4 level received highest score that remained statistically at par with C3 level. The observed effect could be due to increase in protein content in experimental samples that had more impact on viscosity and overrun (Table 4) in the experimental samples. The similar increasing trend for body and texture score observed in the present study was also observed by Patel et al. (2006) who concluded that overall texture acceptance score for an ice cream increased with increase in the level of MPC.

Colour and appearance score had non-significant (P>0.05) variation and it had non-significantly lower score in C_1 level and it increased non-significantly up to C_3 level and decreased in C_4 level. Such minor increase and decrease in flavour score were non-significant (P>0.05).

The score for melting quality was highest obtained for treatment C3, however, it remained statistically at par with treatment C2 and C4. The score for melting quality was improved with increase in protein content up to C3 level and further it decreased non-significantly (P>0.05). Increase in protein content (Table 1) in the present study along with reduced overrun (Table 3) has affected the melting quality score of the resultant product. The total score increased significantly (P<0.05) in all experimental samples. Such increase was significant up to C3 level and further addition of chakka in manufacture of frozen yoghurt could not impart significant impact on total score. The highest total score for frozen yoghurt was obtained for treatment C_3 containing 20.0 per cent chakka. Total score obtained in the treatment C_1 and C_4 were statistically at par with each other. Opposite trend for overall liking was reported by Yanni and Ingolf (2023) and it might be due to the different control sample (Frozen dessert, containing

Table 4: Effect of varying levels of chakka on sensory properties of frozen yoghurts

Level of chakka	Sensory Scores*				
	Flavour (45)	Body & Texture (30)	Colour & Appearance (10)	Melting quality (5)	Total score$^{@}$ (90)
C_0	40.13^{d}±0.13	26.03^{d}±0.29	9.28±0.16	3.62^{c}±0.29	79.06^{c}±0.22
C_1	41.88^{b}±0.88	27.06^{c}±0.27	9.24±0.13	4.04^{b}±0.17	82.22^{b}±1.04
C_2	42.98^{a}±0.54	27.82^{b}±0.38	9.42±0.12	4.32^{ab}±0.21	84.54^{a}±0.97
C_3	43.26^{a}±0.42	28.29^{a}±0.31	9.47±0.14	4.56^{a}±0.20	85.58^{a}±0.41
C_4	41. 07^{c}±0.26	28.34^{a}±0.32	9.20±0.15	4.47^{a}±0.24	83.08^{b}±0.70

*Mean ± SD, (n = 4), NS – Non-significant, the values indicated column wise having same superscripted alphabet does not differ significantly (P>0.05) from each other, C_0 containing 25.0 % skim milk yoghurt and C_1, C_2, C_3 and C_4 are frozen yoghurts having 12.0, 16.0, 20.0 and 24.0 % of chakka in the blend respectively. Bacteria score (10) is not considered in total score.

Table 5: Comparative assessment of microbiological quality of optimized frozen yoghurt

Frozen Yoghurt	Lactic Acid Bacteria Counts (log_{10}cfu/g)*	Yeast & Mold Counts (cfu/g)*
C_0	7.88^{e}±0.03	8.05^{c}±0.83
C_1	8.53^{d}±0.06	7.90^{c}±0.57
C_2	9.18^{c}±0.02	8.25^{c}±0.81
C_3	9.72^{b}±0.06	9.60^{b}±1.03
C_4	10.08^{a}±0.04	10.80^{a}±0.92

Mean ± SD, (n = 4), the values indicated column wise having same superscripted alphabet does not differ significantly (P>0.05) from each other. C_0 is frozen yoghurts containing 25 % skim milk yoghurt, C_1 is 12 % chakka and C_2 is 16 % chakka C_3 is 20% and C_4 is 24 % chakka.

no yoghurt addition) and thus increasing acidity by addition of yoghurt/starined yoghurt might have resulted in decreasing score.

The overall acceptability of the frozen yoghurt sample increased significantly ($P<0.05$) with an increase in the level of chakka from sample C0 to C3. While, the total sensory score decreased from sample C3 to C4, that could be due to higher perceived acidic flavour. The score for flavour, melting quality and total score also increased up to sample C3 then it decreased, whereas, the body and texture score increased with the addition of chakka in frozen yoghurt up to C4.

Microbiological qualities of the frozen yoghurts as affected by addition of chakka

In the present study, though the major aim was to fortify protein content in frozen yoghurt, the lactic acid bacterial (LAB) count was also studied (Table 5), as the culture employed has potential probiotic characteristics. It was observed that LAB count increased significantly with increasing level of chakka compared to control (FY_0) frozen yoghurt samples. It increased significantly from 7.88 log cfu/g for C0 sample to 10.08 log cfu/g in C4 sample being highest in LAB count (Table 5). Similar LAB count is reported by Muzammil and Rasco (2018) in the production of frozen yoghurt supplemented with oligofructose and glycerol. Magdy et al. (2022) also reported similar LAB count at zero day in Bio-frozen yoghurt. Data observed for LAB count in present study was in similar trend for MRS lactobacilli count for zero day as reported by Olson et al. (2021).

Yeast and Mold count observed in present study was well within the legal limits provided for yoghurt, which is 50-100/g. However, Mahrous and Abd-El-Salam (2014) reported higher Yeast and Mold count (190 – 290/g) in different functional frozen yoghurt samples fortified with Omega-3 and vitamin E.

Conclusion

Addition of chakka/strained yoghurt in place of set yoghurt in manufacture of frozen yoghurt resulted in initial increase and later decrease in total solids and fat content at higher rate of addition of chakka, while protein content increased and carbohydrate content decreased. Acidity increased and pH decreased due to higher acidity component (chakka) in the samples. Addition of chakka had significant positive impact on viscosity, hardness and melting resistance of the frozen yoghurts, however, negative impact on overrun was observed. The overall acceptability, reflected by total score improved up to 20% rate of addition of chakka in ice cream mix. Thus in manufacture of frozen yoghurt, a successful addition of strained yoghurt/chaka can be done up to 20% level that resulted in increase in protein content of frozen yoghurt by approximately 32 per cent. Potential probiotic (LAB) count increased significantly in frozen yoghurt samples containing chakka compared to control frozen yoghurt containing skim milk yoghurt.

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