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STABILITY AND SENSORY EVALUATION OF ICE CREAM PREPARED WITH ACETYLATED CASSAVA STARCHES

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ABSTRACT

The rheological behaviour of stabilizers contribute to good sensory attributes of ice creams. This study therefore investigated the rheological and stability of the ice cream formulated from acetylated cassava starches. Three varieties of cassava (TME 419, TMS 98/0505 and TMS 98/0581) were processed into native starches which were acetylated at substitution levels of 10, 15, 20, 25 and 30%. Ice cream produced with the native and acetylated starches was analyzed for percentage overrun, foam stability, melt down rate sensory attributes (colour, taste, creaminess, mouth feel and appearance) and consumer preference. Statistically significant difference in all the data were determined by Analysis of Variance (ANOVA) while Least Significant Difference (LSD) were used to separate the means. The percentage overrun ranged between 66.44 and 126.40, the foam stability ranged from 97.48 to 99.39%. The melt down resistance of the ice cream samples decreased with increase in the concentration of acetylation. The mean sensory scores of colour for the ice cream made with native and acetylated starches ranged between (2.80 – 2.90) and (2.92 – 304) respectively. The mean sensory scores for consumer preference ranged between 6.20 and 7.06. These results are indicators to good stabilizing effect of acetylated cassava starches in ice cream formulations.

Keywords: Acetylation, Cassava starch, Stabilizer, Ice cream, Sensory properties.

INTRODUCTION

Ice cream is a dairy food product which is whipped in order to add air bubbles into it and it contains air bubbles or foams dispersing in the unfrozen phase which contribute to a soft texture, light body and retardation of melting (Sofjan and Hartel, 2004). It is a three component foam made up of a network of fat globules and ice crystals dispersed in a high viscosity aqueous phase (SilvaJunior and SilvaLAnnes, 2011). Ice cream is the most popular frozen desert all over the globe and it is a combination of milk, sweetener, stabilizer, emulsifier and flavouring agents, egg products, colouring additives and hydrolyzed products of starch (Alizadeh *et al*., 2014). A typical compositional range for the components used in ice cream mix, according to Murtaza *et al*. (2004), is milk fat (10 – 16%), milk solids non-fat

(9 – 12%), sucrose (9 -12%), corn syrup solids (4 - 6%), stabilizer/emulsifier (0.1 – 0.5%), total solids (3.6 – 4.5%) and water (55 – 64%).

Stabilizers are group of ingredients (usually polysaccharides) commonly used in ice cream formulation. They perform several functions in ice cream such as increasing the viscosity of the continuous phase thereby contributing to the eating qualities like body and creaminess. They regulate the development of crystals; promote smooth texture (Alkali *et al*., 2009). Stabilizers are added in ice cream to increase the viscosity of the mix, to improve air incorporation, air cell distribution, body and texture, storage stability and melting properties.

Stabilizers also minimize the development of large crystals and ultimately enhance desired finished structure in ice cream (Murtaza *et al*., 2004). Stabilizers used in ice cream are normally polysaccharide gums, which serve to enhance viscosity in the ice cream mix and in the unfrozen phase of the ice cream following frozen process. They contribute to ice cream structure and alter textural characteristics (Thaiudon and Goff, 2003). Examples of stabilizers mostly used in ice cream production are locust bean gum (LBG), guar gum, carrageenan and other commercial stabilizers that contain a mix of gums and emulsifiers (Thaiudon *et al*., 2008). Using stabilizer replacers such as modified tapioca starch does not only lower the cost but also result in better texture and lower melting point since they have been proven to inhibit freeze thawing (Raina *et al*., 2006).

The rheological behaviours of stabilizers and ice creams contribute to good sensory qualities including mouth feel, hence, the ice-cream manufacturers use blends of stabilizers to achieve the desired characteristics. Emulsifiers are sometimes integrated with the stabilizers in blends but their functions and actions are different from stabilizers. They are used to improve whipping quality of the mix, produce a drier ice cream, provide smooth body texture in finished product and produce a product with good stand up properties and melt resistance (Murtaza *et al*., 2004).

The stabilizers are hydrated and are dispersed in water to reduce the amount of free water in the ice cream mix. The main functions of the stabilizers could be summarized as increasing mix viscosity, preventing syneresis, improving whipping properties, preventing ice crystal formation, improving texture and melting resistance and regulating sensory properties (Ludvigse, 2011). Stabilizers are added to ice cream to hinder the recrystallization phenomena, to increase the viscosity of the ice cream mix and to improve the texture and mouth-feel and to enhance the shape retention of ice cream blocks (Marshell *et al*., 2003).

Various hydrocolloids, such as guar gum, carboxymethyl cellulose, locust bean gum, carrageenan and xanthan gum have been used as ice cream stabilizers with each stabilizer and blends exhibiting unique functional properties. (Soukoulis *et al*., 2008; BaharamParvar *et al*., 2010). Ice cream and related products are generally aerated and characterized as frozen foams. The gas phase volume varies greatly from a minimum of 10 – 15% to a maximum of 50% (Goff, 2002). Air is an important component of ice cream and affects the physical and sensory properties as well as storage stability. If low amount of air is applied, the resulting ice cream is dense, heavy and cold eating; on the other hand, if a higher amount of air is used, the texture is lighter, creamier and warm eating (Ludvigse, 2011). The higher the overrun, the softer the ice cream resulting in a higher profit. However, higher overrun with many small air bubbles may cause a fluffy texture which is less acceptable to consumers (Marshell *et al*., 2003).

In the report of Alakali *et al*. (2009), the overrun of ice cream increased from 20% to between 21 and 25% on addition of food binders at different concentrations. Moeenfard and Tehrani (2008), in their report on the study of the effect of some stabilizers on the physicochemical and sensory properties of ice cream type frozen yogurt, observed an overrun value in samples with range of 41.02 to 47.14%. In the study carried out by Thaiudom *et al*. (2008), there was no significant difference in the overrun values of ice cream containing commercial stabilizers and modified tapioca starches whereas ice cream containing acetylated starches showed the least overrun. In the study of Alizaddeh *et al*., (2014), it was reported that ice creams with high sucrose have relatively lower overrun. Murtaza *et al*. (2004) also reported that the percentage overrun was significantly affected in ice cream mixes having different stabilizer/emulsifier blends.

The physical structure of ice cream affects its melting rate (Muse and Hartel, 2004) and to improve this, stabilizers are added (Murtaza *et al*., 2004). As the ice cream melts, heat transfers from the warm air surrounding the product into the ice cream to melt the ice crystals. The melt down rate of ice cream is affected by many factors including the amount of air incorporated, the nature of the ice crystals and the network of fat globules during freezing. It has been reported that ice creams with low overruns melted quickly whereas ice creams with high overruns melted slowly (Muse and Hartel, 2004) and had a good melting resistance.

In the report of Choo *et al*. (2010), it was observed from the meltdown curves that ice cream containing virgin coconut oil at 4 and 8% had low melting rate at the beginning of time. Garti and Sato (2001) also mentioned that melting resistance of ice cream produced from mix made with different fat decreased in the order of cream, vegetable fat and butter. Murtaza *et al*. (2004) reported that melt down was significantly affected in ice cream mixes containing different stabilizer/emulsifier blends. In the report of Alizadeh *et al*. (2014), the ice cream melting rate showed an increasing trend in proportional to amount of used stevia while ice creams with high overruns melted slowly due to reduced rate of heat transfer (Sofjan and Hartel, 2004) Ice cream industries are using stabilizers/emulsifier blends which are imported and very costly This implies drain on foreign earning (Murtazal *et al*. 2004; Choo *et al*., 2010). This study, therefore, investigated the possibility of using a local stabilizer like acetylated starch in the ice cream industry.

MATERIALS AND METHODS

Acetylation of the native starch

Acetylation was done according to the method of Iheagwara (2012) with slight modification. One hundred gram of starch was dispersed in 500 ml of distilled water and stirred for 20 min. The pH was adjusted to 8.0 using 3% NaOH. Acetic anhydride (10, 15, 20, 25 and 30 g) was added slowly to the mixture (to obtain 10, 15, 20, 25 and 30% concentration respectively) while maintaining a pH range of 8.0 – 8.5. The reaction was allowed to proceed for 5 min after the addition of the acetic anhydride. The pH of the slurry was adjusted to 4.5 using 10% HCl. The starch was filtered and washed four times with water and dried in cabinet dryer at 40 ±2 ^{o}C for 48 h. The acetylated starch was packaged in high density polyethylene bag and kept until required for ice cream production and laboratory analyses.

Production of ice cream from native and acetylated starches

Ice cream was produced according to the method of Choo *et al.* (2010) and Seidu (2009). The ice cream mix contained a mixture of about 400 ml water, 800 g milk solid non-fat (MSNF), 300 g sugar, 150 g egg white, 0.5 ml flavor and 0.25 g acetylated starch prepared from TME 419, TMS 98/0505 and TMS 98/0581 varieties. The product was pasterurized and homogenized at 71 ^{o}C for 30 min and thereafter cooled to 44 ^{o}C. The mixture was allowed to age at 4.4 ^{o}C for 3 – 4 h to freeze. The product was packaged in plastic containers pending analysis and sensory evaluation.

Determination of percentage (%) overruns

The percentage overrun of the ice cream was determined according the method of Hui *et al.* (2004). Ice cream (30 g) was whipped in a domestic mixer (model: bowl and stand mixer HM 430, Kenwood, China) for 5 min and the weight of the mix recorded and the percentage added air to the product was used in calculating the overrun as shown in equation 1

$$\text{Percentage overrun} = \frac{W_2 - W_1}{W_1} X\,100 \qquad (1)$$

Where: W_1 = weight of unit value of ice cream (g)
W_2 = weight of unit volume of mix (g)

Determination of foam stability

The foam stability of the ice cream was determined according to the method of Alakali *et al*. (2009). About 200 ml of the ice cream mix was blended for 2 min in a domestic blender (Marlex, Excella model, Kanchan International Limited, Daman, India). The mix was poured into 250 ml graduated cylinder and the volume of foam produced recorded as V_1. After 5 s the final volume (V_2) of the foam was measured and the percentage foam stability expressed as in equation 2.

$$\text{Foam stability} = \frac{V_1 - V_2}{V_1} X\,100 \qquad (2)$$

V_1 = Initial volume (ml)
V_2 = Final volume (ml)

Determination of meltdown rate

The meltdown rate of the ice cream was determined according to the method of Alakali *et al*. (2009) with slight modification. The ice cream (30 g) was placed on 1 mm stainless-steel mesh put on a beaker. The dripped weight was taken for 45 min every 5 min. the data was used to determine the melting rate according to equation 3

$$\text{Meltdown rate} = \frac{\text{wt}}{\text{s}} \qquad (3)$$

wt = weight of dripped ice cream (g)
s = time in min

Determination of sensory attributes of ice cream

Sensory evaluation of the ice cream was done according the method of Alakali *et al*. (2009) with slight modification. Twenty five semi-trained panelists evaluated the samples using descriptive method after 24 h of refrigeration storage to select the best two ice cream from each of the varieties. The selected best samples were left to attain a temperature of 8±2 °C before evaluation of the attributes of colour, taste, aroma, mouthfeel and preference scores on a 7-point hedonic scale (7 = like mostly, 6 = like moderately, 5 = like slightly, 4 = neither like nor dislike, 3 = dislike slightly, 2 = dislike moderately, 1 = dislike mostly).

Statistical analysis

Data generated in three replicates were analyzed statistically with the Statistical Analysis Systems (SAS) package (version 8.2 of SAS institute Inc, 1999). Statistically significant differences ($p<0.05$) in all data were determined by Analysis of Variance (ANOVA) procedure while Least Significant Difference (LSD) were used to separate the means. Correlation coefficient between variables was obtained using Pearson correlation coefficient analysis.

RESULTS

Effect of Concentration and Variety on the Rheological Properties of Ice-cream Prepared with Acetylated Cassava Starch

The results of the effect of concentration and variety on the rheological properties of ice cream prepared with acetylated cassava starch from TME 419, TMS 98/0505 and TMS 98/0581 are presented in Tables 1, 2 and 3 respectively.

Percentage overrun of ice-cream

The values of overrun of ice cream as presented in Tables 1 to 3 ranged between 66.44% and 126.40%. Ice-cream prepared with acetylated starch from TMS 98/0505 at 15% concentration had the lowest value (66.44%) while ice-cream prepared with acetylated starch from TME 419 at 10% concentration had the highest value (126.44%). In the samples from TME 419 and TMS 98/0505, significantly (p<0.05) low overrun values were noted with increased acetylation from 10 to 20% and 10 to 15%, respectively whereas, in TMS 98/0581, significantly (p<0.05) high values were noted with increased concentration of acetic anhydride.

Table 1: Rheological properties of ice-cream prepared with acetylated cassava starch from TME 419 as affected by concentration of acetic anhydride

Sample	Percentage overrun	Foam stability (%)
10%	126.40a	98.62a
20%	67.02b	97.48b

Mean values with the same letters within the same columns are not significantly (p>0.05) different.

Table 2: Rheological properties of ice-cream prepared with acetylated cassava starch from TMS 98/0505 as affected by concentration of acetic anhydride

Sample	Percentage overrun	Foam stability (%)
10%	101.22a	99.39a
15%	66.44b	98.99b

Mean values with the same letters within the same columns are not significantly (p>0.05) different.

Table 3: Rheological properties of ice-cream prepared with acetylated cassava starch from TMS 98/0581 as affected by concentration of acetic anhydride

Sample	Percentage overrun	Foam stability (%)
10%	67.41b	99.11a
20%	101.48b	98.73b

Mean values with the same letters within the same columns are not significantly (p>0.05) different.

Foam stability of ice-cream.

The values of foam stability (Tables 1 to 3) ranged between 97.48% and 99.39%. The highest value was observed in the ice-cream prepared with starch acetate from TMS 98/0505 at 10% concentration while the lowest value was recorded for ice-cream prepared with starch acetate from TME 419 at 20% concentration. In all the varieties, increased concentration significantly (p<0.05) reduced foam stability of ice-creams.

Melt down rate/resistance of ice-cream

The results of the melt down rate/resistance are shown in Figures 1, 2 and 3 for ice cream prepared with acetylated starches from TME 419, TMS 98/0505 and TMS 98/0581, respectively. Concentration of acetylation had significant (p<0.05) effect on melting resistance. Results showed that in all the varieties, as the degree of acetylation increased, melting resistance reduced significantly. In essence, the highest melting resistance was obtained for ice cream samples prepared with acetylated starches of 10% acetylation.

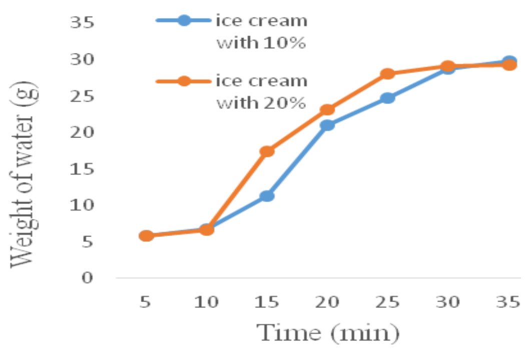

Figure 1: Melt down rate/resistance of ice cream prepared with acetylated starch from TME 419

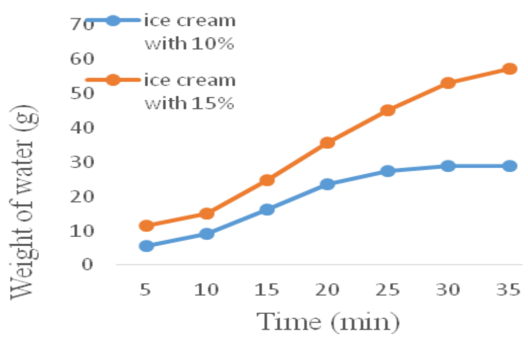

Figure 2: Melt down rate/resistance of ice cream prepared with acetylated starch from TMS 98/0505

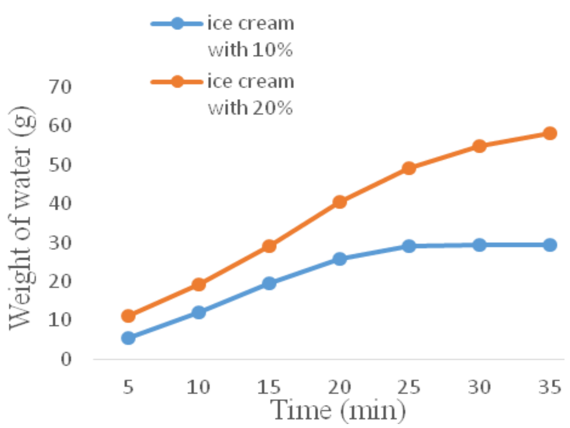

Figure 3: Melt down rate/resistance of ice cream prepared with acetylated starch from TMS 98/0581

Sensory Characteristics of Ice Cream Prepared with Acetylated Cassava Starch as Influenced by Concentration and Variety

Screening result of ice cream using descriptive method

Tables 4 to 6 present the mean sensory scores for colour, taste, creaminess, firmness, mouth feel and appearance attributes of ice cream prepared with acetylated cassava starch of different concentrations and varieties. In all the varieties, the mean sensory scores of colour from the samples prepared with native starches (2.80 to 2.90) were lower than the scores obtained for samples prepared with acetylated starches (2.92 to 3.04). However, statistically, there was no significant ($p>0.05$) difference among the mean scores.

Mean values with the same letters within the same columns are not significantly ($p>0.05$) different.

Consumer preference outcome

Mean sensory scores of consumer preference outcome are presented in Tables 7 to 9. The mean colour scores for TME 419 ranged between 6.20 and 6.53, in TMS 98/0505, the scores ranged between 6.20 and 6.40 while the range in TMS 98/0581 was 6.56 to 7.06. The mean scores of commercial ice cream and samples prepared with acetylated starches did not differ significantly ($p>0.05$). However, the highest scores were awarded to the commercial ice cream in all the varieties except in TMS 98/0581 where sample prepared with 15% acetylated starch was awarded the highest score.

The taste score in TME 419 ranged between 5.66 and 6.46, while it ranged between 5.73 and 5.86 in TMS98/0505 and 5.60 to 6.35 in TMS 98/0581. The mean taste score in the control sample was significantly ($p<0.05$) higher than the samples prepared with acetylated starches in all the varieties. The scores for aroma in all the samples were not significantly ($p>0.05$) different. It was also observed that there was no significant (*p*>0.05) difference in mouthfeel and overall acceptability among the samples.

DISCUSSION

All the values of percentage overrun obtained in this study were higher than values reported for carboxymethyl cellulose (CMC) commonly used as commercial stabilizers (Alakali *et al*., 2009). The volume of air in ice-cream relates to the overrun which is normally reported in percentage (Marshell *et al*., 2003). The higher the overrun, the softer the ice-cream, resulting in a higher profit. The results obtained for foam stability showed that ice-creams prepared with starch acetated from TMS 98/0505 at 10% concentration was the most stable. This might be attributed to the fact that acetylation significantly ($p<0.05$) reduced peak viscosities of the starches.

Table 4: Sensory attributes of ice-cream prepared with acetylated cassava starch from TME 419 as affected by concentration

Sample (ice cream with)	Colour	Taste	Creaminess	Firmness	Mouthfeel	Appearance
Native	2.90a	5.00a	1.28a	3.44a	3.60a	2.56a
10%	3.00a	4.80a	1.32a	3.20a	3.60a	2.76a
15%	2.92a	4.92a	1.36a	3.16a	3.24a	2.72a
20%	2.88a	4.92a	1.48a	3.52a	3.60a	2.60a

Mean values with the same letters within the same columns are not significantly (*p*>0.05) different.

Table 5: Sensory attributes of ice-cream prepared with acetylated cassava starch from TMS 98/0505 as affected by concentration

Sample (ice cream with)	Colour	Taste	Creaminess	Firmness	Mouthfeel	Appearance
Native	2.86 a	4.68 c	1.48 a	3.08 a	3.60 a	2.60 a
10%	2.96 a	7.76 a	1.32 a	3.24 a	3.72 a	2.64 a
15%	3.04 a	5.00 b	1.32 a	3.08 a	3.64 a	2.76 a
20%	3.00 a	4.64 c	1.32 a	3.16 a	3.40 a	2.28 a

Mean values with the same letters within the same columns are not significantly (*p*>0.05) different.

Table 6: Sensory attributes of ice-cream prepared with acetylated cassava starch from TMS 98/0581 as affected by concentration

Sample concentration	Colour	Taste	Creaminess	Firmness	Mouthfeel	Appearance
Native	2.80 a	4.84 a	1.44 a	3.32 a	3.80 a	2.56 a
10%	2.92 a	4.76 a	1.32 a	3.16 a	3.56 a	2.52 a
15%	3.04 a	4.84 a	1.44 a	3.24 a	3.24 a	2.60 a
20%	3.00 a	4.64 a	1.52 a	3.36 a	3.72 a	2.20 a

Mean values with the same letters within the same columns are not significantly (*p*>0.05) different.

Table 7: Consumer preference of ice-cream prepared with acetylated cassava starch from TME 419 as affected by concentration

Sample	Colour	Taste	Aroma	Mouthfeel	Overall acceptability
Commercial ice cream	6.70a	7.40a	6.40a	5.73a	6.40a
Ice cream with10%	6.53a	5.66c	6.60a	5.40a	6.00a
Ice cream with 15%	6.20a	6.46b	6.23a	5.93a	6.20a
		=			

Mean values with the same letters within the same columns are not significantly (p>0.05) different.

Table 8: Consumer preference of ice-cream prepared with acetylated cassava starch from TMS98/0505 as affected by concentration

Sample	Colour	Taste	Aroma	Mouthfeel	Overall acceptability
Commercial ice cream	6.70a	7.40a	6.40a	5.73a	6.40a
Ice cream with 10%	6.20a	5.73b	6.73a	6.13a	6.07a
Ice cream with 15%	6.40a	5.86b	6.33a	6.13a	6.53a

Mean values with the same letters within the same columns are not significantly (p>0.05) different.

Table 9: Consumer preference of ice-cream prepared with acetylated cassava starch from TMS 98/0581 as affected by concentration

Sample	Colour	Taste	Aroma	Mouthfeel	Overall acceptability
Commercial ice cream	6.70a	7.40a	6.40a	5.73a	6.40a
Ice cream with10%	6.56a	6.33b	6.20a	6.60a	6.27a
Ice cream with 15%	7.06a	5.60c	6.67a	6.06a	6.40a

Mean values with the same letters within the same columns are not significantly (p>0.05) different.

This is a confirmation of the report of Thaiudom *et al*. (2008) that stabilizers with higher viscosities will give ice-creams with more foam stability.

Figures 1 to 3 show the results of the melt down rate/resistance. All the samples melted slowly in the first 10 min but melting rate increased thereafter. There was direct correlation between results of the melting resistance and percentage overrun as increase in overrun enhances melting resistance. The melting resistance of ice cream is affected by many factors, including the amount of air incorporated. This result agrees with earlier report that ice cream with lower overruns melted quickly while those with high overruns began to melt slowly and had a good melting resistance (Moeenfard and Tehrani, 2008).

From Tables 4 to 6. It was observed that all the samples were formulated to have equal level of taste and creaminess, hence, there was no significant (p>0.05) difference in the taste and creaminess of the samples. The highest intensity of smoothness was recorded for samples prepared with 10 and 20% starch acetate in TME 419, 10 and 15% in TMS 98/0505, 10 and 20% in TMS 98/0581. These samples were selected from the varieties as the best after the descriptive test for further investigation in consumer preference evaluation. Selection is mainly based on texture attributes like smoothness (Choo *et al*., 2010).

CONCLUSION

The results from this study revealed that there was reduction in overrun and foam stability of ice cream prepared with acetylated starches with increased concentration while there was no significant difference in the consumer preference between commercial ice cream and formulated ice cream as these are indicators to good stabilizer effect of acetylated starches and could, therefore, be concluded that acetylation would improve the characteristics of cassava starch when utilized as a stabilizer in ice cream formulations and acetylated cassava starch at 10% concentration of acetic anhydride could be utilized as stabilizer in ice cream production.

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