Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)
An Online International Journal Available at http://www.cibtech.org/jls.htm
2011 Vol. 1 (2) April – June, pp. 111-118/Patel et al.
Research Article

Evaluation of Suitability of Sago (Tapioca Starch) As a Functional Ingredient in Ice Cream

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ABSTRACT

The present study was planned and conducted to evaluate the suitability of sago (tapioca starch) as a functional ingredient in ice cream. In this study an attempt was made to prepare a regular fat (10.0%) ice cream using a combination of sago and whey protein concentrate (WPC-70) as stabilizer and emulsifier respectively and see whether it can compare favourably with premium ice cream. The experimental ice cream (10.0% fat) was compared against two control ice creams, one having 10.0 % fat and other having 14.0% fat using commercial stabilizer (Na-alginate) and emulsifier (glycerol monostearate). The tentative formulation of sago and WPC based ice cream was studied using vanilla as flavouring. Sago and WPC was incorporated in experimental ice cream mix at 1.0 and 0.5% (w/w) respectively. Sago in combination with WPC helped in imparting desired body and texture, and richness quite similar to premium ice cream. The sensory characteristics of experimental ice cream were at par with those of premium ice cream but significantly greater than those of regular control ice cream. It can be concluded that regular ice cream can be successfully prepared using sago and WPC with sensory characteristics at par to that of premium ice cream. Such ice cream was sensorily more acceptable than regular ice cream made using commercially available stabilizer and emulsifier.

***Key Words**: Tapioca, Sago, Natural, Ice cream, Stabilizer*

INTRODUCTION

In recent years, consumer interest in the relationship between diet and health has increased substantially. There is much greater recognition today that people can help themselves and their families to reduce the risk of illness and disease and to maintain their state of health and well being through a healthy lifestyle, including the diet. Increasing preference of consumers towards natural ingredients has tempted ice cream manufacturers to search for new ingredients including health beneficial effects. Starches open up new opportunities for manufacturers to create a wide variety of ice cream and frozen desserts with desirable melt-in-mouth textures and full, clean flavours especially for low-fat versions (Koxholt 2000). Sago is well known as tapioca pearl or *saboodana* in Indian market. Process tolerant tapioca starches have a bland flavour and are ideal in delicately flavoured ice creams. In addition to full flavour transparency, tapioca starches are suitable for HTST and UHT systems (Koxholt 2000). Sago is reported to deliver health benefits such as serving as demulcent and destitute of irritating properties. Tapioca starch forms an excellent diet for the sick and convalescent. Sago has a low caloric value (3.1 kcal/g) compared to other carbohydrates. Gelatinized starch has thixotropic properties which imbibes great amount of water in food system to give gelling-like effect, affecting the mouth feel of product. However, no reports are available in the literature regarding use of sago in manufacture of ice cream. Whey and whey products have been used successfully in ice cream and frozen dairy desserts. The use of judicious amounts of whey protein typically results in superior finished product quality - flavor, body-texture and freeze/thaw stability with attendant cost reduction. The whipability and foaming function of whey proteins adds to desirable performance during freezing of ice cream influencing overrun. In this context, it was envisaged to formulate regular (10% fat) ice cream using sago and WPC to replace commercial stabilizer and emulsifier respectively and assess its sensory quality to see if it can purport to simulate a premium ice cream. Therefore, the present project has been contemplated to standardize the formulation for full-fat ice cream using sago and WPC as natural stabilizer and emulsifier, to assess the ice cream for its physico-chemical, rheological and sensory characteristics, to compare experimental ice cream with two control product regular (10% fat) and premium (14%

fat) ice cream made using commercial stabilizer and emulsifier and to assess the calorie-contribution of experimental ice cream vs. Premium ice cream.

MATERIALS AND METHODS

Fresh, raw mixed (cow and buffalo) milk was used as the base material for ice cream manufacture. Sagar^{tm} brand skim milk powder and WPC-70 obtained from Mahaan Protein Ltd., Uttar Pradesh was used. Alginate-S4^{TM} of S. Square & Co., Gwalior and Glycerol Mono Stearate (GMS) was obtained from M/s. Brion Fine Chemicals, Mumbai. Vanilla essence No. 1 obtained from M/s. Bush Boake Allen (India) Ltd., Chennai. Tapioca sago was obtained from M/s. Sabu Traders, Salem, Tamilnadu. Sago was initially soaked in 3.33 times (by wt) of skim milk at 37 ^{0}C for 10 min. Gelatinization of soaked sago was carried out by heating it at 85 ^{0}C for 10 min in a boiling water bath.

Preparation of Ice Cream Mix and Freezing

The quantity of milk, cream, skim milk powder, sucrose, sodium alginate, sago and GMS required for a 5 kg batch was calculated using serum point method. Skim milk powder and other dry ingredients (except sago) were mixed with a part of sugar prior to incorporation in milk-cream mixture at about 50 ^{0}C. The mixes were further heated to 80 ^{0}C and the gelatinized sago paste was added to the mix and mixed thoroughly. The mixes were then homogenized in a double stage homogenizer (Goma-make, Model No. H-502, M/s. Goma Engineering Pvt. Ltd., Thane, Mumbai) at 2000 and 500 psi pressures in the first and second stage respectively and pasteurized at 80 ^{0}C for 5 min. The pasteurized mixes were immediately cooled to 3-4 ^{0}C and aged overnight at same temperature. The flavouring ingredient (i.e. Vanilla) was added just prior to freezing.

For preparing different batches of ice creams (two controls and one experimental), the aged mixes were frozen in a horizontal batch freezer (M/s. Pal Engg. Pvt. Ltd., Ahmedabad, Gujarat) (cylinder capacity 10 lit). The temperature of the circulating refrigerant was -23 to -30 ^{0}C. After freezing the mix to a semi-solid consistency (which took around 20-25 min), as inferred from the load on the ammeter (3 amp) and accumulation of ice on the freezer door, air was whipped at a pressure at 10-15 psi for 2 min. The ice cream was drawn directly into 100 ml High Impact Polystyrene (HIPS) cups and 1 lit. wax coated paper board cartons. The surfaces of the cup was leveled and then covered with wax coated paper board lids. The filled ice cream cups/packs were then transferred immediately to a hardening tunnel (maintained at –25 ^{0}C) for 2-3 h and then transferred to a deep freeze maintained at –18 $\pm$ 2 ^{0}C. The hardened ice creams were subjected to compositional analysis, melting quality test and organoleptic evaluation.

Analyses of Ingredients

The fat content of milk and cream were estimated by Gerber method (ISI 1977). The total solids of milk was determined by the standard procedure using a Mojonnier Milk Tester (Model D, Mojonnier Brothers Co., Chicago, USA) (Anonymous 1959). The titratable acidity of milk was determined by standard method (ISI 1961). The moisture content of sago and ice cream mixes were determined by standard method using 2 g sample (ISI Handbook of Food Analysis 1989). The fat content of ice cream mix and sugar content were determined by the standard method using 5 g of mix (Anonymous 1989). The protein content of the ice cream mixes was determined by Kjeldahl method (AOAC 1980). The ash content was determined following the standard method (ISI 1961). The viscosity of ice cream mix was determined after ageing mixes at 3 ± 2 ^{0}C for 24 h using a 'Haake' Viscometer (Model VT-550. Gebr, Haake gmbh, Germany). The equipment was standardized to system No. 1 MV-DIN with a factor of 61.4 Pa/N-cm and M factor of 1.29 (min/s) using speed level 10 (i.e. 500 rpm). This speed level was selected from amongst the speed levels 1 – 10, as it gave consistent result. The values of viscosity were expressed in mpa.s. The specific gravity of ice cream mix was determined at 20 ^{0}C using a specific gravity bottle (Ling 1963). Overrun in ice cream was determined as per the method given by Marshall *et al.,* (2003). The method given by Loewenstein and Haddad (1972) was employed for evaluating the melting characteristics of ice cream.

Sensory Analysis

Fresh samples of ice cream 100 ml cups after 24 h of hardening at -18 ± 2 ^{0}C in hardening room were tempered to -12 ± 2 ^{0}C for 1-2 h in a retail cabinet for sensory evaluation. Sensory evaluation was performed in a well-lit and ventilated laboratory. The panel members were selected from among the faculty members on the basis of familiarity with judging ice cream and based on experience and their capacity to distinguish quality variations and other attributes in ice cream. The final selection of panelists (6 in number) was done on the basis of results of triangle test using ice cream. A modified version of ADSA ice cream scorecard was used in paper form (Bodyfelt *et al.,* 1988). The total number of samples evaluated per session was not more than 3. Panelists were asked to rinse their mouth with lukewarm water (containing 1% by wt sodium chloride) before assessing each sample and to expectorate al the ice cream samples.

All the samples were simultaneously presented to each panelist in a random order. All the samples were coded with a 3 digit random number.

Statistical Analysis

The mean values of each attributes under study were subjected to statistical analysis using Completely Randomized Design with equal number of observations. The ANOVA for the values of each attribute were performed to evaluate the effect of sago and WPC on physico-chemical and sensory characteristics of ice cream. The means for the data were separated by Least Significant Difference test (Snedecor and Cochran 1980). The significance was pre-established at < 0.05.

RESULTS AND DISCUSSION

Formulation of Sago Based Ice Cream

Preliminary trials were conducted to select the level of milk fat, MSNF, sago, WPC, and sugar. According to PFA (2006) regular ice cream should have minimum of 10.0 % milk fat. Hence, it was decided to keep 10.0 % milk fat in experimental ice cream. The MSNF content of ice cream varies inversely with the fat content. The MSNF content tried in preliminary trials was 10.0, 11.0 and 12.0 % (w/w) in ice cream. The ice cream containing 12.0% MSNF had powdery taste. Regular ice cream with 10.0 % MSNF gave desirable body and texture, without imparting any powdery taste. Moreover, it was sufficient to ensure minimum protein content prescribed by PFA in ice cream (i.e. 3.5 %). The solid not fat content of regular ice cream was 11.0 % to meet minimum requirement of protein as per PFA standards. In experimental ice cream MSNF content was 10.0 % because we added WPC, which compensated the requirement of protein content.

In premium ice cream fat content was higher; so MSNF level was kept as low as possible that is 10 %, only to meet protein requirement (min. 3.5 %).

Sweetness depends on the concentration of sugar in water of the mix (Marshall *et al.*, 2003). Fat content too affects the perceived sweetness intensity of sweeteners (Weit *et al.*, 1993). Ice cream containing 0.5 % milk fat was perceived to be sweeter than those containing 4.0, 6.0 and 9.0 % fat (Prindiville *et al.*, 1999, 2000). To select the level of sweetener in the preliminary trial, sucrose was used at the rate of 15.0, 15.5 and 16.0% (w/w) in the ice cream formulation. For obtaining ice cream with optimum sweetness it was found necessary to add sucrose at the rate of 16.0%.

Water has been the medium used for gelatinization of starch. Few researchers have studied milk as a medium for starch gelatinization (Abu-Jdayil *et al.*, 2004a, 2004b). Water as medium for gelatinization of sago may create problem of dilution of total solids in ice cream. Hence, in present study it was decided to use whole milk as medium for gelatinization of starch present in sago. Varying quantities of whole milk viz., 600, 800, 1000, and 1200 g was used to soak 300 g of powdered sago. The one prepared with 1000 g milk showed good gel characteristics. Milk quantity lower than 1000 g resulted in sticky gel. Use of 1200 g of milk resulted in somewhat weaker gel. Therefore, a level of 1000 g milk per 300 g sago was selected for gelatinization. Three levels of sago (unsoaked basis) i.e. 1.0, 1.5, and 2.0 % by wt of mix was tried out. Higher levels resulted in slight gummy and pasty bodied ice cream. Hence, 1.0 % sago (unsoaked) was used as natural stabilizer in experimental ice cream. No other stabilizer was used.

Table 1. Formulation for experimental and control ice creams

Sr. No.	Constituents	Level (%)		
		Sago based ice cream (S)	Regular ice cream (Control A)	Premium ice cream (Control B)
1.	Milk fat	10.0	10.0	14.0
2.	MSNF	10.0	11.0	10.0
3.	Sweetener (sucrose)	16.0	15.0	16.0
4.	Stabilizer (Na-alginate)	-	0.20	0.10
5.	Emulsifier (GMS)	-	0.20	0.10
6.	Sago	1.0	-	-
7.	Whey Protein Concentrate	0.5	-	-
	Total solids	37.50	36.50	40.20

Table 2. Chemical composition of experimental and control ice creams

	Constituents (%)				
	Fat	**Protein**	**Total Carbohydrate**	**Ash**	**Total Solids**
S	10.29	4.09	22.83	0.77	37.95
CA	10.33	4.07	21.65	0.83	36.88
CB	14.33	3.83	21.94	0.73	40.84
Statistical analysis					
SEM	0.089	0.033	0.084	0.011	0.06
CD(0.05)	0.269	0.101	0.253	0.034	0.181
C.V.%	1.88	2.05	0.93	3.59	0.38

Abbrev: S - Sago based ice cream (10 % fat); CA - Control A (10% fat); CB - Control B (14% fat)

Table 3. Physical properties of experimental and control ice creams

	Acidity (% LA)	**Viscosity (mpa.s)***	**Overrun (%)**	**Melting resistance****
S	0.219	83.00	75.91	43.64
CA	0.213	71.67	78.60	52.41
CB	0.213	91.00	73.18	44.27
Statistical analysis				
SEM	0.002	0.694	0.547	0.522
CD(0.05)	NS	2.091	1.649	1.572
C.V.%	1.95	2.08	1.77	2.73

(Based on six replications)

* Viscosity measured at 20 ^{0}C; ** g of ice cream melted at 37.5 ^{0}C for 40 min.

Abbrev: S - Sago based ice cream (10 % fat); CA - Control A (10% fat); CB - Control B (14% fat)

Table 4. Sensory quality of experimental and control ice creams

Ice cream	Sensory score for				
	Flavour (45)	Body & texture (30)	Melting quality (5)	Colour and appearance (5)	Total sensory quality (100)*
S	38.29	26.98	4.67	4.68	89.32
CA	35.75	26.55	4.2	4.58	85.99
CB	39.07	27.84	4.63	4.64	90.92
Statistical Analysis					
SEM	0.854	0.347	0.1	0.107	1.055
CD(0.05)	2.57	NS	0.302	NS	3.18
C.V.%	5.55	3.13	5.46	5.66	2.91

* Max. Score of 15 was given for Bacterial quality to all samples.

Abbrev: S - Sago based ice cream (10 % fat); CA - Control A (10% fat); CB - Control B (14% fat)

Table 5. Calculated calorific value of the vanilla flavoured sago based regular fat vs. A premium ice cream mix (per 100 g mix).

Sr. No.	Ingredient	Sago based ice cream (%)	Sago based ice cream energy (Kcal)	Regular ice cream (%)	Regular ice cream energy (Kcal)	Premium ice cream (%)	Premium ice cream energy (Kcal)
1.	Fat	10.00	87.90	10.00	87.90	14.00	123.06
2.	MSNF*	10.00	36.64	11.00	40.30	10.00	36.64
4.	Sugar	16.00	61.92	15.00	58.05	16.00	61.92
5.	Na- alginate	-	-	0.2	0.78	0.10	0.38
6.	GMS	-	-	0.2	1.66	0.10	0.83
7.	Sago**	1.0	3.87	-		-	-
8.	WPC	0.5	1.60	-		-	-
	Total Cal.		191.93		188.69		222.83

**MSNF contain approx. 36 % protein and 55 % lactose*

*** Sago contained 12 % moisture and 7 % resistant starch which do not impart energy.*

Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)
An Online International Journal Available at http://www.cibtech.org/jls.htm
2011 Vol. 1 (2) April – June, pp. 111-118/Patel et al.
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Three levels of WPC viz., 0.5, 1.0, and 1.5 % was attempted in experimental ice cream. The functional characteristics of whey proteins such as water binding, emulsification and foaming adds to desirable performance during freezing especially whipping ability. Hence, there was no need to add any permitted emulsifier. The stabilizer and emulsifier content of regular ice cream was slight higher than premium ice cream; because high stabilizer content in premium ice cream was shown to give a soggy body and higher emulsifier content caused destabilization of fat during freezing of premium ice cream. The physico-chemical and sensory characteristics of the regular fat sago based ice creaam (10.0% fat) which was designated S, was compared against a regular fat (10 %) control (designated control A) and premium (14.0 % fat) control (designated control B) ice creams. The formulation (Table 1) for sago and WPC based regular fat ice cream was tried out with vanilla flavouring. This experimental ice cream was compared with control A (regular) and control B (premium) ice creams. Vanilla was added at the rate of 0.1% in all the 3 ice creams. Totally, six replications were undertaken.

The results of experiment are discussed below. Table 2 shows the average values of compositional parameters of the experimental and two control vanilla ice creams. Control B had the least protein content, which was significantly lower than the other two ice creams (i.e. S and Control A). The protein content of S was similar to that of Control A even though the former had lower MSNF (i.e. 10.0 vs. 11.0). This was due to the protein contributed by WPC over and above the one inherent in MSNF in S. The total carbohydrate of experimental ice cream was significantly higher than that of control-A and control-B. The contribution of carbohydrate by sago in experimental ice cream led to the observed significant difference. The significantly higher ash content of control-A ice cream was due to its higher MSNF (11.0 %) than the other two. Table 3 shows the average values of physical parameters monitored viz. Acidity, viscosity, overrun and melting resistance of ice cream mix/ice cream. The highest protein content associated with sample S could have led to the higher acidity of sample S. The relation between MSNF and acidity is already documented (Marshall *et al.,* 2003). The values of acidity observed in present study are similar to the ones reported by Gabriel and others (1986), Neshawy and others (1988), and Patel *et al.,* (2010).

Viscosity of ice cream mix is affected by several factors, viz. Composition, kind and quality of ingredients, processing and handling of mix, total solids, temperature, etc. The acidity of ice cream mix also affects the viscosity of ice cream mixes (Marshall *et al.,* 2003). The higher viscosity of the mix based on sago and WPC could be ascribed to the water binding capacity of both gelatinized starch of sago as well as inherent property of WPC. Since control B ice cream had the highest total solids (i.e. 40.2%), there was less water in the mix to be frozen. This might have led to the highest viscosity value observed in such ice cream. Schmidt *et al.,* (1993) found that the use of carbohydrate-based fat replacers in reduced calorie ice cream resulted in mixes with higher viscosity. Flack (1988) reported that denatured proteins have much greater water binding capacities. The whey proteins present in WPC used in experimental ice cream got denatured too during mix pasteurization treatment, contributing to the viscosity of such ice cream. The starch contained in potato led to increased viscosity of ice cream mixes containing added potato pulp (Das *et al.,* 1989). Starch has been implicated for increased mix viscosity and restricting ice crystal growth during storage of ice cream (Cottrell and others 1980).

The least overrun found in control-B is obvious since milk fat has been known to be overrun depressant. The premium ice creams commercially available in market are associated with low (25-45%) overrun (Marshall *et al.,* 2003). Moreover, control-B mix had the highest viscosity amongst all ice creams. High viscosity does not favor whipping ability. The sago based experimental ice cream had higher overrun compared to control-B, but was lower than that of control-A. The experimental ice cream relied on WPC and to some extent on sago to perform as emulsifier and stabilizer respectively in comparison to commercial emulsifier (GMS) and stabilizer (Na-alginate) used in control-A. However, probably due to higher viscosity obtained in sago based ice cream mix, it had some detrimental effect on whippability. The results obtained during the present investigation corroborate with that of Das *et al.,* (1989), who found that enhanced viscosity of ice cream mix containing potato pulp had an adverse effect on overrun in ice cream. The slower meltdown of 'S' ice cream compared to control-A (both containing 10.0% fat) could have been as a result of greater stabilizing effect exerted by combination of sago and WPC compared to the effect exerted by Na-alginate and GMS. Moreover, GMS does not have as good water binding capacity as does WPC especially in its denatured form. Furthermore the starch in its gelatinized form in sago based ice cream led to high melting resistance. On the other hand, the high melting resistance associated with control-B ice cream is due to highest TS of the mix (40.2%), with further contribution by Na-alginate in such formulation. Control-B also had the highest fat content (14.0%); fat is known to retard meltdown of ice cream. Guinard *et al.,* (1997) reported that fat content affects the perceived rate of melting of different foods. Hyvonen *et al.,* (2003) reported that higher fat content in ice cream seems to retard melting. However, such melting rate is influenced by the type and rate of emulsifier used since emulsifier affects the 'deemulsification of fat' that takes place during freezing in the freezer. Slow melting generally indicates over stabilization and such condition can be corrected by reducing the amount of stabilizer and/or emulsifier.

Table 4 shows the average values of sensory parameters viz. Colour and appearance, flavour, body and texture, melting quality and total sensory score for vanilla ice creams. Control-A had the least flavour score which differed significantly from the scores assigned to 'Control-B' as well as 'S'; the later two however were at par with each other. The superior flavour of premium ice cream (control-B) is obvious due to the high fat content imparts richness as well as better mouth feel. However, sago based experimental ice cream had significantly higher flavour score than its counterpart (Control-A) having same fat content (i.e. 10.0%). This indicates that presence of gelatinized starch from sago and WPC together led to superior flavour impact compared to use of Na-alginate and GMS used in control-A. Ohmes *et al.,* (1998) emphasized the importance of fat as a flavour modifier in delicately flavoured ice cream like vanilla. Jobling (2004) reported that tapioca starch had a bland taste which has advantages in many delicately flavoured food applications. Goubet *et al.,* (1998) reported that retention and release of aroma compounds from food matrices is governed by the specific interactions between aroma compounds and food compounds. Flavour release was least in 18.0 % fat ice cream and higher in lower fat versions; fat retarded the flavour release (Hyvonen *et al.,* 2003). Starch and other hydrocolloids have been shown to interact with flavour compounds by binding them (Hau *et al.,* 1996). Control-B (Premium ice cream) had marginally better body and texture than 'S' as well as 'Control-A' ice cream. However, such difference was non-significant. This implies that all the three ice cream samples had acceptable body and texture characteristics. The superior melting quality of sago based experimental sample could be ascribed to the action of sago (gelatinized starch) and WPC (denatured protein) building up viscosity necessary for developing melting resistance. The improved melting quality in control-B (premium ice cream) arose from the initial high TS as well as high fat content, which coalesce together during freezing to aid in melting resistance. It is seen from Table 4 that the total sensory score of sago based experimental ice cream was significantly higher than that of control-A ice cream; however, the latter ice cream had score at par with that of control-B (premium grade). This is obvious since samples control-B and 'S' had significantly superior score for flavour and marginally higher score for other aspects.

Comparison of Energy Value of Sago Based Regular Ice Cream with Regular and Premium Ice Cream

The energy value was calculated by taking the energy value for fat, protein and carbohydrates as follows: fat, 8.79; protein 4.27 and carbohydrates, 3.87 kcal/g. Based on the data, the energy value of the sago based ice cream is 191.93 kcal/100 g., the energy value of regular ice cream is 188.69 kcal/100 g., the energy value of an premium ice cream is 222.83 kcal/100 g. (Table 5). Therefore, we can say that experimental and regular ice cream provides almost same energy, while premium ice cream provides higher energy than other both ice cream. The experimental ice cream offers 31.0% less calorie than premium ice cream even though both the ice creams are similar in sensory and physico-chemical characteristics.

Sago and WPC served to make ice cream more acceptable than its 10.0% fat control and even made it somewhat closer in sensory aspect to premium ice cream. Sago did perform as stabilizer and flavour modifier while WPC acted as an emulsifier as does GMS in commercial ice creams. Sago and WPC can be used as functional ingredient in regular fat vanilla ice cream; such ice cream can be comparable with regular and premium ice cream in terms of flavour, body and texture, melting characteristics, and colour and appearance as well as overall acceptability. The experimental ice cream gives same amount of calorie as given by regular ice cream. However the calorie given by experimental ice cream is 31.0% less compared to premium ice cream though having same sensory and physico-chemical characteristics.

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