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Effect Of Partial Acid Hydrolysed and Heat Moisture Treated Starches on the Quality of Low- Fat Ice Cream

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ABSTRACT
In the present study, we investigated the impact of partial acid hydrolyzed and heat moisture treatment ofsorghum starchon the quality indices of low-fat ice cream. Starch was extracted from sorghum and the purity checked. The native starch was subjected to modification conditions: heat moisture treatment of 20% moisture at 90^0C temperature (HMT_1); heat moisture treatment of 20% moisture at 110^0C temperature (HMT_2); heat moisture treatment of 30% moisture at 90^0C temperature (HMT_3) heat moisture treatment of 30% moisture at 110^0C temperature (HMT_4); partial acid hydrolysis in succession with heat moisture treatment of 20% moisture at 90^0C temperature (PAH – HMT_1); partial acid hydrolysis in succession with heat moisture treatment of 20% moisture at 110^0C temperature (PAH – HMT_2); partial acid hydrolysis in succession with heat moisture treatment of 30% moisture at 90^0C temperature (PAH – HMT_3); partial acid hydrolysis in succession with heat moisture treatment of 30% moisture at 110^0C temperature (PAH – HMT_4); and partial acid hydrolysis (PAH). The modified starches and the native forms were first evaluated for pasting and functional properties using standard laboratory recommended methods. Low fatice cream was produced usingthe native and modified starches. The ice cream samples were subjected to acceptability test using 9-Point hedonic scale. Commercial ice cream was used as control. The data generated were statistically analyzed. The pasting properties of Sorghum starch samples ranged from: Peak viscosity, 18-442 RVU; Trough viscosity, 1.0-296RVU; Breakdown value, 2.0-146RVU; Final viscosity, 27-512; Setback value, 13-216RVU; Pasting time, 4.8-5.13min and Pasting temperature, 0.00-95.00^0C. The functional properties ranged from: Bulk Density, 0.67-0.89g/m Water Absorption Capacity, 127-176%; Oil Absorption capacity, 60.90-73.20% Swelling Power, 2.20-3.40g/g and Solubility Index, 5.41-8.59%. The mean scores of the ice cream ranged from: Taste, 6.30 to 8.35; Color, 6.55 to 7.80; Meltdown, 3.70 to 7.75; Flavor, 6.55 to 7.68; Texture, 6.30 to 7.58; and Overall acceptability 6.15 to 7.85.Modification measures applied improved the pasting attributes of the sorghum starch coupled with lesser tendency for syneresis and weeping during cooling of the paste. Water and oil absorption capacities of the starch were significantly improved. Thus, ensures the usefulness of the starch performance in product development. Finding shows that fat can be replaced with 15% modified sorghum starch in ice cream making.

Keywords: Partial acid hydrolysis, Heat moisture treatment, Starch Quality, Low- fat ice cream

I. INTRODUCTION

Globally, sorghum is one of the most important cereal crops and is a rich source of starch (approximately 70%), making it an ideal raw material for various applications in industries. (Singh et al., 2011). Sorghum has great drought-tolerance, thus playing a critical role for food security in some semiarid areas of Asia, Africa, and Latin America. The nutritional properties of sorghum are unique and variety dependent. Sorghum is gluten-free, thus can be consumed by people with celiac disease. They form the major source of carbohydrates in human diet and are therefore of great economic importance. In food industries, it is used as an additive or as main ingredient. When used as an additive, it acts as thickener as well as stabilizer and modifies the textural properties of food (Eliasson and Gudmundsson, 2006). However, in its native form, it

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has limited application as food ingredient due to its inability to withstand extreme shear forces, high temperature and elevated pH. In addition, starches in their native form have strong retrogradation and decomposition tendency (Berski, et al., 2011). Also, some starch granules are inert, insoluble in water at room temperature, highly resistant to enzymatic hydrolysis and consequently lacking in functional properties, as a result, native starches are often modified to develop specific properties such as solubility, texture, adhesion and tolerance to the heating temperatures used in industrial processes to the heating temperatures used in industrial processes (Singh et al., 2007; Sweedmanet al., 2013).

Several methods have been developed to produce modified starches with a variety of characteristics and applications, making it highly flexible and changing its physicochemical properties and structural to increase its value for food and non-food industries (Lopez et al., 2010). Chemical and physical modifications are commonly used to produce starches with special properties(Qingjieet al., 2013).Acid modification changes the physicochemical propertiesof starch without destroying its granule structure. Acid modification also increases solubility and gelstrength and decreases viscosity of starches.Heat moisture treatment (HMT) is another important physical treatment employed for enhancing the functional properties of native starch. During HMT, starch granules are subjected to low moisture levels (<35 % moisture w/w) for a period of time, usually between 15 min and 16 hours at temperatures above the glass transition temperature (Tg), but below gelatinization temperature (Gunaratne and Hoover 2002).

Studies involving the use of acid hydrolysis and HMT for starch modifications have been reported and documented. However, combined effects of Partial acid hydrolysis (PAH) and HMT on the various attributes of starch has not been fully elucidated. In our present study, we utilize PAH and HMT to modify sorghum starch with a view to widen its industrial application as fat replacer in ice cream making.The process is economical and judiciously use locally available and underutilized crops as proposed in this present work. The overall objective of this research work is to establish the effect of partial acid hydrolysis in succession with heat moisture treatment on the pasting and functional characteristics of sorghum, starch with the view to incorporate the starches as ingredient in fat free icecream.

II. MATERIALS AND METHOD

Material

Sorghum used was purchased from Lafenwa market in Abeokuta, Ogun State and it was stored at room temperature in a sack. All chemicals used in the analysis were of analytical grade.

Extraction of Starch from Grains

Starch extraction was performed according to the method of Singh et al., (2007). Firstly, the grain was wet milled into a smooth paste and filtered using muslin cloth and allowed to sediment. Thereafter, the mixture was dewatered and starch was washed three times. The resulting starch cake was spread on trays and dried using a cabinet dryer for 48 hrs at 40 °C. The dried starch samples were milled with blender and sieved through 100pm sifter, packaged in high density polyethylene bags and stored at 4 °C for further analysis.

Preparation of partial acid hydrolyzed Starch

The method of Kaur et al. (2011) was employed with slight minor modification. Approximately 2kg of the native starch each of the cereal was weighed and dissolved in 0.1N solution of dilute HCl in a bowl. Acid solution (0.1 N HCl) was prepared by adding 356 mL of HCL to 4000 mL distilled water. The solution was stirred into conical flasks and placed in water bath at the temperature of 35 ^{0}C for 8hrs. During this period, the starch had settled and the supernatant was decanted. The collected starch was washed with distilled water six times consecutively and the thereafter washed with 80% ethanol which was prepared by diluting 80ml of ethanol into 20ml of distilled water. The pH of the starch was checked and re-adjusted to pH 7 (neutral). In order to adjust the pH of the medium, 1.0 N solution of NaOH was prepared by dissolving 4g of NaOH pellets into 100mL of distilled water. The supernatant was then decanted and then settled starch was poured on a foil paper and dried using a cabinet dryer at 45^{0}C to moisture content less than 10%. The dried starch was then milled. 250g of the starch was set aside for analysis while 1kg of the partial acid hydrolyzed starch was used for the heat moisture processing.

Preparation of Acid hydrolyzed Starch in combination with Heat Moisture Treated Starch

The method of Senanayake et al. (2013), with minor modification was used for the preparation of heat moisture treated starch.1kg of the previously hydrolyzed starch was weighed and divided into four portions (250g each) and poured into four polyethylene (Ziploc) bags. The moisture content of

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the starch was determined and used to calculate the percentage of water that would be required to increase the moisture content of the starch to 20% and 30% respectively. The wet starch was equilibrated in the polyethylene bags to allow even distribution of water to every starch granule. This was done for 24hrs. The well equilibrated starches were poured into Duran bottles and pressed with spatula to ensure there is no air space within the starch granules till the bottle is filled to the brim (for bottles that are not filled up, cotton wool was used to stuff it up till it was air tight and covered up). The four Duran bottles were labeled according to the percentage of starch moisture and temperature to be used i.e. 20% moisture at 90 ^{0}C, 30% moisture at 90 ^{0}C and 20% moisture at 110 ^{0}C, 30% moisture at 110 ^{0}C. The lid, body and bottom of the bottles were also labeled accordingly. The filled Duran bottles were then placed in ovens at 90 ^{0}C and 110 ^{0}C respectively for 6hrs. Afterwards the bottles were removed from the oven. The starch was forced out of the bottles and spread on foil and then allowed to cool in desiccators. The moisture content was determined using oven drying method. Thereafter, the starch was dried in a cabinet dryer at 50 ^{0}C for 24hrs. The dried starch was milled using a blender to achieve a finer texture, and packaged in polyethylene bags for necessary analysis.

Analysis of pasting properties of the samples

Pasting properties of the starch samples were determined using Rapid ViscoAnalyser (RVA Techmaster, Newport Scientific Pty Limited, Warriewood, Australia). Briefly,3 g of the starch sample was mixed with 25 mL of distilled water inside the RVA test canister and this was lowered into the RVA system. The slurry was heated from 50 to 95°C and cooled back to 50°C within 12 min, rotating the can at a speed of 160 rpm with continuous stirring of the content with a plastic paddle. The parameters measured were peak viscosity, trough, breakdown viscosity, setback viscosity, final viscosity, pasting temperature and time (Newport Scientific, 1998).

Analysis of the functional properties and proximate composition of the samples

Bulk density of the starch samples was determined using the method described by Mpotokwaneet al. (2008), water oil absorption capacity as described by Sathe and Salunkhe (1981), swelling power and solubility index as described (Leach et al., 1957) and dispersibility as described by Kulkarni and Ingle (1991).

Sensory evaluation

The sensory evaluation of the ice cream was determined using the method of Herald et al., (2008) through the judgement of 18 trained panelists. Ice cream samples were taken out from frozen storage (-18°C) after 24 hours past of hardening and randomly offered to the panelists. The samples were coded with three-digit random numbers in odourless plastic cups with all the orders of serving completely randomized. A 9-point hedonic scale was employed to determine the degree of liking of the product (9 = extreme like, 5 = neither like nor dislike, 1 = extreme like) the sample were rated for colour and appearance, flavor / taste, body / texture and overall acceptability.

Statistical analysis

All analysis was conducted in triplicate and results expressed as the mean ± standard deviation. Statistical analysis wascarried out using one-way analysis of variance (ANOVA) with IBM SPSS 21.0 version (Michigan State University, East Lansing, MI).Duncan's multiple range test was used for mean separation.

III. RESULTS AND DISCUSSION

Pasting properties of the modified and native Sorghum starches

Pasting properties are determined to give a picture of functional behavior of starch during heating and cooling period (Bello – Perez and Paredez-Lop, 2000). Peak viscosity is the maximum viscosity attained by gelatinized starch during heating in water (Shimeliset al., 2006). It indicates the water binding capacity of the starch granule (Shimeliset al., 2006). The modified peak viscosity of the starches ranged from 18 to 281 and that of native was 442 RVU (Table 1). There were significant ($p<0.05$) difference in the starch samples (Table 1). Hamit et al. (2007) reported that the decrease in viscosity value might be due to reduced molecular weight caused by acid hydrolysis. On the contrary Adebowale et al. (2005) in their own report says the decrease in peak viscosity may be attributed to increased molecular binding forces in the starch chains. Apparent reduction in the peak viscosity of the sorghum starch due to modification may ensure the usefulness of the starch performance in product development (Rosidaet al., 2017).

Trough value also known as holding strength is the ability of granules to remain undisrupted when the starch is subjected to a period of constant high temperature and mechanical shear (Olatundeet al., 2017). The trough value ranged from

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1.0 to 296 RVU (Table 1). There were significant among the starch samples (Table 1). Modification applied significantly (P<0.05) reduced the value (Table 3). The decrease in the modified starch samples are in agreement with the report of Qingjiet al. (2013) who reported treated starch samples were lower in trough than those of native starch.

Breakdown value (BD) is a measure of fragility of starch (Colladeet al., 2001). The breakdown value ranged from 2.0 to 146RVU (table 1). There were significant differences (p<0.05) among the starch samples (Table 1). The reduction in these values is in agreement with the report of Qingjieet al. (2013) who reported that reduction of the breakdown value caused by acid hydrolysis and heat moisture treatment show that starches are more stable during continuous heating and shearing. However,Awoluet al. (2017) earlier reported that starch with lower breakdown value has higher capacity to withstand heating and shearing during cooking. In this instant modification greatly and significantly (p<0.05) reduced the breakdown value of the modified sorghum starch as recorded (Table 1). This finding is not in accordance with the report of Olatundeet al. (2017) which viscosity of banana starch. This result has shown that product with low level of breakdown viscosity have the tendency for better resistance to heating and shear- thinning (Adenijiet al., 2010).

Final viscosity (FV) indicates the ability of starch to foam paste or gel after cooking (Ikegwuet al., 2010). It is also the most commonly used parameter to determine a particular starch – based sample quality (Sanniet al., 2006). The final viscosity of the starch ranged between 27 to 512 RVU (Table 1). There were significant differences among the starch samples (Table 1). Final viscosity of the sorghum starch was apparently reduced except for HMTd and PAH (Table 1). The high value in HMTd (228) and PAH (311) is in line with the report of Awolu and Olafinlade (2016) who reported that modification using acetylation and oxidation increased final viscosity of native water yam starch while acid thinning reduced the final viscosity Zhang et al. (2011) earlier reported that a high final viscosity of starch indicated that the paste is more resistant to mechanical shear and may easily foam a more rigid gel Zhang and Hamaker (2008) reported that the difference in the final viscosity may be due to inherent difference in structure of starch molecule, as well as different degree of interaction between starch and its associate compound. A high final viscosity is desirable in many foods products (soups, sauces and dressing); they can be utilized in wet stage production of paper and textile industry where high viscosity is required (Moorthy, 2002).

Setback value is a measure of re-crystallization of gelatinized starch during cooking (Ashogbon and Akintayo, 2012). The setback value of modified starch ranged between 6 to 138 while that of native was 216 RVU (Table 1). There were significant differences (p<0.05) among the starch samples. Modification significantly (p<0.05) reduced the setback value of sorghum starch (Table 1). This present report is disagreement with that of Oduro et al. (2012) who report that the lower setback value indicates higher potential retrogradation tendency of starch. The reduced setback value of the sorghum starch in this research equally ensure its reduced retrogradation tendency in foods. Setback value shows the viscosity of cooked paste after cooking at 50^0C while higher setback value is associated with cohesiveness (Raphealet al., 2011). The workers further reported that high setback viscosity limits the use of starch in food industry.

Peak time or pasting time is the measure of cooking time (Adebowale et al., 2005). The pasting time is an indication that the product is easy to cook. The pasting time of the modified starches ranged from 4.8 to 6.0min whereas the native was recorded for 5.13min (Table 1). There were significant differences (p<0.05) among the starch samples. Modification caused a bit reduction in the pasting time of sorghum starch in the measures of PAH-HMTa andHMTb. This result shows that modified sorghum starch required less time for cooking than the rest of the starch samples. This finding is in variation with that reported by Tijani et al. (2016) who reported that the native starch had the highest value of 4.60min, which suggest more processing time and cocoyam starch acetylated with $NaHCO_3$having the lowest value of 4.47mins.

Pasting temperature (PT) provides an indication of maximum temperature for sample cooking, energy cost involved and other component stability (Ikegwuet al., 2009). The pasting temperature ranged between 0.00 to 95.00min (table 3). There were significant differences between the starch samples (Table 1). The result has shown that sample HMTb, HMTd, PAH where not significantly difference (p<0.05) from the native counterpart. It is important to put on record that the rest starch samples recorded no pasting temperature. However, modification applied drastically reduced the pasting temperature (Table 1).

Functional properties of modified and native sorghum starches

According to Appiah et al. (2011), bulk density is a function of particles size, particle size being inversely proportion to bulk density. The bulk density of modified starches ranged from 0.67 to 0.89 and that of native is 0.71g/m. There was no significant differences ($p<0.05$) in the bulk density of all the starch samples (Table 2). This finding is in line with the report of Oladele and Aina. (2009) who reported that low bulk density of flour will be useful for food formation when used and such product have less retrogradation and that bulk density is a measure of heaviness of a flour sample. Low bulk density starches could provide smooth, texture that indicates fat absorption properties (Oladele and Aina, 2009).

Water absorption capacity represents the ability of a limited water condition (Ghadaet al., 2007). The water absorption capacity of the modified starch ranged from 133 to 176 and of which the native is recorded as 129% in (Table 2). There were significance differences ($P<0.05$) in all the starch samples. The water absorption of the sorghum starch increased significantly as a result of modification. Samples PAH have better water absorption capacity with the value of 176%. Higher water absorption capacity suggests weak association of amylase – amylopectin (Otegbayoet al., 2010) which allow permeability of water into the granule structure. Alimiet al. (2016b) reported that confectionaries and food ingredient such as thickeners will require starch with water absorption capacity is important in bulking and consistency of product as well as baking application. High water absorption capacity is attributed to lose structure of starch polymer which low value indicates the compactness of the structure (Adebowale et al., 2005). The difference in water absorption capacity of the material may be caused by difference in the level of binding of hydroxyl groups that forms hydrogen bonds and covalent bond between starch (Hoover and Sosulsk, 1986).

Oil absorption capacity index is attributed mainly to the physical entrapment of oils, it is an indication of the rate at which the protein binds to fat in food formulation (Singh et al., 2005). The oil absorption capacity for the modified starches ranged from 60.90 to 73.20 and of which the native starch is 62.70%. There were slight significance differences among all the starches. This present study is in line with the report of Awoluet al. (2017), in their research carried out on comparative analysis of functional pasting and morphological characteristic of native and modified tigernut starch with their blends in which their blends are native sweet potato starch, native tigernut starch, heat moisture treated tigernut starch and annealed tigernut starch. Oil absorption capacity is potentially useful in structural interaction in food especially in flavor retention, improvement in palatability and extension of shelf life particular in bakery and meat products where fat absorption is desired Veena and Usha (2018).

The swelling power and solubility index are usually used to assess the extent of interaction between starch chain within the amorphous and crystalline domains of the starch granule (Ratneyakeet al., 2002). The result (Table 2) showed that significant differences ($p< 0.05$) existed among the starch samples in terms of swelling power and the solubility index. The swelling power between 2.20 to 3.40g/g while the solubility index of the starch ranged from 5.41 to 8.59%. the value of native starch was 2.81 and 7.48 in (Table 2). Greater swelling power shows harmonious with higher solubility Kumoro et al. (2012). Flour which lower swelling power and solubility will caused the bakery product not to swell well (Henyet al., 2014). High swelling power suggests that flour could be useful in food system where swelling power is required Singh et al. (2005). HMTc and PAH-HMTd have a bit higher value of 3.40 and 3.11 respectively compared with other samples. Swelling behavior of cereal starch has primarily been reported that a property of their amylopectin contents, amylase acts as an inhibitor of swelling especially in the presence of lipid Tester and Morrison (1990).

Result of the solubility index has shown that modification bring about increasement on the sorghum starch. Partial acid hydrolysis in succession with heat moisture treatment samples of PAH-HMTa and PAH-HMTb have increased a bit higher than the rest of the modified samples. The differences in solubility could be attributed to different chain length distribution in the starch Bello-Perez et al. (2002). This finding is in line with the report of Bremiller (2011) who reported that modification of starches could bring about increased solubility of the starch. The findings of Bainbridge et al. (1996) says that good quality starch with a high starch content and paste viscosity will have low solubility and high swelling volume and swelling power. HMTd equally displayed better solubility value of 8.31%. The increase in heat moisture treated starch of this kind is in agreement with the report of Gunaratne and Hoover (2002) who observe the content of starch lipid complexes increase after heat moisture treatment. Kainuma and French (1971) also reported that the reduction in swelling power with acid treatment was the crystalline region of the starch.

Sensory Evaluation of theLow- Fat ice cream

Sensory evaluation is one of the main-factor that reveals customer demand and perception about the quality of the product (Emamiet al., 2008).In term of taste, the mean value of the ice cream samples ranged between 6.30 and 8.35 (Table 3). There were significant differences ($p<0.05$) among the ice cream samples (Table 3). Commercial ice cream had the highest mean value of 8.35 followed by low-fat ice cream of treatment PAH-HMTb with mean score of 8.00. Low-fat ice cream of PAH-HMTd had the least score of 6.30 (Table 3). Low-fat ice cream with treated sample of PAH-HMTb had higher mean value over the other samples aside from commercial ice cream/high fat ice cream. Ice cream of treatment PAH-HMTd was much preferred in terms of taste among the low-fat ice cream.The mean value of the ice cream samples in terms of color ranged between 6.55 and 7.80 (Table 3). There were significant differences ($p<0.05$) among the ice cream samples (Table 3). Acceptability of the low-fat ice cream in terms of color was the same as that of commercial ice cream/high ice cream. However, lowest mean value was recorded for ice cream with treatment PAH-HMTd. Commercial ice cream had the highest score of 7.80 followed by treatment HMTa (7.75) and HMTd (7.75). Ravindra (2017) earlier reported similar finding that varying level potato starch as fat replacer did not affect the color of reduced fat ice cream. The mean score of ice cream samples in terms of meltdown value ranged between 3.70 and 7.75 (Table 3). There were significant differences ($p<0.05$) in the meltdown of the ice cream samples. Ice cream with treatment PAH had the highest mean score of 7.75 followed by PAH-HMTd; 7.50 and treatment of HMTc with least score of 3.70. The differences in this present research is in close accordance with that of Aykanet al. (2008) who reported that non-fat or reduced fat ice cream samples has a slightly lower melting rate due to the higher water binding capacity of carbohydrate – base fat replacer. According to Ohmeset al. (1998) fat-free ice cream has a slower melting rate than the control sample. Davinder (2012) also earlier reported that the meltdown of ice cream is influenced by its composition, the amount of air incorporated, nature of ice crystal and by the network of fat globules. Meltdown is an important attribute of ice cream which influenced its sensory quality (Elangoet al., 2018).

Flavor is a chemosensory characteristic sensed by receptors found in tongue and nose (Kilcast and Clegg, 2002). The mean score value for the ice cream samples in terms of flavor ranged between 6.55 and 7.88 (Table 3). There were no significant differences ($P<0.05$) among the ice cream sample (Table 3). Low-fat ice cream compared favorably with the commercial ice cream/high fat ice cream in terms of flavor excepts in fewer cases (Table 3). This finding shows that ice cream increased with decrease as the amount of fat replacer is added. This observation is in variation with that report of Karacaet al. (2009) who reported that fat base replacer has lower flavor score than that control. Fat is a solvent for many flavor compounds and acts as a reservoir by slowly releasing flavor. However, this is not replicated by most fat replacer (Li et al., 1997). The mean score value recorded for ice cream in terms of texture ranged between 6.30 and 7.58 (Table 3). There were significant differences ($p<0.05$) among the ice cream samples (Table 3). Low- fat ice cream with treatment of HMTb, HMTa, PAH-HMTd, PAH-HMTb PAH and HMTb had higher mean score than the commercial ice cream/high fat ice cream. This present finding is in line with that of Mahdian and Karazhian (2016) who reported that usage of insulin and milk protein concentrate as fat replacer has no negative effect on the texture of fat reduced ice cream and sample containing insulin were more appealing than control. Similarly, Karacaet al., (2009) reported that reduced and low-fat ice cream sample with added fat replacers has texture similar to that of the control. Texture is an important factor as it influences how a sample of ice cream reacts with a person’s mouth (Tulaget al., 2006). The mean value for the ice cream samples in terms of overall acceptability ranged between 6.15 and 7.85 (Table 3). There were significant differences ($p<0.05$) among the ice cream samples (Table 3). Ice cream with treatment of PAH-HMTb even had higher mean value than the control. Rolland et al. (1990) earlier reported that sensory quality of low low-fat ice cream containing carbohydrate-based fat replacer was more satisfying. In fact, the result shows that low-fat ice cream compared favorably with commercial ice cream in overall acceptability.

Table 1: Pasting Properties of Modified and Native Sorghum Starches

SAMPLE	Peak Viscosity (RVU)	Trough Value (RVU)	Breakdown Value (RVU)	Final Viscosity (RVU)	Setback Value (RVU)	Pasting Time (min)	Pasting Temperature (^{o}C)
HMTa	59±1.24^{f}	53±4.24^{d}	6.0±2.82^{e}	66±2.82^{e}	13±2.82^{e}	5.47±0.01^{d}	0.00±0.00
HMTb	84±3.24^{d}	23±4.24^{f}	61±2.82^{e}	73±2.82^{d}	50±2.82^{e}	4.87±0.01^{a}	88.95±0.00
HMTc	18±4.24^{g}	1.0±4.24^{g}	17±2.82^{d}	27±2.82^{g}	26±2.82^{d}	5.47±0.01^{d}	0.00±0.00
HMTd	247±2.4	150±4.24^{c}	97±2.82^{b}	288±2.82^{e}	138±2.82^{b}	5.27±0.01^{f}	90.45±0.00
PAH-HMTa	63±4.24^{e}	42±4.24^{e}	21±2.82^{d}	70±2.82^{e}	28±2.64^{d}	4.8±0.01^{f}	0.00±0.00
PAH-HMTb	52±4.24^{f}	50±4.24^{de}	2.0±2.82^{e}	59±2.82^{ef}	9±2.44^{ef}	5.8±0.01^{b}	0.00±0.00
PAH-HMTc	71±4.24^{f}	75±4.24^{f}	4.0±2.82^{e}	69±2.82^{f}	6±2.75^{f}	5.53±0.01^{c}	0.00±0.00
PAH-HMTd	53±4.24^{f}	60±4.24^{h}	7.0±2.82^{e}	47±2.82^{h}	13±2.82^{e}	5.40±0.01^{e}	0.00±0.00
PAH-	281±4.2^{b}	258±4.2^{b}	23±2.82^{d}	311±2.82^{b}	53±2.82^{e}	6.07±0.01^{a}	95.00±0.00
NATIVE	442±4.2^{a}	296±4.24	146±2.82^{a}	512±2.82^{a}	216±2.82^{a}	5.13±0.01^{g}	83.15±0.00

Value are means of triplicate analysis + standard deviation values with similar letters within the same column are not significantly different ($P<0.05$)

Keys

HMTa -	Heat moisture treatment 20% moisture at 110^{o}C
HMTb -	Heat moisture treatment 30% moisture at 110^{o}C
HMTc -	Heat moisture treatment 20% moisture at 90^{o}C
HMTd -	Heat moisture treatment 30% moisture at 90^{o}C
PAH-HMTa-	Partial acid hydrolysis –heat moisture treatment 20% moisture at 110^{o}C
PAH-HMTb-	Partial acid hydrolysis –heat moisture treatment 30% moisture at 110^{o}C
PAH-HMTc-	Partial acid hydrolysis –heat moisture treatment 20% moisture at 90^{o}C
PAH-HMTd-	Partial acid hydrolysis –heat moisture treatment 30% moisture at 90^{o}C
PAH-	Alone
NATIVE-	Native starch

Table 2: Functional Properties of Modified and Native Sorghum Starches

SAMPLE	Bulk Density BD (g/ml)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Swelling Power (g/g)	Solubility Index (%)
HMTa	0.74±0.07^{bc}	153±2.82^{c}	65.10±41^{c}	2.93±0.11^{bc}	5.41±0.01^{f}
HMTb	0.69±0.02^{c}	142±41^{d}	62.60±0.28^{de}	2.72±0.14^{cd}	5.43±0.04^{f}
HMTc	0.81±0.02^{b}	133±282^{e}	60.90±0.91^{e}	3.40±0.21^{a}	5.72±0.02
HMTd	0.79±0.01^{b}	146±1.41^{cd}	64.50±0.84^{cd}	2.57±0.08^{d}	8.31±0.01^{b}
PAH-HMTa	0.74±0.02^{bc}	1.74±5.65	68.60±0.70^{b}	2.26±0.8^{e}	8.58±0.04^{a}
PAH-HMTb	0.67±0.02^{c}	154±4.24^{c}	73.20±1.41^{a}	2.22±0.01^{e}	8.59±0.02^{a}
PAH-HMTc	0.74±0.14^{bc}	165±2.82^{b}	65.30±0.42^{c}	2.20±0.07^{e}	7.81±0.02^{c}

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PAH-HMTd	0.69±0.01^{c}	154±5.65^{c}	65.80±1.41^{c}	3.11±0.15^{b}	5.80±0.14^{e}
PAH-	0.89±0.04^{a}	176±2.82^{a}	69.20±0.28^{b}	2.96±0.02^{bc}	5.45±0.02^{f}
NATIVE	0.71±0.14^{c}	129±2.82^{e}	62.70±1.41^{dc}	2.81±0.02^{cd}	7.48±0.02^{d}

Value are means of triplicate analysis + standard deviation values with similar letters within the same column are not significantly different (P<0.05)

Keys

HMTa - Heat moisture treatment 20% moisture at 110^{o}C
HMTb - Heat moisture treatment 30% moisture at 110^{o}C
HMTc - Heat moisture treatment 20% moisture at 90^{o}C
HMTd - Heat moisture treatment 30% moisture at 90^{o}C
PAH-HMTa- Partial acid hydrolysis –heat moisture treatment 20% moisture at 110^{o}C
PAH-HMTb- Partial acid hydrolysis –heat moisture treatment 30% moisture at 110^{o}C
PAH-HMTc- Partial acid hydrolysis –heat moisture treatment 20% moisture at 90^{o}C
PAH-HMTd- Partial acid hydrolysis –heat moisture treatment 30% moisture at 90^{o}C
PAH- Alone
NATIVE- Native starch

Table 3: Sensory properties of low -fat ice cream prepared by using modified and native sorghum starch

Samples	Taste	Color	Meltdown	Flavor	Texture	Overall Acceptability
HMTa	7.65±1.34^{ab}	7.75±1.11^{a}	6.45±1.05^{bc}	7.05±2.08^{a}	7.15±1.8^{a}	6.70±2.43^{ab}
HMTb	7.20±1.64^{abc}	7.50±1.39^{a}	3.75±2.69^{g}	7.35±1.69^{a}	7.58±1.76^{a}	7.55±1.27^{a}
HMTc	6.65±2.23^{bc}	7.25±1.7	3.70±1.97^{g}	6.90±2.07^{a}	6.70±1.30^{a}	6.63±1.08^{ab}
HMTd	7.60±1.09^{ab}	7.75±1.02^{a}	4.00±1.665^{gh}	6.55±1.27^{a}	7.05±1.95^{a}	7.25±1.29^{ab}
PAH	7.15±1.49^{abc}	7.30±1.86^{a}	7.75±1.07^{a}	7.05±1.27^{a}	7.50±1.23^{a}	7.20±1.60^{ab}
PAH-HMTa	7.35±0.98^{abc}	7.50±1.31^{a}	4.85±1.66^{efg}	7.50±0.94^{a}	6.80±1.60^{a}	6.80±1.82^{ab}
PAH-HMTb	8.00±0.95^{a}	7.20±1.76^{a}	6.30±1.21^{cd}	7.25±1.61^{a}	7.35±1.56^{a}	7.85±1.18^{ab}
PAH-HMTc	7.40±1.23^{abc}	7.50±1.10^{a}	5.85±1.72^{cde}	6.90±1.48^{a}	6.65±1.98^{a}	7.45±1.43^{a}
PAH-HMTd	6.30±2.69^{c}	6.55±3.13^{a}	7.50±2.06	6.90±1.48^{a}	7.20±2.10^{a}	6.15±2.88^{b}
NATIVE	7.40±1.23^{abc}	7.55±1.60^{a}	5.15±1.98^{def}	6.95±1.05^{a}	6.30±1.92^{a}	7.45±1.27^{a}
CONTROL	8.35±1.05^{a}	7.80±1.03^{a}	6.85±1.69^{a}	7.68±0.05^{a}	6.85±0.05^{a}	7.70±1.15^{a}

Value are means of triplicate analysis + standard deviation values with similar letters within the same column are not significantly different (P<0.05)

Keys

HMTa - Heat moisture treatment 20% moisture at 110^{o}C
HMTb - Heat moisture treatment 30% moisture at 110^{o}C
HMTc - Heat moisture treatment 20% moisture at 90^{o}C
HMTd - Heat moisture treatment 30% moisture at 90^{o}C
PAH-HMTa- Partial acid hydrolysis –heat moisture treatment 20% moisture at 110^{o}C
PAH-HMTb- Partial acid hydrolysis –heat moisture treatment 30% moisture at 110^{o}C
PAH-HMTc- Partial acid hydrolysis –heat moisture treatment 20% moisture at 90^{o}C
PAH-HMTd- Partial acid hydrolysis –heat moisture treatment 30% moisture at 90^{o}C
PAH- Alone
NATIVE- Native starch

IV. CONCLUSIONS

Findings carried out on pasting properties of the Sorghum starch shows that modification measures applied, considerably reduced the peak viscosity, trough viscosity, breakdown and final viscosity of the sorghum starch. Result of functional properties of the starch shows that water and oil absorption capacity of the sorghum starch were considerably improved. Result of sensory evaluation has shown that fat can be replaced with 15% modified sorghum starch in low- fat ice cream. Low-

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fat ice cream samples were much acceptable as the commercial.

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