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Use of enzyme modified sweet potato starch in formulation of ice cream

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Abstract
This study focuses on use of enzyme modified sweet potato starch in formulation of ice cream. The different formulation were made to standardize the level of enzyme modified sweet potato starch is mixed with khoa viz., 0:100, 10:90, 20:80, 30:70 and 40:60 respectively to replace fat. Results sensory evaluation showed that ice cream sample M_1I_2 received highest sensory score i.e. 8.5 containing 20 per cent enzyme modified starch. Further studies carried for influence of addition of EMS on overrun, total solids, meltdown point and viscosity (cP) of ice cream mix. Results showed overrun value was in the range of 48.41 to 55.32 percent whereas total solid content was in between 34.50 to 37.31 percent. The apparent viscosity of ice cream mix was in the ranged of 129.87 to 147.17cP. Further, chemical properties of ice cream mix were also studied include fat, protein, titratable acidity and pH. It was observed that there was remarkable decrease in fat content from 9.85 to 5.79 percent was noticed with increased EMS level. It could be finally concluded that up to 20% incorporation of enzyme modified sweet potato starch can be used to reduce fat content in formulation of low calorie ice cream.

Keywords: Sweet potato starch, enzyme modification, ice cream, fat replacer, viscosity

Introduction

Ice cream, and most all of the other frozen desserts described above, generally contains seven categories of ingredients: fat, milk solids-not-fat (the principal source of protein), sweeteners, stabilizers, emulsifiers, water, and flavors. For the wide range of frozen desserts, production is similar. Ice cream is a complex food product, in which the removal of one ingredient may affect not only its physical structure but also the sensory characteristics that make it acceptable to consumers. Ice-cream is a delicious, wholesome and nutritious frozen dairy food. Its history goes back to the ancient period, but its future seems endless. It represents one of the most dynamic sectors of the dairy industry. It is the product liked invariably by one and all and is popular throughout the world (Kumar *et al*., 2013) [15]. Ice-cream is also rich source of calcium, phosphorous and other minerals of vital importance in building good bones and teeth. Being rich in lactose, ice-cream favours greater assimilation of the calcium content in the diet. Along with that, icecream is an excellent source of vitamin A, a good source of vitamin B1(Thiamine) and B2 (Riboflavin), and fairly good source of niacin, vitamin E, and in fruit ice-cream, vitamin C and the digestibility and palatability of ice-cream is also very high (De 2004) [9].

Sweet potato is a nutritive vegetable, being an excellent source of vitamin A precursor, certain other vitamins and minerals, energy, dietary fiber and some protein. About 80 to 90 percent of sweet potato dry matter is made up of carbohydrates, consisting mainly of starch and sugars with lesser amounts of pectin, hemicelluloses and cellulose. On average, starch constitutes 60 to 70 percent of the dry matter, but the proportion of starch to other carbohydrates varies greatly (Woolfe, 1992) [21]. Mashed sweet potato is used as an ingredient of ice cream, tarts, baking products and desserts as a substitute for more expensive ingredients. Sweet potato flour is used as a 20% supplement for wheat flour in bread, biscuits or cakes (Department Agriculture, Forestry & Fisheries, 2011) [11].

Consumer acceptance of any food product depends upon taste the most important sensory attribute. Although consumers want foods with minimal to no fat or calories, they also want the foods to taste good (Caceres *et al.*, 2004) [5]. The development of reduced-fat foods with the same desirable attributes as the corresponding full-fat foods has created a distinct challenge to food manufacturers. Due to this; the consumer demand for low-fat foods has encouraged research on reducing the fat content of foods. Problems of inferior organoleptic and physical properties in these products suggested the use of fat replacers (FR) to provide the desirable qualities.

Enzymatic hydrolysis is a biochemical modification reaction. Selective enzymes are used in the hydrolysis to alter the starch structure and to achieve desired functionality. A range of chain lengths corresponding to glucose (dextrose), maltose, oligosaccharides and polysaccharides can be produced depending on the extent of hydrolysis. α-amylase, β-amylase, glucoamylase, pullulanase, and isoamylase are the most common enzymes used for starch modification. These enzymes have been isolated from fungi, yeasts, bacteria, and plants (Xie *et al*., 2005) [22].

Ice cream mix contains the partially crystalline fat globules and casein micelles as discrete particles in a solution of sugars salts, dispersed whey protein, stabilizers, etc. The surface of the fat globule demonstrates the competitive adsorption of casein micelles, globular, partially denatured whey proteins, b-casein, and added emulsifiers. Ice cream contains the ice crystals, air cells and partially coalesced fat globules as discrete phases within an unfrozen serum containing the dissolved material. The partially coalesced fat agglomerates adsorb to the surface of the air cells, which are also surrounded by protein and emulsifier, and link the bubbles through the lamellae between them (Goff and Hartel, 2013) [12]. This provides the characteristic smoothness, dryness and retarded melting rate that are expected from the product. Moreover, fat acts as a flavor delivery system, in particular of molecules that are hydrophobic in nature. However, consumers tend to associate reduced-fat products with a lower sensory quality. (Da Silva *et al*., 2014).

The addition of fat replacers to fat-free Ice cream decreased the amount of ice in the product as fat replacers physically block the formation of ice crystals in the product just as a dairy fat globule does (McArthur, 2009) [17].

Materials and Methodology

Raw Materials

Good quality of Sweet potatoes (*Ipomoea batatas* L.) tubers were purchased from local market of Parbhani, Maharashtra. The tubers were placed in a polyethylene bag to prevent loss of moisture during storage prior to processing and analysis in the laboratory of Department of Food Science and Technology and other ingredients such as khoa, refined sugar, cardamom, milk, cream, skim milk powder, CMC and flavor which were necessary for product development were purchased from local market of Parbhani.

Chemical reagents and glasswares

Chemical reagents of analytical grade, Enzymes and glasswares used during present investigation was available in the Department of Food Science and Technology, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Processing and analytical equipments

The equipment and machineries like knife, Dryers, hot air oven, muffle furnace, ice cream maker, soxhlet apparatus, protein digestion and distillation unit required during the present investigation were available in the Department of Food Science and Technology, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Methodology

Preparation of ice cream by using enzyme modified starches

Table 1: Formulation for preparation of ice cream

Sample code	Ingredients	
	Khoa	EMS
I_0	100	0
M_1I_1	90	10
M_1I_2	80	20
M_1I_3	70	30
M_1I_4	60	40

EMS=Enzyme modified starch

Preparation of ice cream

Ice cream was prepared by using method of De S. (1981) [8] as given in flow sheet 1. Basic formulation used for preparation of ice cream was as per table 1 and the quantity of raw material required was calculated by using method of De S., (2015) [9].

Selection of ingredients
↓
Figuring the mix
↓
Making the mix
↓
Pasteurization of mix
(68.3^0 C for 30 minutes)
↓
Homogenization
↓
Cooling and aging the mix (4 ^{0}C)
↓
Freezing the mix (-4 to -5 ^{0}C)
(Ice cream machine)
↓
Packaging of Ice cream
↓
Hardening and storage (-23 ^{0}C)
↓
Storage (-15 ^{0}C)

Flow sheet 1: Preparation of ice cream

Table 2: Basic formula for preparation of ice cream

Ingredients	Quantity (%)
Milk fat	10
Milk solid not fat	11
Sugar	14.50
Stabilizer & Emulsifier	0.65

Preparation of ice cream by using enzyme modified starch

The fat was replaced with enzyme modified starch (M_1) at 0, 10, 20, 30 and 40 per cent (w/w) and other ingredients were used as per recipe to prepare ice cream by using method as described above (table 3). Prepared ice cream was subjected to organoleptic evaluation and suitable blend of fat: enzyme modified starch was selected for the further analysis.

Table 3: Formulation of ice cream with enzyme modified starch

Ingredients	Quantity				
	I_0	M_1I_1	M_1I_2	M_1I_3	M_1I_4
Milk fat	10	9	8	7	6
Enzyme modified Starch	00	1	2	3	4
Milk solid not fat	11	11	11	11	11
Sugar	14.50	14.50	1.50	14.50	14.50
Stabilizer & Emulsifier	0.65	0.65	0.65	0.65	0.65

Different ice creams samples were prepared by addition of prepared enzyme modified starch (EMS) at the levels of 0, 10, 20, 30 and 40 percent to replace fat. The effect of replacement of fat with enzyme modified starch on organoleptic characteristics of ice cream is presented in table 4.

Physical Properties of ice cream

Overrun

Overrun was determined in duplicate and calculated according to the following equation as per method describe by De S., 2015 [9].

$$\% \text{ Overrun} = \frac{(\text{Volume ice cream}) - (\text{volume of ice cream mix})}{\text{Volume of ice cream mix}} \times 100$$

Total solids

The total solid of ice cream was determined as per method given by Berwal *et al.* (2006) [4]. 3 g of well mixed sample of ice cream in triplicate was transferred to previously dry empty dish. Further it was placed on boiling water bath in order to evaporate maximum amount of moisture till in appeared dry. Then the sample was dried in hot air oven at 120^0C for four hours. The total solids calculated by using given formula.

$$\text{Total solids (\%)} = \frac{W_3\text{-}W_1}{W_2\text{-}W_1} \text{ X } 100$$

Where, W_1= weight of empty dish
W_2= Weight of empty dish + ice cream
W_3= Weight of empty dish + dried ice cream

Meltdown point

To determine the meltdown of ice cream, 80.0 g of sample was put on a wire mesh attached to a graduated cylinder and maintained under a controlled temperature chamber at 25ºC and environment of constant relative humidity (50 ± 1%). The dripped volume was measured at a 10 minute intervals for a total of 45 minutes (Lee and White, 1991) [16]. The first drop time was measured as the volume drip per minute. The data recorded was used to determine the melting rate (ml/minute).

Apparent Viscosity (After Aging)

Viscosity of the unfrozen mixes was measured using a Brookfield LVDV-E Viscometer (Brookfield Engineering Laboratories, Middleboro, MA) with LV Spindle #1 (61) after aging. All measurements were recorded after 15 s at 12 rpm and reported as the apparent viscosity.

Proximate composition of modified sweet potato starch

The modified sweet potato starch were analyzed for proximate composition includes moisture, fat, protein, carbohydrates, dietary fiber and ash as per the standard methods of analysis given by (AOAC, 2005) [1].

Texture profile analysis of Ice cream

Texture analysis was carried out as per method of Akalin *et al*., (2008) [2] with some modifications. TPA was conducted at room temperature using a Texture Analyser (*TAXT*, SDS) equipped with a P/36R stainless steel cylindrical probe. Ice cream samples stored at -18 °C for 5 days were tempered to -10 °C for 24 h before analysis. The conditions for analysis were as follows: penetration distance = 15 mm, force = 5.0 g, probe speed during penetration = 3.3 mm s^{-1}, probe speed pre and post penetration = 3.0 mm s^{-1}. Hardness was measured as the peak compression force (kg) during the penetration of the sample.

Organoleptic evaluation

The products ice cream evaluated for different sensory attributes by using 9-point hedonic rating scale ranging from like extremely to dislike extremely (as per method given by Srilakshmi, 2002) [20]. The semi trained panelists were selected from the staff of College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Results and Discussion

Effect of different levels of EMS on organoleptic properties of ice cream

Ice cream prepared with addition of different level of enzyme modified sweet potato starch was subjected for organoleptic evaluation by using 9 point hedonic rating scale. The data related to various attributes are indicated in table 4.

Table 4: Organoleptic evaluation of ice cream prepared by EMS

Treatment	Sensory Attributes				
	Color & Appearance	Flavor	Taste	Texture & Mouthfeel	Overall Acceptability
I_0	8.51	8.63	8.50	8.43	8.42
M_1I_1	8.18	8.44	8.46	8.36	8.39
M_1I_2	8.09	8.39	8.45	8.35	8.38
M_1I_3	7.90	8.11	8.07	8.05	8.05
M_1I_4	7.84	7.52	7.48	7.77	7.61
SE±	0.017	0.071	0.064	0.060	0.06136
CD@5%	0.051	0.213	0.193	0.183	0.18471

* Each value was an average of three determinations
I_0= Ice cream without starch (Control)
$M_1 I_1$= Ice cream with 10% enzyme modified starch
M_1I_2= Ice cream with 20% enzyme modified starch
$M_1 I_3$= Ice cream with 30% enzyme modified starch
M_1I_4= Ice cream with 40% enzyme modified starch

The data presented in the above table showed that the enzyme modified starch in ice cream formulation not affected the acceptance of the product till 20% level. The control sample (I_0) scored maximum while the treatment M_1I_4 scored least value for color and appearance. The control sample was found statistically significant over the treatments M_1I_1, M_1I_2, M_1I_3 and M_1I_4. The elevated levels of enzyme modified starch affect the flavor, mouthfeel and taste score beyond the level of 20 percent.

Taste is the sensation of flavour perceived in the mouth and throat on contact with a food product. As the flavour is improved it will lead to improved taste. In present investigation the flavor of ice cream was improved as fat was reduced. So the taste also received score in accordance with flavor by the expert panel. The treatment I_0 received highest score (8.63) for flavor by judges of semi trend panel and it was at par with M_1I_1 sand statistically significant over the fat reduced ice creams M_1I_2, M_1I_2 and M_1I_4. Similarly it was observed that I_0 had highest score for taste (8.50) and it was at par with M_1I_1 and M_1I_2 and statistically significant over treatments M_1I_3 and M_1I_4. According to Hyvonen *et al*., (2003) [13] the use of maltodextrin and polydextrose in a fat-free ice cream produced a higher creamy perception which is consistent with our results.

Further it was observed that the control sample (I_0), M_1I_1 and M_1I_2 scored maximum for texture and mouthfeel (8.43, 8.36 and 3.50). The treatments of I_0 of ice cream had scored the highest for texture and mouthfeel by the panel of judges while M_1I_4 gave least score. The ice cream I_0 was found at par with $M_1I_1$and M_1I_1 and statistically significant over other all treatments. Decreased score could be attributed to increase in viscosity of ice cream due to addition of elevated levels of modified starch that would tend to increase the hardness of ice cream. As increased in hardness of ice cream tend to increase the melting resistance.

Hence, on the basis of overall acceptability score (8.38) of ice cream, treatment M_1I_2 in which fat was reduced by 20 per cent enzyme modified starch was standardized for preparation of ice cream.

Table 5: Physical properties of ice cream prepared by using EMS

Treatments	Physical properties			
	Over Run (%)	Total solid (%)	Meltdown point (ml/min)	Viscosity of mix (cp)
I_0	55.32	34.50	1.88	129.87
M_1I_1	54.68	35.32	1.75	134.97
M_1I_2	52.87	36.54	1.68	139.23
M_1I_3	50.22	37.08	1.59	143.41
M_1I_4	48.41	37.41	1.41	147.17
SE±	0.406	0.364	0.036	0.804
CD@5%	1.192	1.069	0.108	2.359

* Each value was an average of three determinations

The effect of addition of sweet potato starch at different levels (10 to 40%) to replace fat on physical properties of ice cream *viz.* overrun, total solids, meltdown point and viscosity of ice cream mix are summarized in table 5. All the physical properties of ice cream were consistently decreased with successive increased level of enzyme modified starch.

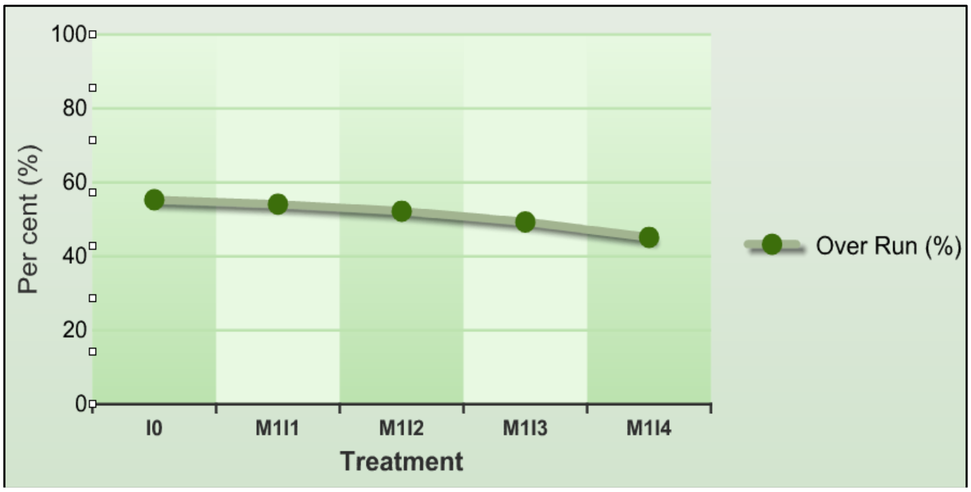

Fig 1: Overrun of ice cream prepared by using EMS

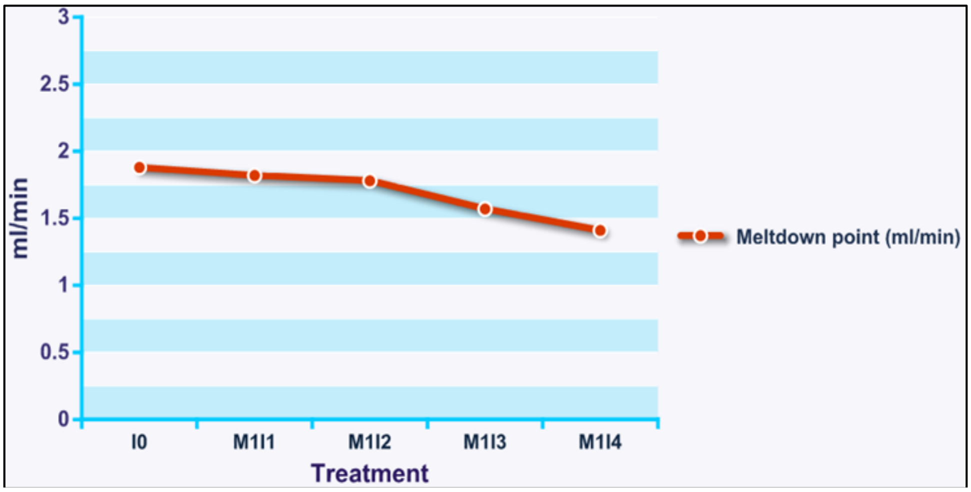

Fig 2: Meltdown point of ice cream prepared by using EMS

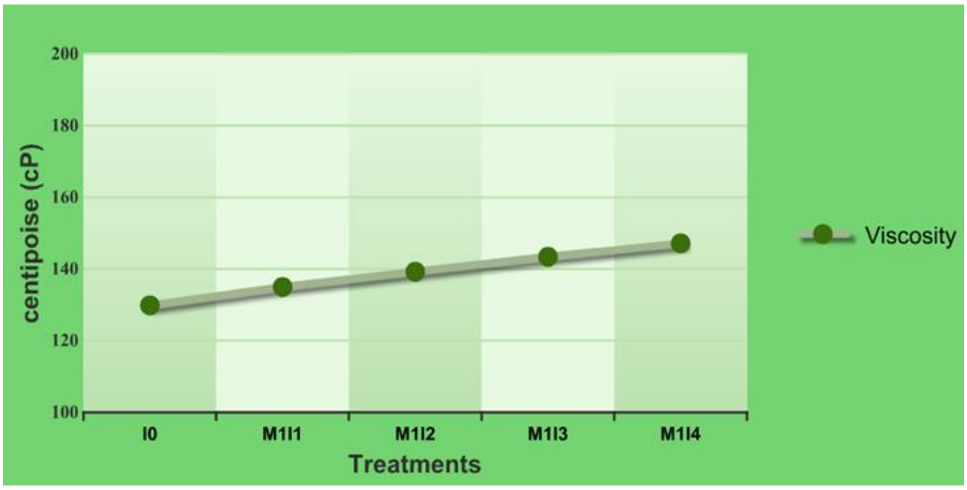

Fig 3: Viscosity of ice cream mix prepared by using EMS

Overrun is associated with the amount of air incorporated during the ice cream manufacturing process. The ice creams obtained in the present study showed overrun of 48.41to 55.32 percent. Control sample (I_0) comparatively was having higher value (55.32%) for overrun which could be explained by incorporation of more air in ice cream mix during freezing. A result obtained from table reported that the overrun of control sample was at par with M_1I_1 and statastically significant over other treatments (M_1I_2, M_1I_3 and M_1I_4). According to Chang & Hartel (2002) [6], the contents of fat, emulsifier, and stabilizer and the processing conditions (whipping temperature and freezing power) can affect air cell development. Thus, the low overrun values of fat reduced ice creams were likely due to the addition of carbohydrate-based fat replacers since they exhibit a viscous behavior that may decrease its whipping capacity.

It is evident from table that the total solid content of different ice cream was in the ranged from 34.50 to 37.31 percent. The treatment M_1I_4 contains the highest amount of solids (37.41%) while the control sample (I_0) showed least value (34.50%) for total solids. The increasing trend of per cent total solids was found among all the treatments with the decreasing level of fat. The fat reduced ice cream (I_4) at par with treatment M_1I_3 and significant over control (I_0), M_1I_1 and M_1I_2 ice creams. The increased percentage of total solids could be attributed by increased level of starch among all the treatments. Similar results were concluded by Murtaza *et al.* (2014) [18] and Aykan *et al.* (2008) [3].

The results of meltdown of prepared ice cream revealed that as the level of fat reduced from 10 to 6 per cent (as per formulation) there was reduction in melt down of ice cream. The ice cream, I_0 showed highest melting rate (1.88) while the sample, M_1I_4 showed lower melting rate (1.41 ml/min) as compare other treatment. The decreased levels melting rate among the treatments (M_1I_1, M_1I_2, M_1I_3 and M_1I_4) as compare to control sample (I_0) was due to addition of starch which had tendency to form H bonds with water which increased the viscosity of the ice cream mix thus increasing its resistance to melting. The result of meltdown of control treatment (I_0) was at par with M_1I_1 and statistically significant over reduced fat ice creams M_1I_2, M_1I_3 and M_1I_4. The treatments M_1I_1 and M_1I_2 were comparable with control sample. So, sweet potato enzyme modified starch can be added to replace fat up to 20% as beyond this limits it tends to increases hardness.

According to Koxholt *et al.*, (2005) [14] amylopectin starch can be a waxy starch (i.e., no more than about 10% amylose by weight), including waxy corn (waxy maize, when added to the frozen dessert, provides an improved reduction in the melt down of the frozen dessert versus a frozen dessert formulated without the functional starch.

The viscosity of the liquid is important. If the liquid is too viscous, it is difficult to beat and therefore to incorporate the air; if it is not viscous enough, the film between the air bubbles rapidly drains, and the bubbles coalesce. Ice cream mix is pseudoplastic. As the shear rate increases, the viscosity decreases. Thus, to characterize the viscous behavior of an ice cream mix, both the underlying viscosity and the shear rate dependence are necessary.

The data pertaining to the viscosity of ice cream mix after aging revealed that the It could be seen from the table 42, that the apparent viscosity of ice cream mix was in the ranged of 129.87 to 147.17cP. The viscosity of different treatments was significantly affected by the addition of varying levels of EMS to replace the fat. The treatment (M_1I_4) was having maximum viscosity (147.17cP) while control sample (I_0) showed minimum viscosity (129.87 cP). The elevation in viscosity in all the treatments could be attributed to increased level of EMS in the formulations. An increase in viscosity with increasing concentrations of polysaccharides was also observed by Aykan *et al.*, (2008) [3].

Chemical properties of ice cream prepared using EMS

The ice cream prepared by replacing of 10, 20, 30 and 20 per cent of fat with enzyme modified sweet potato starch (EMS) for the purpose of its reduced calories. The effect of these replacements on compositional values like fat, protein, acidity and pH of control (I0) as well as experimental samples (M_1I_1, M_1I_2, $M_1I_3$and M_1I_4) is tabulated in table 6. The fat content was ranged from 5.79 to 9.85 per cent. Fat content shown to decreased linearly with substitution replacement level. The fat content of different ice creams was similar to that of formulation due to standardization of fat in both the milk and cream.

Table 6: Chemical properties of ice cream prepared by using EMS

Treatment	Chemical Properties			
	Fat (%)	Protein (%)	Titrable acidity (%)	pH
I_0	9.85	4.21	0.213	6.32
M_1I_1	8.81	4.24	0.211	6.41
M_1I_2	7.90	4.28	0.210	6.42
M_1I_3	6.88	4.31	0.208	6.48
M_1I_4	5.79	4.33	0.206	6.50
SE±	0.091	0.016	0.001	0.023
CD@5%	0.275	0.047	0.003	0.070

* Each value was an average of three determinations

The results obtained for protein content of different ice cream was ranged from 4.21 to 4.33 percent. The reduced fat ice cream, M_1I_4 showed highest value while control sample had shown lowest value for protein content. The M_1I_4 found at par with M_1I_3 and statistically significant over all the other ice creams. There was no significant difference observed in protein content with increased level of starch. The slight increased in protein content could be attributed by chemical composition starch. The acidity and pH varied within a narrow range. Also from the table it was observed that there was no significance difference observed in per cent titrable acidity and pH.

The percent acidity was decreased with increased level of EMS in ice cream. The control sample (I_0) showed highest value for (0.213%) while the treatment M_1I_4 shown to have least value of titrable acidity. The control found at par with M_1I_1 and M_1I_2 and statistically significant over M_1I_3 and M_1I_4. The pH of different treatment was ranged from 6.32 to 6.50. Decreased acidity and increased pH value could be attributed to the nature of composition of EMS that showed a tendency to increase the pH value of the resultant ice cream. Similar results were reported by Salem *et al*., (2016) [19]. According to Yilsay *et al.*, (2005) [23] acidity and pH are related to the composition of the ice cream mix – an increase in MSNF raises acidity and lowers pH.

Conclusion

It could be concluded that use of enzyme modified sweet potato starch can be well utilized in formulation of ice cream as a fat replacer. Study revealed that ice cream sample M_1I_2 containing 20% sweet potato in which fat was reduced by 20 per cent enzyme modified starch was oraganoleptically acceptable

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