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Utilization of sweet potato solids for value-addition to chocolate ice cream

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Sweet potato is rich in carotenoids and fiber and confers sweetness to the product in which it is utilized. The aim of the research was to utilize sweet potato in the form of 'osmo-vac' dehydrated powder in medium-fat (6.0% fat) 'chocolate ice cream' for value-addition. Use of sweet potato powder (SPP) at 2.0 to 4.0% level did not affect the sensory quality of chocolate ice cream appreciably. SPP when used at 4.0% level in 'medium-fat' chocolate ice cream led to enrichment of the ice cream with β-carotene and fiber; it could replace 40.0% of milk fat and 10.0% of sugar in ice cream. Ice cream containing 4.0% SPP tended to have markedly higher total carbohydrates and total solids content as compared to control 'medium-fat' ice cream. Presence of SPP in ice cream led to slight impairment in its overrun. The 'medium-fat' chocolate ice cream prepared utilizing 4.0% SPP had sensory scores similar to those of 'full-fat' (10.0% fat) control ice cream. Ice cream is an ideal medium for utilizing sweet potato solids contributing to value-addition to the frozen delicacy.

Keywords: Chocolate ice cream, Fat replacer, Osmotic dehydration, Sensory quality, Sweet potato, Vacuum drying

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Sweet potato (*Ipomoea batatas* L.) is a starchy, tuberous root vegetable. Few popular varieties of purple sweet potato grown in India are Co 3, Co CIP 1, Sree Nandini, Sree Vardhini, Kiran, Sree Bhadra, Gouri, Sankar, etc.; the orange colored varieties include Regal, Vardaman and ST 14[1]. The predominant taste of sweet potato is sweet, owing to the presence of maltose and sucrose[2]. Sweet potatoes are rich in carbohydrates (including starch) and fibers and a good source of carotenes, thiamine, riboflavin, niacin, vitamins A and C, and minerals such as K, Zn, Ca, Mg and Fe[1]. The sweet potato is one of the staple foods in the diets of Maori people, Papua New Guineans and the Hawaiians[3].

A major portion of sweet potato is eaten as a vegetable after boiling, baking or frying. They are converted into chips and flour[4]. Blend of flour comprising of sweet potato and wheat is suited for preparing noodles and some baked goods[5]. The mode of utilizing sweet potato in some countries includes (i) boiled and eaten with stew, (b) boiled and pounded with boiled/fermented cassava or boiled/ground yam, (c) dried or milled for sweetening of porridge, (d) sliced into chips, dried and fried in vegetable oil or boiled with vegetables[6].

Sweet potato flour made using drying is an effective way to increase the carotenoid and fiber content and increases its storability. The phenolic constituents of sweet potato exert anti-aging, anti-cancer, anti-bacterial, anti-inflammatory, anti-hypertensive properties and can ameliorate type-2 diabetes[7]. Orange fleshed varieties of sweet potato had greater antioxidative substances (*i.e.,* β-carotene, chlorogenic acid, vitamin C) as compared to the cream fleshed varieties[8]. The ice creams prepared using sweet potato flour (SPF) alone and blend of SPF and tapioca flour had superior antioxidative property as revealed from their total phenolic content, 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity and Ferric Reducing Antioxidant Power (FRAP). However, there was some impairment in the texture of product, culminating in somewhat lower overall acceptability compared to control ice cream devoid of such flours[9].

Cocoa is derived from *Theobroma cacao* tree. The pH of alkalized cocoa powder ranges between 7.0 and 8.0[10]. Cocoa powder is used as a flavouring ingredient in chocolate ice cream at levels of 2.0-4.0% by weight

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of mix[11]. Cocoa is a rich source of polyphenols such as catechins, anthocyanins and proanthocyanidins[12].

Osmotic dehydration is the process of dewatering of food by application of high osmotic pressure. Such treatment to vegetable tissue leads to water loss and sugar gain[13], improving the shelf life of such vegetable.

Ice cream is a frozen delicacy prepared by blending both dairy and non-dairy ingredients. Owing to the health aspects as well as considering the cost aspects, ice cream industry strives to introduce 'medium-fat' and even 'low-fat' version of ice creams in the market to cater to the calorie-conscious consumers. The loss of solids in lower-fat version of ice cream can be partly made through use of 'osmo-vac' treated sweet potatoes; the carbohydrates inherent in sweet potato solids can serve to improve the mouth feel of 'medium-fat' ice creams. Few reports appear in literature pertaining to the use of sweet potato (puree or flour form) in ice cream-like products for value-addition[14,15]. Ranatunga and Sajiwanie (2019)[16] had developed probiotic ice cream utilizing sweet potato puree.

Materials and Methods

Dairy ingredients

Raw, chilled (4°C) mixed milk (cow and buffalo milk) and cream (42.0% fat) were procured from Vidya dairy, Anand (Gujarat). Skim milk powder (SMP) of 'Sagar' brand was used in the ice cream mix formulation.

Non-dairy ingredients

Cane sugar was obtained from local Anand market. Sodium alginate (M/s. Himedia Laboratories Pvt. Ltd., Mumbai) and Glycerol-mono-stearate (GMS, M/s. Loba Chemie, Mumbai) were used as the stabilizer and emulsifier in ice cream respectively. Cocoa powder of 'Cadbury brand' was used. 'Gauri' variety of sweet potato (purple skinned) was purchased from Anand vegetable market.

Equipment

Vacuum tray dryer (M/s. Perfect Engineering & Allied Works Pvt. Ltd., Vadodara, Gujarat) located at Anubhav dairy, Anand was used to prepare dried sweet potato. A two-stage homogenizer (M/s. Goma, Mumbai) was employed to homogenize the ice cream mix. Freezing of ice cream mix was performed in a batch ice cream freezer (M/s. Pal Engineering Pvt. Ltd., Ahmedabad; 4.0 kg mix capacity) located at SMC College of Dairy Science, Anand. Blast tunnel hardener (M/s. Pal Engineers, Ahmedabad) was used to harden the ice cream.

Preparation of osmotically (partly) dehydrated sweet potato shreds

In one batch, 50.0 kg of washed sweet potatoes (75.5% moisture, analyzed in raw stage) were peeled and then treated with 1.50% sodium meta-bisulphite solution to arrest browning[17]. Shredded potatoes were blanched in hot water (95°C) for 5 min[18] and then dipped in hypertonic sugar solution (55.0% strength) maintaining 45±2°C for 8 h[19]. Such osmo-dehydrated shreds were loaded (5.0 kg shreds were spread over six stainless steel trays) in a vacuum tray dryer. The conditions maintained were vacuum of 650±10 mm of Hg column (temperature in chamber 57±2°C) for 10 h. The dried potato shreds were ground and sieved through ASTM-70 sieve. The sweet potato powder (SPP) was packaged in low density polyethylene (LDPE) bags (≥ 80 µm) and stored at refrigerated (7±2°C) condition.

Preparation of ice cream mix and ice cream

The quantities of milk, cream, SMP, sucrose, cocoa powder, SPP, Na-alginate, GMS required for a batch (*i.e.,* 4.0 kg of ice cream mix) was calculated by serum point method[11]. The composition of the ice cream mix was 6.0% fat, 12.5% MSNF, 0.25% Na-alginate and 0.15% GMS; SPP was used at level of 2.0-4.0% by weight of mix. Sucrose was used at 13.5 to 15.5% rate. The required quantities of ingredients were weighed, mixed and blended thoroughly. Cocoa powder was used at 3.0% level, prior to homogenization. The mix was heated to 70°C and subjected to homogenization (10.34 and 3.45 MPa; two-stage pressure). The homogenized mix was pasteurized at 80°C for 10 min. and cooled to 7±2°C and aged overnight (15 h).

The various batches of ice cream mixes were frozen and whipped in a direct expansion type batch freezer (capacity 8.0 L/batch); temperature of the refrigerant was -25.0±3°C. During whipping, the air pressure was maintained at 10.0±3.0 psi for 2-3 min. The ice cream was drawn at temperature of 4.5±0.5°C. The frozen ice cream was packaged in 120 mL High Impact Polystyrene (HIPS) ice cream cups and transferred to a blast tunnel hardener (-23°C ±2°C) for hardening; period being 2.5 h. The hardened ice creams were transferred to deep freeze cabinet (-18±2°C).

Analysis of milk, milk products and sweet potato powder

The milk was analyzed for fat, TS and acidity; Cream and skim milk powder (SMP) were analyzed for fat and TS; Ice cream mix and ice cream were analyzed for fat, protein and ash using standard method (FSSAI 2022)[20]. The SPP was analyzed for protein[21], fat[22], ash[22] and TS[22]. The fiber and β-carotene content of SPP were analyzed by CALF laboratory, Anand. The total carbohydrate content of ice cream as well as SPP was obtained by difference.

Sensory scoring of ice cream

A panel comprising of 12 judges from Faculty of Dairy Science, Anand judged the ice creams for their sensory quality using modified version of American Dairy Science Association (ADSA) 100 point score card. The judges were selected taking help of 'Duo-trio' and 'Triangle' tests[23].

Statistical analysis

Completely Randomized Design (CRD) was used to analyze the data collected in the investigation[24].

The investigation was divided in three parts as follows: 1. Optimizing the level of SPP in 'medium-fat' chocolate ice cream; 2. Optimizing the level of sugar in chocolate ice cream; and 3. Comparison of value-added 'medium-fat' chocolate ice cream containing SPP with two control ice creams.

Results and Discussion

Particulars about sweet potato powder

The yield of SPP (4.5% moisture) from raw tuber was 49.4%. The osmo-treated and vacuum tray dried SPP (95.5% TS) was rich in fiber (5.80%) and β-carotene (*i.e.,* 106 µg/100 g of powder). Other constituents of SPP were as follows: 1.10% fat, 2.50% protein, 85.09% carbohydrates and 1.01% ash.

I. Optimizing the level of sweet potato solids in chocolate ice cream

The selection of optimized formulation was based on sensory evaluation of ice cream. The ice cream scoring maximum sensory score, without any marked adverse effect on ice cream properties (*i.e.,* viscosity of mix, overrun in ice cream) would be the criteria for selection. SPP was used in the formulation of 'medium-fat' chocolate ice cream at levels of 2.0, 3.0 and 4.0% by weight of mix; sugar was used at 14.0% level only. The osmotic treatment subjected to sweet potato shreds made them somewhat sweeter.

Proximate composition and physical properties of ice creams as influenced by the level of sweet potato solids

All the four chocolate ice creams (one control; rest experimental) complied with the Food Safety and Standards Act (FSSA) standards[25] for 'medium-fat' (*i.e.,* fat range 2.5 to 10.0%) ice cream. The fat and protein content of ice creams remained unaffected by the treatment. The carbohydrate content of control (C) and experimental ice cream containing 2.0% SPP (SP2) was at par with each other; such values of the two products were significantly ($p<0.05$) lower than the values associated with ice creams SP3 and SP4 (Table 1). The ash content of all the experimental ice creams was significantly ($p<0.05$) higher as compared to that of 'C'. However, the ash content of ice creams SP2 and SP3, as well as SP3 and SP4 was at par with each other. Ice cream SP4 had significantly ($p<0.05$) higher ash as compared to SP2 (Table 1). It is obvious that use of higher level of SPP would raise the ash content of resultant ice cream[11]. When the TS of any individual experimental ice cream was compared with its counterpart (considering difference of 1.0% SPP), they were found to be at par with each other. However, ice creams SP2 and C had similar TS. Ice cream SP4 had significantly ($p<0.05$) higher TS as compared to SP2. Comparing the values of TS of

Table 1 — Proximate composition and physical properties of chocolate ice creams prepared using varying levels of SPP

Parameters (%)	Ice cream prepared utilizing SPP at levels (% w/w of mix)				CD (0.05)
	Control (0)	2.0	3.0	4.0	
		Chemical composition			
Fat	6.52±0.06	6.54±0.04	6.55±0.05	6.56±0.08	NS
Protein	5.05±0.07	5.10±0.18	5.12±0.08	5.14±0.1	NS
Carbohydrate	24.02^{c}±0.42	24.26^{c}±0.28	25.12^{b}±0.28	25.98^{a}±0.38	0.54
Ash	1.34^{c}±0.02	1.37^{b}±0.04	1.38^{ab}±0.05	1.39^{a}±0.02	0.02
TS	36.93^{c}±0.67	37.27^{bc}±0.70	38.17^{ab}±0.36	39.07^{a}±0.72	0.98
		Physical properties			
pH	6.48±0.02	6.47±0.03	6.46±0.03	6.46±0.04	NS
Overrun	72.88^{a}±0.85	71.08^{b}±0.65	70.88^{b}±0.69	70.50^{b}±0.81	1.17

sample 'C', the experimental ice creams SP3 and SP4 had significantly ($p<0.05$) higher value (Table 1).

The acidity/pH of ice cream mix is an important factor in obtaining the product having desirable flavor and texture; they play a role in controlling the overrun of ice cream too. Acidity values of the ice creams ranged between 0.19 and 0.25 % LA. The normal acidity of ice cream mixes varies with their MSNF content. A lower pH is undesirable as it leads to lower heat stability, excess viscosity, impairs whipping ability and leads to inferior flavor[26]. The normal pH of ice cream mix ranges between 6.3 and 6.5. Use of additives such as cocoa powder can influence its pH; the pH of cocoa powder may vary *i.e.,* whether it is alkalized or otherwise[27].

All the four chocolate ice creams (C, SP2, SP3 and SP4) had pH values that was at par with each other. The pH value of experimental ice creams ranged from 6.46 to 6.47; control ice cream had pH of 6.48 (Table 1). Chocolate ice cream containing 1.5% sago powder plus cocoa powder (*viz.,* 2.0 to 4.0%) led to chocolate ice creams having markedly higher carbohydrates, ash and TS content as compared to control ice cream, devoid of sago powder[28].

Ice cream containing high TS and low overrun tended to produce heavy and soggy ice cream, while low TS and high overrun tended to produce a fluffy ice cream[11]. The butterfat content, overrun and flavouring matter are critical determinants to the sensory quality of ice cream[29]. The incorporation of SPP in the formulation of chocolate ice cream had a significant ($p<0.05$) influence on its overrun. Control ice cream had significantly ($p<0.05$) higher overrun (*i.e.,* 72.88%) as compared to experimental ice creams; the latter three ice creams had overrun ranging between 70.50 and 71.08% (Table 1). The starch inherent in SPP might have led to increased mix viscosity of the experimental chocolate ice creams, leading to the impairment in overrun.

The overrun of vanilla ice cream prepared utilizing sugar beet molasses was 46.7%; control ice cream had 52.2% overrun[30]. The overrun of control full-fat (18.53% fat) chocolate ice cream (without orange peel fiber) and reduced-fat (5.29% fat) ice cream incorporating 1.10% orange peel fiber was 46.0 and 25.0%, respectively[31].

Sensory scores of ice creams containing varying levels of sweet potato solids

The popularity of ice cream is due to its delectable taste and cooling nature. Hence, assessment of the sensory properties of ice cream as affected by the inclusion of any specialized ingredients (*viz.,* sweet potato solids) is of significance.

The sensory scores of chocolate ice cream (Table 2) indicates that the only attributes affected significantly ($p<0.05$) by the level of SPP were body and texture and total sensory scores. The color and appearance, flavor and melting quality scores remained unaffected by the levels of SPP in ice cream formulation. The body and texture score of SP4 was significantly ($p<0.05$) greater than the scores associated with rest three ice creams (*i.e.,* C, SP2, SP3). However, the total sensory scores of SP4 and SP2 were significantly ($p<0.05$) greater than the scores of ice creams C and SP3 (Table 1); the latter two products had similar total sensory scores.

The maximum level of SPP used (*i.e.,* 4.0% level) contributed to the highest level of native starch from sweet potato leading to superior body and texture score. The supremacy in the body and texture score culminated in such product having the highest total sensory score too (*i.e.,* 90.01 out of 100.0).

Medium fat mango ice cream prepared utilizing 2.5% sago along with 0.025% sodium alginate had the desired sensory quality, including the body and texture score[32].

II. Optimizing the level of sugar in chocolate ice cream containing sweet potato powder

Medium-fat chocolate ice cream was prepared using 4.0% SPP (selected from part I), while three sugar levels (*i.e.,* 13.5, 14.0, 14.5%) was studied. The

Table 2 — Sensory scores of chocolate ice creams containing sweet potato powder

Sensory attributes	Ice cream prepared using SPP at levels (% w/w of mix)				CD (0.05)
	0	2.0	3.0	4.0	
Flavour (45)	40.43±0.70	40.72±0.43	39.88±0.69	40.55±0.71	NS
Body and texture (30)	25.27±0.68[a]	25.55±1.02[a]	25.66±0.75[a]	25.80±0.75[b]	0.50
Melt quality (5)	4.22±0.36	4.12±0.33	4.14±0.36	4.08±0.42	NS
Colour and appearance (5)	4.41±0.24	4.47±0.14	4.52±0.24	4.58±0.12	NS
Total score[#] (100)	89.33±1.74[c]	89.87±0.75[a]	89.20±1.04[bc]	90.01±1.79[a]	0.60

Total sensory score includes 15.0 for bacterial quality, SPP – Sweet potato powder, Sugar level in experimental and control ice creams was 14.5% and 15.5%, respectively

control ice cream was formulated to contain 15.5% sugar. It was assumed that presence of sugars inherent in sweet potato (plus the sugar diffusion into their tissues during osmotic treatment) might permit use of lesser quantity of externally added sugar in preparing such experimental ice cream.

Proximate composition and physical properties of ice cream

The control (15.5% sugar) as well as three experimental ice creams (13.5 to 14.5% sugar) complied with the FSSA requirements for 'medium-fat' ice cream[25]. It is evident from Table 3 that the parameters that were significantly ($p<0.05$) affected by the varying sugar levels in ice cream were the carbohydrate and TS content.

The carbohydrate content of ice creams prepared using 13.5 and 14.0% sugar, as well as those prepared using 14.0 and 14.5% sugar was at par with each other. However, 'C' had the least carbohydrate content (*i.e.,* 23.33%); such value was significantly ($p<0.05$) lower than those associated with the three experimental ice creams (Table 3). All the experimental ice creams had similar TS content. The fat, protein and ash content of ice creams remained unaffected by the level of sweetener used in ice cream.

It is obvious that the carbohydrate content of ice cream would increase when sugar is added at an incremental level. Even though ice cream 'C' utilized the maximum quantity of sugar (*i.e.,* 15.5%), it had the least carbohydrate content. Such observed difference could be ascribed to the carbohydrates contributed by SPP in experimental products. Obviously, all the experimental ice cream samples had markedly higher carbohydrate as well as TS content as compared to 'C' ice cream.

An increase in the carbohydrate and consequent increase in TS content of ice cream is obvious when using higher level of sweetener. The chocolate ice cream made using 4.0% cocoa, 12.0% sucrose and 4.0% glucose syrup had carbohydrate content of 26.90%, while that made using same level of sucrose with 4.0% fructose syrup had 27.21% carbohydrates. The TS content of chocolate ice creams containing 4.0% each of glucose syrup and fructose syrup (plus sucrose) was 44.55 and 44.96%, respectively[33].

The variation in the level of sugar in ice cream, with or without SPP, did not have any marked influence on the pH of the product. The pH of the ice creams varied between 6.45 and 6.46 (Table 3).

The control ice cream had significantly ($p<0.05$) higher overrun as compared to the experimental ice creams. The latter three ice creams had overrun that was at par with each other (Table 3).

The overrun of ice cream depends on several factors including presence of heat treated dairy ingredients, type of dairy/non-dairy ingredients (*i.e.,* sweeteners), TS of mixes, the type and amount of stabilizer-emulsifier, etc.[33,34]. The marked variation in the overrun noted between 'C' and experimental ice creams could be ascribed to the difference in the TS and freezing point (FP) of the ice cream mixes. Such variation is bound to have an influence on the viscosity as well as the freezing properties of ice cream mixes. The overrun in ice cream made using sucrose (FP of -2.9°C) and 42 High Fructose Corn Syrup (HFCS) (FP of -4.6°C) were 69.30 and 39.2% respectively. Greater depression in the FP of mix had a deleterious effect on the overrun of product[35]. The varying rate of sugar influences the FP of ice cream mixes.

Sensory scores of ice creams as influenced by the level of sweetener

Since SPP was prepared from osmotically treated sweet potato shreds, they had high sugar content (*i.e.,*

Table 3 — Proximate composition of control and experimental chocolate ice creams as affected by the level of sugar

Parameters (%)	Ice cream prepared using sugar level (%)				CD (0.05)
	C15.5	SP13.5	SP14.0	SP14.5	
		Chemical composition			
Fat	6.52±0.08	6.56±0.07	6.56±0.05	6.56±0.08	NS
Protein	5.1±0.13	5.1±0.141	5.11±0.14	5.09±0.11	NS
Carbohydrate	23.33±0.38[c]	25.45[b]±0.34	25.93[ab]±0.72	26.40[a]±0.58	0.82
Ash	1.44±0.07	1.49±0.09	1.49±0.11	1.49±0.13	NS
TS	36.40[b]±0.65	38.60[a]±0.60	39.09[a]±0.90	39.54[a]±0.77	1.15
		Physical properties			
pH	6.45±0.03	6.45±0.04	6.45±0.03	6.46±0.02	NS
Overrun	71.77[a]±0.66	69.91[b]±0.64	70.26[b]±0.63	70.66[b]±0.81	1.02

C – Control ice cream without SPP; SP – Sweet potato solids containing ice creams; SP13.5, SP14.0, SP14.5 – Sweetener level of 13.5, 14.0 and 14.5% in mix, respectively

85.09%). Hence, there was a need to balance the total sugar in experimental ice creams by reducing the level of externally added sucrose.

The sensory quality of ice creams (Table 4) revealed that except for flavour, all other sensory scores (*i.e.,* color and appearance, body and texture, melting quality, total score) were not influenced markedly by the varying levels of sugar. The flavour score of ice creams C15.5, SP14.0 and SP14.5 was significantly ($p<0.05$) greater than the score of SP13.5. Such finding was anticipated since the carbohydrate content in SP13.5 was the least making the resultant product lack desired sweetness. Ice creams SP14.0, SP14.5 and C15.5 had similar flavor scores; such scores was significantly ($p<0.05$) greater than the score associated with SP13.5 (Table 4).

The total sensory score of all the chocolate ice creams was at par with each other; however, SP13.5 had the least score. Hence, any sugar level from amongst 14.0 and 14.5% could be considered for chocolate ice cream containing SPP. However, considering the highest scores for flavour, body and texture and total sensory of SP14.0 from amongst the experimental samples (Table 4) 14.0% sugar level was selected. Chocolate ice cream is usually formulated to contain higher level of sugar (17.0-18.0%) as compared to plain ice creams (*i.e.,* 13.5-15.0%)[34]. According to Stampanoni-Koeferli *et al.* (1996)[35], the rich taste of milk fat in vanilla ice cream was enhanced with an increase in the sugar level. However, raising the sugar level retarded the milky flavor intensity of such ice cream. As a result of interactions among ingredients in the formulation and the changes in the nature or quantity of ingredients (*i.e.,* sugar) might have exerted an adverse effect on the sensory profile of the resultant ice cream[36]. Harwood *et al.* (2013)[37] utilized 13.0% sucrose and 3.7% corn syrup solids in chocolate ice cream (14.0% fat). Chocolate flavor and creaminess were positively correlated with the product's acceptance, while the consistency was negatively related with its acceptability.

III. Comparison of value-added ice cream with control full-fat and medium-fat ice creams

Medium-fat experimental (MFE, 6.0% fat) chocolate ice cream containing 4.0% SPP and 14.0% sucrose was compared with medium-fat control (MFC, 6.0% fat) and full-fat control (FFC, 10.0% fat) ice creams; the latter two ice creams were formulated to contain 15.5% sucrose and devoid of SPP. The MSNF of FFC mix was 'kept lower *i.e.,*'11.5% (since higher fat led to higher TS), while MFC and MFE mixes were formulated to contain 12.5% MSNF.

Composition and physico-chemical properties of ice creams

All the chemical constituents were significantly ($p<0.05$) affected by varying the milk fat and presence/absence of SPP in ice cream (Table 5). FFC and the medium-fat products (MFC, MFE) conformed to the respective classes of product laid down by FSSA[25]. FFC had significantly ($p<0.05$) higher fat as compared to the two 'medium-fat' ice creams; the latter two had similar fat content. The protein content of FFC was significantly ($p<0.05$) lower as compared to that of MFC and MFE; the latter two had similar protein content (Table 5). The total carbohydrate of MFE was significantly ($p<0.05$) greater than the values associated with FFC and MFC; latter two products had similar carbohydrate content (Table 5).

The ash content of MFE (*i.e.,* 1.35%) was significantly ($p<0.05$) greater than that (*i.e.,* 1.21%) associated with FFC. When comparing MFC with MFE, as well as FFC with MFC, the ash content was similar (Table 5). Ice creams FFC (*i.e.,* 39.92%) and MFE (*i.e.,* 39.18%) had similar TS values; such values were significantly ($p<0.05$) greater than that of MFC (*i.e.,* 37.01%) (Table 5).

The marked difference in the fat content of FFC vs. MFC and MFE is self-explanatory; the latter two ice creams had 6.0% milk fat. Since ice cream mix FFC

Table 4 — Sensory scores of control and experimental chocolate ice creams as affected by the sugar level

Sensory attributes	Ice cream prepared using sugar level (%, w/w)				CD (0.05)
	C15.5	SP13.5	SP14.0	SP14.5	
Flavour (45)	$40.28^a \pm 0.43$	$35.78^b \pm 1.32$	$39.20^a \pm 1.47$	$38.54^a \pm 1.35$	1.87
Body and texture (30)	26.20±0.62	25.81±1.38	27.01±0.20	26.15±0.59	NS
Melt quality (5)	3.90±0.36	4.37±0.36	4.14±0.19	4.22±0.21	NS
Colour and appearance (5)	4.45±0.32	4.26±0.48	4.51±0.28	4.45±0.14	NS
Total score# (100)	90.32±1.22	86.62±4.08	90.58±0.34	88.27±1.56	NS

#Total sensory score includes 15.0 for bacterial quality; Figures in parentheses indicate maximum score; C – Control ice cream without SPP, SP – Sweet potato solids containing ice cream

Table 5 — Proximate composition and physical properties of medium-fat and full-fat chocolate ice creams

Parameters (%)	Category of ice cream			CD (0.05)
	FFC	MFC	MFE	
		Chemical composition		
Fat	10.30[a]±0.34	6.36[b]±0.1	6.42[b]±0.09	0.29
Protein	4.66[b]±0.09	5.07[a]±0.09	5.16[a]±0.05	0.11
Carbohydrates	23.75[b]±0.43	24.28[b]±0.49	26.25[a]±0.51	0.66
Ash	1.21[b]±0.03	1.30[ab]±0.08	1.35[a]±0.10	0.11
TS	39.92[a]±0.84	37.01[b]±0.91	39.18[a]±0.53	1.07
Dietary fiber		0.70	1.15	
β-carotene*		8.73	12.48	
		Physical properties		
pH	6.48±0.04	6.47±0.02	6.45±0.03	NS
Overrun (%)	75.60[a]±0.52	72.16[b]±0.33	71.47[b]±0.91	0.88

FFC – Full-Fat Control, MFC – Medium-Fat Control, MFE – Medium-Fat Experimental
*unit is μg/100 g

was formulated to have lower MSNF (*i.e.,* 11.50 vs. 12.50%) content as compared to MFC and MFE, the latter two products had significantly ($p<0.05$) higher protein content (Table 5). The highest total carbohydrate content associated with MFE could be attributed to the contribution of carbohydrates by SPP. The markedly higher ash content of MFE (vs. FFC) could be ascribed to the higher MSNF *(i.e.,* 12.5 vs. 11.5% for FFC) as well as the presence of SPP (Table 5). The markedly higher TS content of FFC relative to MFE could be ascribed to the higher fat and sugar content in the former product. The similar TS associated with samples FFC and MFE could be ascribed to the presence of 4.0% SPP and somewhat higher MSNF in MFE (*i.e.,* 12.5%), despite having lower fat content. The β-carotene and fiber content of ice cream MFE was higher by 42.95% and 64.28%, respectively when compared with such values for MFC (Table 5). Arslaner and Salik (2007)[38] noted an increase in the protein, ash and TS content of reduced calorie ice creams containing dried mulberry powder and walnut paste compared to control, devoid of walnut paste. The low-fat ice creams utilizing such additives had TS, protein and ash content of 31.59%, 4.30% and 2.00%, respectively.

The pH of all the three ice creams was at par with each other; pH ranged from 6.45 to 6.48 (Table 5). Ice cream FFC had the maximum overrun (*i.e.,* 75.6%) which was significantly ($p<0.05$) higher than other two ice creams (*i.e.,* MFC, MFE). The latter two ice creams had similar overrun (Table 5). The markedly higher overrun associated with FFC (vs. MFC and MFE) could be ascribed to the absence of SPP and higher TS content which rather favoured whipping. Higher body-building TS tends to favour overrun in ice cream, while increased viscosity of ice cream mix owing to the presence of greater quantum of viscosity building solids (*viz.,* starch in rose hip) impairs the overrun of ice cream[39].

Since ice cream FFC had the highest TS (*i.e.,* 39.92% TS, inclusive of 11.5% MSNF), such product had the maximum overrun. Mixes having higher TS comprising of body-building solids (*i.e.,* MSNF portion) tended to favor overrun in ice cream[40]. Though, MFE and FFC ice creams had similar TS content, the presence of SPP possibly led to impairment in the overrun of former ice cream. The highest carbohydrate content of MFE (Table 5) must have exerted greater depression in FP of ice cream mix, leading to impairment in overrun. The influence of FP and TS of ice cream mixes on the overrun of ice creams is documented in literature[41]. Utilization of rose hip fruit at level of 5.0% by weight of mix was beneficial with regard to overrun of ice cream; the values were 36.68 and 33.04% respectively for ice creams containing 10.0 and 0% fruit tissues[39]. Sameen *et al.*[42] noted a decrease in the overrun of ice creams containing sweet potato starch as compared to control ice cream, devoid of starch. The overrun of ice creams was 43.74 and 46.87 % respectively for the products containing 0.25 and 0.50% starch; control ice cream had 52.58% overrun.

Sensory scores of experimental and control chocolate ice creams

The sensory scores for colour and appearance, body and texture and melting quality of all the ice creams were at par with each other (Table 6).

As anticipated, FFC ice cream had the highest score for flavour (*i.e.,* 41.0 out of 45.0) as well as total sensory score (*i.e.,* 91.25 out of 100.0). FFC and MFE had statistically similar flavor scores. The

Table 6 — Sensory scores of experimental and control chocolate ice creams

Sensory parameters	Chocolate ice creams			CD (0.05)
	FFC	MFC	MFE	
Flavour (45)	41.00^{a}±0.85	38.49^{b}±0.85	40.58^{a}±0.61	0.97
Body and texture (30)	26.63±0.83	25.91±0.77	27.16±0.74	NS
Melt quality (5)	4.36±0.12	4.29±0.15	4.12±0.09	NS
Colour and appearance (5)	4.25±0.06	4.30±0.20	4.31±0.17	NS
Total score[#] (100)	91.25^{a}±1.09	87.99^{b}±0.74	91.17^{a}±0.94	1.30

[#]Total sensory score includes 15.0 for bacterial quality; FFC: Full-Fat Control, MFC: Medium-Fat Control, MFE: Medium-Fat Experimental

flavour scores of these two ice creams were significantly ($p<0.05$) greater than the score of MFC (Table 6). The total sensory scores followed exactly the pattern exhibited by the flavour score (Table 6). The overall acceptability scores of experimental rose hip fruit (@ 5.0%) ice cream got impaired (*i.e.,* score of 6.3 vs. 7.0 for control on 9-point scale); higher levels (*i.e.,* 10.0, 15.0%) of fruit incorporation retarded the sensory scores of ice creams further[39].

Milk fat influences the perceived bitterness in chocolate ice cream, as bitter compounds may partition away from the aqueous phase of an emulsion, making them less perceived by the taste receptors[11]. In freshly prepared low-fat (2.50% fat) chocolate ice cream, use of Simplesse @ 2.5% by weight of mix served as a fat replacer[31]. This clearly indicated that the presence of osmo-dehydrated and vacuum dried SPP in the ice cream mix formulation served as a fat replacer. The sensory panel could not distinguish the flavour of ice creams containing 10.0% fat (without SPP) and 6.0% fat (with SPP); even the total score of these two ice creams was similar. Hence, it could be construed that use of 4.0% SPP in the mix formulation could successfully replace 40.0% of the milk fat in chocolate ice cream. Prindiville *et al.*[43] reported superior perceived creaminess and lower intensity of cocoa flavour in chocolate ice cream having higher milk fat (6.0, 9.0%) than the ice creams made using lower (*i.e.,* ≤4.0%) fat. Chocolate ice cream containing milk fat were more stable with regard to texture during storage of product[34]. According to one report sweet potato starch used @ 1.0% by weight could lower the milk fat content by 45.50% in medium-fat (6.0%) vanilla ice cream[44]. Wijaya *et al.*[45] prepared purple coloured ice cream, without resorting to the use of colourant, by utilizing purple sweet potato @ 33.0% by weight of mix. The overall acceptability of such ice cream by panelists revealed that such ice cream was rated 'liked very much' and 'liked it' by 19.2% and 80.8% of the panelists, respectively.

Conclusions

Sweet potato tuber root can be preserved adequately using 'osmo-vacuum' dehydration method to obtain dried sweet potato as against the obsolete traditional techniques. The osmotic treatment led to sugar gain in such dehydrated product, plus the inherent sugars present in the root enabled such solids to partly replace (~ 10.0%) sugar in chocolate ice cream when SPP was used at recommended level of 4.0% by weight of ice cream mix. Use of SPP at the recommended level in medium-fat (6.0%) chocolate ice cream confers advantage with regard to enriching the product with β-carotene as well as dietary fiber; the product has sensory acceptability similar to that of full-fat (10.0%) control product. Use of 4.0% SPP in ice cream could serve as a fat replacer enabling 40.0% reduction in the milk fat content.

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Conflict of Interests

All the authors declare that there is no conflict of interest among the author, financially or otherwise.

Author Contributions

JA conceived and planned the research work. Review of literature was done combinedly by JA and PC. PC performed the research work under guidance of JA and BM. CC and JA performed the analyses other than chemical, including sensory evaluation of the product. BM performed the chemical analyses of the raw materials as well as of the final ice cream products. PC wrote the research manuscript. JA and BM edited the research manuscript.

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