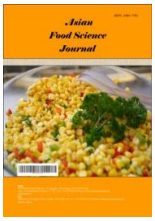

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Physicochemical, Sensory and Microbial Qualities of Ice Cream Stabilized with Hydrocolloids from Achi (*Brachystegia eurycoma*) and Ofor (*Detarium microcarpum*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author TMO designed the study. Author KOA performed the statistical analysis. Authors KOA and CME wrote the protocol and author KOA wrote the first draft of the manuscript. Author KOA managed the analyses of the study. Authors KOA, CME, CHA, JIA and ANI managed the literature searches. All the authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate the physicochemical, sensory and microbial qualities of ice cream stabilized with hydrocolloids from Achi (*Brachystegia eurycoma)* and Ofor (*Detarium microcarpum.*
Study Design: A *4×5* split-plot in completely randomized design.
Place and Duration of Study: Department of Food Science and Technology, Faculty of Agriculture, University of Nigeria, Nsukka, Enugu State Nigeria between August 2018 and July 2019.
Methodology: Raw seeds of Achi (*Brachystegia eurycoma*) and Ofor (*Detarium microcarpum*) were purchased from Ekeonunwa market, Owerri, Imo State, Nigeria and processed into flours.

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Hydrocolloids from flours of Achi and Ofor were defatted with n-hexane (50 g/250 ml at 26±2°C) dispersed in distilled water (10 g/250 ml), centrifuged (1250 rpm/30 mins and 1500 rpm/30 mins for achi and ofor respectively). The supernatants obtained were dissolved in isopropanol, decanted dried in a hot air oven (60°C, 10 h), pulverised using a blender and stored in air –tight containers. Twenty (20) litres of ice cream samples were produced. Four (4) litres of the mix was measured out as control (i.e. plain ice cream without any stabilizer). Sixteen (16) additional ice cream mixes were produced in the same way by the addition of CMC, *achi* hydrocolloids, *ofor* hydrocolloids and a mixture of hydrocolloids from both *achi* and *ofor* as stabilizers, each at 0.1%, 0.2%, 0.3%, 0.4% concentrations. The physicochemical, sensory and microbial properties of the ice cream samples formulated were carried out.

Results: The outcome of physicochemical analysis revealed that viscosity (31.65 ± 0.17 cP – 82.50 ± 0.00 cP), overrun (19.30 ± 0.00% - 98.73 ± 0.00%), total solids (24.36 ± 0.33% - 54.00 ± 1.55%) and melting resistance (36.50 ± 0.58% - 92.50 ± 0.58%) were significantly ($P < 0.05$) affected by the type of stabilizers as well as their concentrations. The total titratable acidity (0.02 ± 0.00% - 0.02 ± 0.00%) and pH (6.74 ± 0.00 - 7.05 ± 0.05) of the ice cream samples showed no appreciable significant ($P > 0.05$) difference. The overall acceptability (5.80 ± 1.99 - 7.65 ± 1.00), aftertaste (5.45 ± 2.28 – 7.20 ± 0.89), mouthfeel (5.85 ± 1.79 - 7.25 ± 1.37) and homogeneity (5.20 ± 1.96 - 7.60 ± 1.39) were significantly ($P< 0.05$) influenced as deduced from the sensory result.

Conclusion: The incorporation of local stabilizers significantly improved the physicochemical, sensory and microbial qualities of ice cream produced. Hydrocolloid extracts of *Detarium microcarpum* (Ofor), plant-based natural stabilizer is a capable replacer of CMC in ice cream production because of its higher viscosity than other stabilizers and CMC, agreeable consistency, better consumer preference than other stabilizers, enhanced qualities – slow melting rate i.e. high melting resistance, commendable pseudo-plasticity, effectual overrun which will yield more profits for ice cream manufacturers, bring about a new variety of ice creams that are safe for consumption. Hydrocolloid extracts of *Detarium microcarpum*, at 0.3%, showed more desirable similar effects on the physicochemical, sensory and microbial qualities of ice cream samples formulated compared to CMC and could, therefore be recommended as a replacer of CMC in ice cream production.

Keywords: *Ice cream; hydrocolloids; stabilizers; Brachystegia eurycoma; Detarium microcarpum; physicochemical; sensory qualities.*

1. INTRODUCTION

Hydrocolloids, often referred to as gums, are long-chain polymers, majorly carbohydrate, that thicken or gel in aqueous systems, forming the creamy viscosity that mimics fat [1]. They are high molecular weight polymers of animal, plant or microbial origin that form viscous solutions or gels in water. They first occurred in exudates from trees or bushes, plant extracts, flours from seeds or grains, slimy products of fermentation processes, and many other natural products [2]. Due to the presence of a large number of hydroxyl groups in their structure, hydrocolloids are well known to have great affinity for water molecules. Thus, they can be regarded as hydrophilic compounds. Hydrocolloids produce a two-phase system consisting of a dispersed phase and a continuous phase (water), an intermediate between a suspension and a true solution, thus exhibiting the characteristics of a colloid. Based on the affinity for water molecules and their ability to produce dispersion, hydrocolloids can be regarded as *hydrophilic colloids* or *hydrocolloids* [2].

Hydrocolloids have found their usefulness in food, agricultural, pharmaceutical, and chemical industries. This is as a result of their biocompatibility, naturalness and soft-solid texture [3]. Hydrocolloids have been obtained from many sources including natural and artificial ones.

Brachystegia eurycoma is a lesser known natural source of hydrocolloid popularly found in the Eastern part of Nigeria, called *Achi* by the Igbos, *Eku* or *Akalado* by the Yorubas, *Apaupau* by the Ijaws, and *Dewen* in Benin [4]. Extraction of hydrocolloids from the seeds of *Brachystegia eurycoma* involves sorting, cleaning, milling into flour, and defatting [5].

Plate 1. Brachystegia eurycoma seeds (Achi)
Source: Uzomah and Odusanya (2011)

Detarium microcarpum Guill. and Perr. (Fabaceae) is one of the popular leguminous tree species of Africa (and also in some parts of Asia), which is known to have high medicinal value [6]. The seeds occur singly and are embedded within the hard, disc-shaped, brownish fruits. The aged or dried seeds are utilized in the eastern part of Nigeria as a soup thickener after being processed into flour [7]. The seed polysaccharide has been reported to be used as a natural stabilizer in processed fruit products [8].

Hydrocolloids have a wide variety of functional properties in food. In the food industries, they are used as thickening agents in soups and sauces, gelling agents, emulsifying agents, as stabilizers in yoghurt, ice cream, fruit juice production, etc. Their ability to modify the rheological system of food is the major reason for the various applications of hydrocolloids in foods [2].

Ice cream, being a product in which hydrocolloid's use has been seen, is a frozen food typically eaten as snacks or dessert. It is usually made from dairy products such as milk and cream, and often combined with fruits or other ingredients and flavours. It is typically sweetened with sucrose, corn syrup, cane sugar, beet sugar and/or other sweeteners. Typically, flavourings and colourings are added in addition to stabilizers. The mixture is stirred to incorporate air spaces and cooled below the freezing point of water to prevent detectable ice crystals from forming. The result is a smooth, semi-solid foam that is solid at a very low temperature (2°C). It becomes malleable as its temperature increases [9].

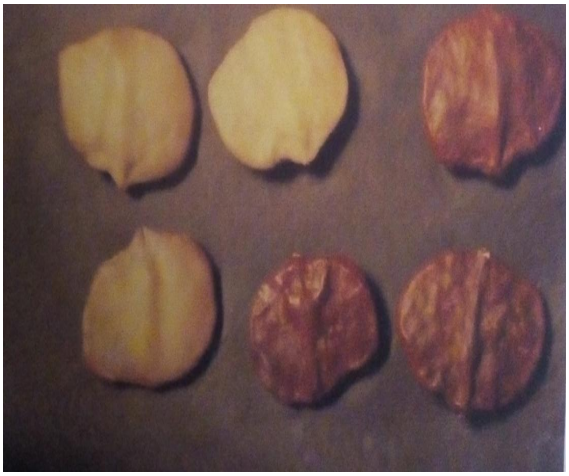

Plate 2. Raw seeds of *Detarium microcarpum*
Source: Onwuamaegbu (1995)

2. MATERIALS AND METHODS

2.1 Procurement of Materials

Raw seeds of *Brachystegia eurycoma* (Achi) and *Detarium microcarpum* (Ofor) were purchased from Ekeonunwa market, Owerri, Imo State, Nigeria. The full cream milk, sugar, egg, vanilla essence, Sodium carboxymethylcellulose (CMC) were all purchased from Ogige main market, Nsukka, Enugu State, Nigeria.

2.2 Raw Materials Preparation

2.2.1 Processing of *Detarium microcarpum* (Ofor)

Processing of *Detarium microcarpum* was carried out according to the method of [10]. *Detarium microcarpum* seeds were sorted and cleaned to remove dirt from the seeds. The seeds were soaked in water at room temperature for six (6) hours in order to soften the tissues for easy dehulling. The hydrated seeds were dried in an oven kept at 60°C for three (3) hours. The dried seeds were dehulled mechanically using attrition milling machine. The powder was sieved through and then packaged in airtight containers until further use.

2.2.2 Processing of *Brachystegia eurycoma* (Achi)

Brachystegia eurycoma seeds were processed in accordance with the method of [10]. Seeds of *Brachystegia eurycoma* were sorted out and cleaned to rid the seeds of dirt. The seeds were toasted for 30 minutes and soaked in water at room temperature for six (6) hours in order to soften the tissues for easy dehulling. Dehulling process was carried out manually and the adhering seed coats were scrapped off using knife. The seed coats were then removed thereafter, by washing. These were then sun-dried to constant weight, milled into powder and sieved in order to obtain smooth and uniform fine particles. The particles so obtained were packaged in airtight containers until further use.

2.3 Extraction of Hydrocolloids

Hydrocolloids were extracted from the seeds of *Brachystegia eurycoma* and *Detarium microcarpum* as described by Adikwu and Enebeke [11] with slight modifications. Flours obtained from the seeds of *Brachystegia eurycoma* and *Detarium microcarpum* were defatted with n-hexane (50 g / 250 ml, w/v basis) for six (6) hours at room temperature (26 ± 2°C) by maceration technique. Defatted flours of *Achi* and *Ofor* were dispersed repeatedly in distilled water (10 g / 250 ml) and made to undergo continuous hydration by stirring with a clean glass rod for two (2) hours. These were poured into centrifuge tubes for centrifugation at 1250 rpm (*Achi*) and 1500 rpm (*Ofor*) respectively, for fifteen (15) minutes.

The supernatants from the two samples were poured into a large beaker while their residues, were reconstituted with fresh distilled water, stirred and centrifuged the second time to obtain another supernatant. The supernatants generated from the first and second centrifugation process were pooled together and mixed with food-grade isopropanol. The supernatants were stirred rigorously and allowed to settle. The hydrocolloids were spooled out and the clear liquor from each sample decanted. The trapped solvent from each sample was removed by filtration. Re-precipitation of the crude hydrocolloids obtained by fresh isopropanol was later carried out. The precipitated crude hydrocolloids were dried in a hot air oven at 60°C for ten (10) hours. The hydrocolloids were cooled in a dessicator and pulverised using a blender. The dried, pulverized hydrocolloids were stored in a sealed container.

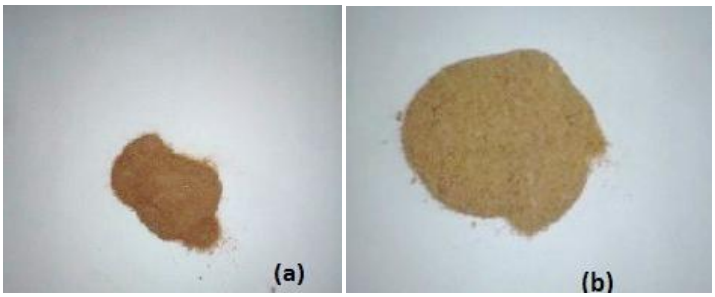

Plate 3. (a) Pulverised brachystegia eurycoma hydrocolloids (b) Pulverised *Detarium microcarpum* hydrocolloids

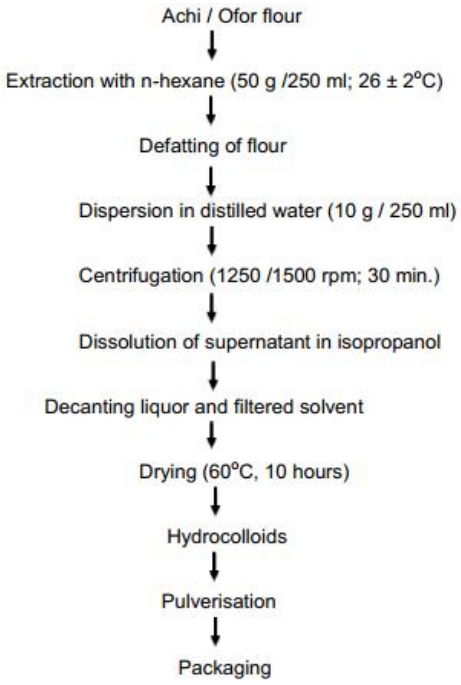

Fig. 1. Extraction of hydrocolloids from *Achi* and *Ofor* flour
Source: Adikwu and Enebeke [11]

2.4 Production of Ice Cream

125 g of full cream powdered peak milk was added to 105.6 ml of vegetable oil together with 50 ml of liquid chicken egg and 109.4 g of sugar and made up to 1075 ml with water to produce ice cream mix at 13% fat and 14% sugar. A total quantity of 20 litres of ice cream mix was produced by measuring approximately 2325.59 g of powdered full cream peak milk, 1964.65 ml of vegetable oil, 2035.35 g of sucrose and 930.23 ml of whole liquid fresh chicken egg and made up to 20 litres with water. The ice cream mix was divided into four (4) portions corresponding to four (4) main treatments (i.e. I+C, I+A, I+B and I+O). Each treatment contained 5 litres corresponding to 0.0%, 0.1%, 0.2%, 0.3%, and 0.4% of each of the stabilizers used. The flow chart for the production of ice cream samples is shown in Fig. 2.

2.5 Sample Analysis

2.5.1 Physico-chemical analysis

2.5.1.1 Determination of total solids

The total solid content of ice cream samples was determined using AOAC [12]. At 130°C, the sample (5 g) was dried to a constant weight in a hot air oven.

2.5.1.2 Determination of melting resistance

Melting resistance of ice cream so produced was evaluated according to the method described by Huse et al. [13]. Blocks of ice cream (100 g) at about -14 ± 4°C was placed on a stainless-steel screen with aperture of 5 mm diameter, located on top of a beaker. The initial weight (W_1) was taken before placing it on the screen and the final weight (W_2) of ice cream block were taken after 45 minutes at room temperature.

2.5.1.3 Determination of overrun

The Overrun was determined using a standard 100 ml cup according to the modified method described by Hui et al. [14]. The weight of the ice cream mix was taken before aeration and the weight of the ice cream obtained after aeration was taken.

2.5.1.4 Determination of viscosity

Viscosity of the ice cream samples was measured using a Capillary Flow method described by Tyler [15]. The apparatus was fitted up. By raising or lowering the runway tube of the capillary, the head of the sample was adjusted so that the liquid emerged slowly as it dropped. The sample (liquid) was collected in a beaker. The rate of flow was then determined. The pressure head, h was also measured and the temperature of the sample recorded.

2.5.1.5 Determination of pH

The pH of the ice cream samples (100 ml) was measured electrometrically using a standard pH meter (model 20 pH Conductivity meter, Denver Instrument, United Nations Inventory Database) according to AOAC method [12]. This instrument was standardized using buffer solution of pH 4.0 and 9.0. The pH electrode was dipped into ice cream and after a few minutes of equilibration, the pH of the ice cream was measured.

2.5.1.6 Determination of Total Titratable Acidity (TTA)

Total Titratable acidity of the samples was determined by the method described in the AOAC method [12]. 10 g of each of the ice cream samples was titrated against 0.1 M NaOH solution using 0.3 ml phenolphthalein as an indicator. The volume of NaOH (ml) that neutralized the sample was recorded.

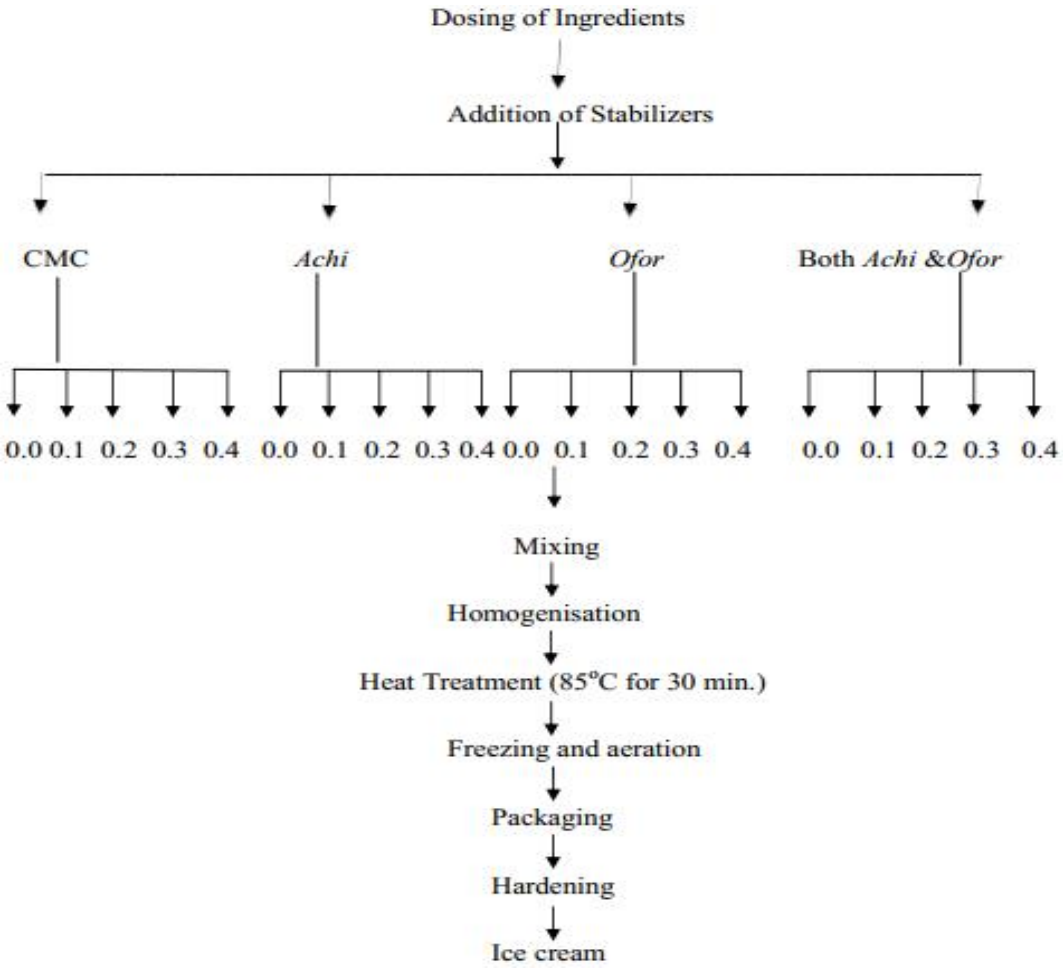

Fig. 2. Production of ice cream

2.5.2 Sensory evaluation

The sensory evaluation was carried out using a 20-man semi-trained panelists. Each panelist evaluated the ice cream samples using a 9-point Hedonic scale (where *9* = *extremely like* and *1* = *extremely dislike*) [16] for colour, homogeneity, taste, mouth feel, aftertaste and overall acceptability.

2.5.3 Microbiological analysis

Microbiological analysis of the ice cream samples was carried out. Serial dilution of each of the samples was done and the samples placed at ambient temperature. The Total Viable Count (TVC), Coliform Count and Mould Count were determined using pour plate method on Nutrient agar, McConkey agar and Sabouraud Dextrose agar respectively as described by Prescott et al. [17].

2.6 Data Analysis and Experimental Design

The experiment was performed in triplicates and based on a *4×5* split-plot in completely randomized design using SPSS software (Version 23). Means of the treatments were compared using Duncan's New Multiple Range Test. Statistical significance was accepted at $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Effect of Stabilizers and Concentrations on the Physico-chemical Properties of Ice Cream

Results of physicochemical properties of ice cream samples I + A (Ice cream + hydrocolloids of *achi*), I + B (Ice cream + hydrocolloids of Both

achi and *ofor*), I + C (Ice cream + CMC), I + O (Ice cream + hydrocolloids of *ofor*) and I (Ice cream without any stabilizer) are presented in Table 1.

3.1.1 Total solids

The total solids of the ice cream samples stabilized with different stabilizers ranged from 24.36 ± 0.33% to 57.02 ± 2.96 (Table 1). Milk does not contain substantial amount of sugar. Therefore, the high total solid contents in the ice cream samples could be traced to the quantity of sugar added. The total solids of ice cream samples differed significantly ($P < 0.05$) upon incorporation of different types of stabilizers, in relation to the control sample. The highest and lowest values of the total solids were at 0.4% I+B and in the control sample (I). This could be attributed to the synergistic effect of *achi* and *ofor* used in the sample. The results showed that there was more significant ($P < 0.05$) improvement in the total solids of samples I+B than the values obtained from samples I+A, I+O and I+C. There was significant ($P < 0.05$) difference in total solids of ice cream samples with different stabilizers at different concentrations.

3.1.2 pH

The pH values of ice cream samples were within the range of 6.74 ± 0.00 to 7.05 ± 0.05 (Table 1). When CMC was used to stabilize the ice cream samples, there was no significant ($P > 0.05$) difference in the pH values of samples I+C at 0.1%, 0.3% and 0.4% concentrations respectively. However, when compared with the control samples (I), each of the samples stabilized with CMC showed significant ($P < 0.05$) difference in pH values. It was observed that no significant difference in pH values was obtained in samples I+O at 0.3% and 0.4% respectively. Similarly, with a mixture of hydrocolloid extracts of both *achi* and *ofor*, there were no significant ($P > 0.05$) difference in the pH values of samples I+O at 0.3% and 0.4%. In relation to the control, samples stabilized with hydrocolloid extracts of *achi* (samples I+A) had their pH values significantly ($P < 0.05$) different from each other at varying concentrations (0.1% to 0.4%).

3.1.3 Melting resistance

The melting resistance of the ice cream samples ranged from 36.50 ± 0.58% to 92.00 ± 0.00% (Table 1). There was significant ($P < 0.05$) difference in the melting resistance of all ice cream samples. The effects of the concentrations of the samples were compared. The melting resistance of samples I+C at 0.4%, was the highest (92.50 ± 0.58%), followed by I+O at 0.4% (68.00 ± 0.00%), I+A at 0.4% (62.00 ± 0.00%), and I+B at 0.4% (60.50 ± 0.58%). The melting resistance of the ice cream samples at different concentrations differed significantly ($P < 0.05$). Thus, the higher the concentration, the higher the melting resistance. Although all the stabilizers increased in melting resistance as concentration increased, they were not increasing at the same rate and extent. The interactions between the stabilizers and their concentrations were significantly ($P < 0.05$) different. Generally, the ice cream samples stabilized with stabilizers had better melting resistance than the control samples. According to [18], stabilizers due to water holding and micro-viscosity, enhancement ability, significantly affect the melting rate of ice cream. [19] reported that destabilization of fat, the size of ice crystal and the homogeneity coefficient, affect the rate of melting of ice cream.

3.1.4 Overrun

The overrun of ice cream samples prepared with different stabilizers, which ranged from 19.30 ± 0.00% to 41.68 ± 0.05% (Table 1), differed significantly ($P < 0.05$). The samples I+A at 0.1% concentration had higher overrun value (41.68 ± 0.05%) than the samples I + O at 0.3% (41.35 ± 0.05%), samples I+A at 0.2% (38.73 ± 0.00%) and samples I+C at 0.1% (37.81 ± 0.05 %). In relation to the control sample (I), the overrun of the ice cream samples at different levels differed significantly ($P < 0.05$) and were dose-dependent. The interactions between the stabilizers and levels of the samples were significantly ($P < 0.05$) different. Results showed an indirect or inverse correlation between overrun and melting resistance i.e. as the overrun increases, the melting resistance decreases and vice- versa. [20] reported that ice creams with lower overruns were harder and had higher melting resistance than those with high overruns which melted more quickly. Overrun which describes the amount of air incorporated in ice cream mix, is significant to manufacturers who desire good product quality and returns [21].

3.1.5 Viscosity

The viscosity of ice cream samples stabilized with different stabilizers were within the range of

31.65 ± 0.17cP to 82.50 ± 0.00cP (Table 1). The viscosity of all ice cream samples differed significantly ($p < 0.05$) from each other when different types of stabilizers were used. The viscosity of the ice cream samples I+O was the highest followed by samples I+C, samples I+A and while in samples I+B, the lowest viscosity value was obtained. The viscosity of the samples was highest at 0.4% concentration. and differed significantly ($P < 0.05$) at different concentrations. Results also showed that the higher the concentration of stabilizers, the higher the viscosity. All the samples increased in viscosity as concentrations of stabilizers increased but not at the same rate and extent. Samples stabilized with *ofor* (I +O) showed higher rate and extent than the other samples. This corroborates with the report of [22] that, an increase in stabilizer quantity could lead to a multifold elevation in viscosity.

3.1.6 Total titratable acidity

Results also showed that total titratable acidity of ice cream samples prepared with different stabilizers ranged from 0.01 ± 0.00% to 0.02 ± 0.00%. Generally, there was no significant ($P > 0.05$) difference in the TTA of the samples I+O, I+A and I+B in relation to the control samples I. However, there was significant ($P< 0.05$) difference in the TTA of samples prepared with CMC (I+C) at 0.1% concentration. This buttresses the fact that hydrocolloids extracted from *Detarium microcarpum* (*Ofor*), *Brachystegia eurycoma* (*Achi*) could be substituted for exotic stabilizers such as CMC in ice cream production.

3.2 Effect of Stabilizers and Concentrations on the Sensory Properties of Ice Cream

3.2.1 Colour

Mean scores of colour of the ice cream samples stabilized with different stabilizers were within the range of 5.90 ± 2.07 to 7.90 ± 0.91 (Table 2). The mean colour score for the control sample was 6.45 ± 1.26. With reference to the control samples I, there was no significant ($P > 0.05$) difference in the mean colour scores of the samples stabilized with hydrocolloid extract from *ofor* at 0.1%, 0.2%, 0.3% and 0.4% levels respectively. When the ice cream samples were stabilized with hydrocolloid extract from *achi*, there was no significant ($P > 0.05$) difference in the colour of ice creams at 0.1% and 0.4% concentrations. Similarly, when the ice cream samples were prepared with mixed hydrocolloid extracts of both *achi* and *ofor*, the mean colour scores at 0.1% and 0.3% showed no significant ($P < 0.05$) difference while those samples stabilized with CMC at 0.2%, 0.3% and 0.4% also showed no significant ($P > 0.05$) difference. Ice cream samples prepared with 0.4% CMC was the most preferred (7.90 ± 0.91). This could be attributed to the shining and glossy appearance which CMC imparts to food [23]. The samples stabilized with *ofor* (Samples I+O) showed steady increase in the mean colour scores as the concentrations increased, in relation to the control sample.

3.2.2 Taste

Mean scores of taste were within the range of 5.50 ± 1.91 to 7.45 ± 1.14 (Table 2). The type of stabilizer used in the ice cream formulation affects the sensory attributes such as taste, appearance, homogeneity (consistency), aftertaste, mouthfeel and overall acceptability. There were no significant ($P > 0.05$) differences in the mean taste scores of samples stabilized with CMC at 0.2%, 0.3% and 0.4% levels respectively. In relation to the control samples, there were no significant ($P > 0.05$) difference in the mean taste scores of samples stabilized with 0.2% and 0.3% hydrocolloid extract from *ofor*. Similarly, when hydrocolloid extracts of both *achi* and *ofor* are mixed and were used to formulate ice creams at 0.1% and 0.3% concentrations, there was no significant ($P > 0.05$) difference in the mean taste scores. However, significant ($P < 0.05$) difference existed in the mean taste scores of all samples stabilized with hydrocolloid extracts of *achi* at 0.1%, 0.2%, 0.3% and 0.4% respectively.

The mean score of homogeneity (consistency) of ice cream samples ranged from 5.20± 1.96 to 7.60 ± 1.39). When compared with the control samples, there were no significant ($P > 0.05$) difference in the homogeneity scores of samples stabilized with 0.2% hydrocolloid extract from *ofor*. There were however, significant ($P<0.05$) differences in the mean homogeneity scores of ice cream samples stabilized with CMC, *achi*, hydrocolloid extracts of both *achi* and *ofor* at 0.1%, 0.2%, 0.3% and 0.4% concentrations. The highest homogeneity score was obtained from samples stabilized with 0.4% CMC (7.60 ± 1.39). The samples stabilized with *CMC* (Samples I+C) gave a steady increase in the mean homogeneity scores as the concentrations increased, with reference to the control samples.

Table 1. Physicochemical properties of ice cream samples stabilized with different stabilizers

Sample	Conc. (%)	Total solids (%)	pH	Melting Resistance (%)	Viscosity (cP)	Overrun (%)	Titratable acidity (%)
I	0.0	20.03^{a} ± 8.55	6.70^{c} ± 0.00	39.88^{c} ± 6.57	41.17^{d} ± 0.03	39.49^{b} ± 11.08	0.02^{a} ± 0.00
I + C	0.1	24.36^{b} ± 0.33	6.93^{a} ± 0.01	36.50^{a} ± 0.58	42.20^{e} ± 0.23	37.81^{e} ± 0.05	0.01^{b} ± 0.00
I + C	0.2	27.77^{def} ± 0.06	7.05^{g} ± 0.05	38.00^{bc} ± 0.00	46.05^{g} ± 0.17	30.15^{a} ± 0.02	0.02^{a} ± 0.01
I + C	0.3	29.68^{hi} ± 0.27	6.92^{a} ± 0.01	52.50^{f} ± 1.73	55.93^{k} ± 0.03	29.71^{c} ± 0.00	0.02^{a} ± 0.00
I + C	0.4	27.54^{d} ± 2.86	6.91^{a} ± 0.00	92.50^{e} ± 0.58	60.60^{l} ± 0.69	26.28^{d} ± 0.02	0.02^{a} ± 0.00
I	0.0	20.03^{a} ± 8.55	6.70^{c} ± 0.00	39.88^{c} ± 6.57	41.17^{d} ± 0.03	39.49^{b} ± 11.08	0.02^{a} ± 0.00
I + O	0.1	26.27^{c} ± 0.08	6.82^{d} ± 0.00	44.00^{d} ± 1.16	76.60^{m} ± 0.35	37.81^{e} ± 0.02	0.02^{a} ± 0.00
I + O	0.2	27.69^{de} ± 0.05	6.79^{e} ± 0.01	53.00^{g} ± 0.00	78.40^{n} ± 0.23	35.54^{f} ± 0.00	0.02^{a} ± 0.00
I + O	0.3	28.74^{g} ± 0.03	6.83^{de} ± 0.01	59.00^{k} ± 1.16	81.80^{o} ± 0.23	41.35^{g} ± 0.05	0.02^{a} ± 0.01
I + O	0.4	29.61^{h} ± 0.31	6.83^{de} ± 0.04	68.00^{o} ± 0.00	82.50^{p} ± 0.00	34.63^{d} ± 0.03	0.02^{a} ± 0.00
I	0.0	20.03^{a} ± 8.55	6.70^{c} ± 0.00	39.88^{c} ± 6.57	41.17^{d} ± 0.03	39.49^{b} ± 11.08	0.02^{a} ± 0.00
I + A	0.1	30.09^{j} ± 0.01	6.89^{ab} ± 0.04	55.50^{i} ± 0.58	33.00^{b} ± 0.00	41.68^{g} ± 0.05	0.02^{a} ± 0.00
I + A	0.2	31.86^{k} ± 0.14	6.74^{f} ± 0.00	58.00^{j} ± 0.00	42.90^{bc} ± 0.12	38.73^{i} ± 0.00	0.02^{a} ± 0.01
I + A	0.3	42.22^{l} ± 0.05	6.87^{b} ± 0.04	61.00^{m} ± 1.16	50.15^{h} ± 0.06	27.84^{bc} ± 0.05	0.02^{a} ± 0.00
I + A	0.4	45.32^{m} ± 0.08	6.92^{a} ± 0.00	62.00^{n} ± 0.00	53.30^{j} ± 0.46	31.55^{h} ± 0.13	0.02^{a} ± 0.00
I	0.0	20.03^{a} ± 8.55	6.70^{c} ± 0.00	39.88^{c} ± 6.57	41.17^{d} ± 0.03	39.49^{b} ± 11.08	0.02^{a} ± 0.00
I + B	0.1	46.39^{n} ± 0.22	6.89^{ab} ± 0.00	53.50^{gh} ± 1.73	31.65^{a} ± 0.17	24.61 ± 0.01	0.02^{a} ± 0.00
I + B	0.2	51.62^{o} ± 0.13	6.90^{ab} ± 0.02	47.00^{e} ± 1.16	38.90^{c} ± 0.00	32.85^{d} ± 0.01	0.02^{a} ± 0.01
I + B	0.3	54.00^{p} ± 1.55	6.78^{e} ± 0.02	55.50^{i} ± 0.58	44.23^{f} ± 0.03	33.78^{d} ± 0.03	0.02^{a} ± 0.00
I + B	0.4	57.02^{q} ± 2.96	6.91^{a} ± 0.00	60.50^{l} ± 0.58	51.31^{i} ± 0.01	19.30^{j} ± 0.00	0.02^{a} ± 0.01

Values are means ± standard deviation of two replicate readings. Values in the same column carrying different superscript are significantly different (P < 0.05)
Keys: I + A = Ice cream + hydrocolloids from achi; I + B = Ice cream + hydrocolloids from Both achi and ofor; I + C = Ice cream + CMC;
I + O = Ice cream + hydrocolloids from ofor; I = Ice cream without any stabilizer (Control)

Table 2. Sensory Scores of Ice cream samples stabilized with different stabilizers

Sample	Conc. (%)	Colour	Taste	Homogeneity	Mouthfeel	Aftertaste	Overall acceptability
I	0.0	$6.45^{bc} \pm 1.26$	$6.59^{abcde} \pm 0.49$	$5.50^{ef} \pm 1.26$	$6.18^{ab} \pm 0.44$	$6.33^{abcd} \pm 0.50$	$6.59^{bcdefg} \pm 0.80$
I + C	0.1	$7.35^{ab} \pm 1.04$	$5.50^{e} \pm 1.91$	$6.30^{bcdef} \pm 2.00$	$6.00^{b} \pm 1.38$	$5.80^{cd} \pm 1.91$	$6.15^{defg} \pm 1.84$
I + C	0.2	$7.80^{a} \pm 0.77$	$7.45^{a} \pm 1.14$	$7.15^{abc} \pm 1.35$	$7.25^{a} \pm 1.01$	$6.70^{abc} \pm 1.63$	$7.45^{ab} \pm 1.10$
I + C	0.3	$7.70^{a} \pm 0.85$	$7.40^{a} \pm 1.05$	$7.35^{ab} \pm 0.99$	$6.75^{ab} \pm 1.52$	$6.80^{abc} \pm 1.28$	$7.20^{abc} \pm 1.24$
I + C	0.4	$7.90^{a} \pm 0.91$	$7.25^{a} \pm 1.07$	$7.60^{a} \pm 1.39$	$7.25^{a} \pm 1.37$	$7.10^{ab} \pm 1.33$	$7.65^{a} \pm 0.75$
I	0.0	$6.45^{bc} \pm 1.26$	$6.59^{abcde} \pm 0.49$	$5.50^{ef} \pm 1.26$	$6.18^{ab} \pm 0.44$	$6.33^{abcd} \pm 0.50$	$6.59^{bcdefg} \pm 0.80$
I + O	0.1	$6.55^{bc} \pm 1.64$	$6.00^{cde} \pm 2.03$	$5.65^{def} \pm 1.98$	$5.95^{b} \pm 1.99$	$5.45^{d} \pm 2.28$	$5.95^{fg} \pm 2.01$
I + O	0.2	$6.65^{bc} \pm 1.14$	$6.30^{abcde} \pm 1.45$	$5.60^{ef} \pm 1.57$	$6.30^{ab} \pm 1.26$	$6.10^{abcd} \pm 1.29$	$6.45^{bcdefg} \pm 1.14$
I + O	0.3	$6.70^{bc} \pm 1.03$	$6.50^{abcde} \pm 1.85$	$6.45^{bcde} \pm 1.36$	$6.40^{ab} \pm 1.50$	$6.20^{abcd} \pm 1.70$	$6.65^{abcdefg} \pm 1.57$
I + O	0.4	$6.75^{bc} \pm 1.29$	$6.00^{cde} \pm 1.49$	$5.70^{def} \pm 1.81$	$6.05^{b} \pm 1.73$	$5.70^{cd} \pm 1.63$	$6.05^{efg} \pm 1.45$
I	0.0	$6.45^{bc} \pm 1.26$	$6.59^{abcde} \pm 0.49$	$5.50^{ef} \pm 1.26$	$6.18^{ab} \pm 0.44$	$6.33^{abcd} \pm 0.50$	$6.59^{bcdefg} \pm 0.80$
I + A	0.1	$7.20^{ab} \pm 1.44$	$7.10^{abc} \pm 1.48$	$6.80^{abcd} \pm 1.51$	$6.60^{ab} \pm 1.23$	$7.20^{a} \pm 0.89$	$7.05^{abcde} \pm 1.00$
I + A	0.2	$7.70^{a} \pm 1.08$	$7.30^{a} \pm 1.78$	$7.10^{abc} \pm 1.29$	$7.15^{a} \pm 1.30$	$7.00^{ab} \pm 1.65$	$7.15^{abcd} \pm 1.66$
I + A	0.3	$5.90^{c} \pm 2.07$	$5.75^{de} \pm 1.94$	$5.20^{f} \pm 1.96$	$5.85^{b} \pm 1.79$	$5.95^{bcd} \pm 1.96$	$6.10^{efg} \pm 1.74$
I + A	0.4	$7.15^{ab} \pm 1.42$	$7.20^{ab} \pm 1.15$	$6.40^{bcde} \pm 1.60$	$6.55^{ab} \pm 1.50$	$6.60^{abcd} \pm 1.35$	$6.80^{abcdefg} \pm 1.32$
I	0.0	$6.45^{bc} \pm 1.26$	$6.59^{abcde} \pm 0.49$	$5.50^{ef} \pm 1.26$	$6.18^{ab} \pm 0.44$	$6.33^{abcd} \pm 0.50$	$6.59^{bcdefg} \pm 0.80$
I + B	0.1	$6.55^{bc} \pm 1.23$	$6.60^{abcde} \pm 1.35$	$6.15^{cdef} \pm 1.63$	$6.40^{ab} \pm 1.31$	$6.75^{abc} \pm 1.33$	$6.75^{abcdefg} \pm 1.12$
I + B	0.2	$6.20^{c} \pm 1.77$	$6.10^{bcde} \pm 1.94$	$5.90^{def} \pm 1.15$	$6.05^{b} \pm 1.57$	$5.70^{cd} \pm 1.92$	$5.80^{g} \pm 1.99$
I + B	0.3	$6.77^{bc} \pm 1.30$	$6.40^{abcde} \pm 1.73$	$5.85^{def} \pm 1.14$	$6.35^{ab} \pm 1.35$	$6.25^{abcd} \pm 1.52$	$6.30^{cdefg} \pm 0.98$
I + B	0.4	$7.35^{ab} \pm 0.99$	$6.70^{abcd} \pm 1.49$	$6.50^{abcde} \pm 1.64$	$6.55^{ab} \pm 1.70$	$6.45^{abcd} \pm 1.61$	$6.85^{abcdef} \pm 1.09$

Values are means ± standard deviation. Values in the same column carrying different superscript are significantly different ($P < 0.05$)

Keys: I + A = Ice cream + hydrocolloids from achi; I + B = Ice cream + hydrocolloids from both achi and ofor; I + C = Ice cream + CMC; I + O = Ice cream + hydrocolloids from ofor; I = Ice cream without any stabilizer (Control)

3.2.4 Mouthfeel

The mean scores of mouthfeel of ice cream samples stabilized with CMC, hydrocolloid extracts of *achi*, *ofor* and both extracts were within the range of 5.85 ± 1.79 to 7.25 ± 1.37 (Table 2). In ice creams stabilized with the mixture of hydrocolloids from *achi* and *ofor* (Samples I+B) at 0.1%, 0.3% and 0.4%, there were no significant (*P >0.05*) differences in their mean mouthfeel scores with respect to the control samples (Table 3). When a*chi* hydrocolloid extracts were used at 0.1% and 0.4% respectively, the mean mouthfeel scores of the samples were statistically not significant (*P > 0.05*). For those ice creams produced with hydrocolloid extracts from *ofor* at 0.2% and 0.3% levels, there were no significant (*P > 0.05*) differences in the mouthfeel scores. Within the samples, ice creams stabilized with 0.1% and 0.4% *ofor* hydrocolloid extracts, showed no significant (*P > 0.05*) differences in the mouthfeel scores also. Similar trend was observed in samples stabilized with CMC at 0.2% and 0.4% respectively. The highest mean mouthfeel score was obtained in samples I+C at 0.4% concentration (7.25 ± 1.37). This could be attributed to the effect of hydrocolloids in the reduction of ice crystals formed in large and medium particles, improvement of textures as well as colour [24].

3.2.5 Aftertaste

The mean after taste scores of ice cream samples were within the range of 5.45 ± 2.28 to 7.20 ± 0.89 (Table 2). In comparison to the control samples, samples stabilized with CMC at 0.2% and 0.3% concentrations showed no significant (*P > 0.05*) difference in their aftertaste. With samples I+A being formulated, only the samples at 0.4% level gave no significant (*P > 0.05*) difference in the aftertaste mean scores, with respect to the control samples. Other samples produced with hydrocolloid extracts of *achi* (samples I+A) were significantly (*P < 0.05*) different from one another at 0.1%, 0.2%, 0.3% and 0.4% concentrations with respect to the control samples. There were no significant (*P > 0.05*) differences in the aftertaste of ice cream samples stabilized with 0.3% and 0.4% mixed hydrocolloids from both *achi* and *ofor* (i.e. Samples I+B), in relation with the control samples. Similarly, ice cream samples stabilized with 0.2% and 0.3% hydrocolloid extracts of *ofor* showed no significant (*P > 0.05*) difference in the mean aftertaste scores, with respect to the control samples. This buttresses the fact that hydrocolloid extracts of *ofor (Detarium microcarpum)* could be capable replacer of CMC as stabilizers in ice cream production.

3.2.6 Overall acceptability

The mean overall acceptability scores of ice cream samples stabilized with CMC, *achi, ofor*, both *ofor* and *achi* hydrocolloid extracts ranged from 5.80 ± 1.99 to 7.65 ± 1.00 (Table 3). The type of stabilizers used in the production of ice cream greatly affects its overall acceptability. There were significant (*P < 0.05*) differences in the overall acceptability of the samples stabilized with the mixture of hydrocolloids from both *achi* and *ofor* at 0.1%, 0.2%, 0.3% and 0.4% concentrations. Similar trends were observed when hydrocolloid extracts of *achi* and CMC were used as stabilizers at the aforementioned concentrations. However, when the hydrocolloids extract from *ofor* was used as stabilizers, there was no significant (*P > 0.05*) difference in the overall acceptability of samples I+O at 0.2% when compared with the control samples.

3.3 Effect of Stabilizers and Concentrations on the Microbiological Qualities of Ice Cream

3.3.1 Total viable count

The Total Viable Count (TVC) of the ice cream samples ranged from 1.8 x 10^4 CFU / g to 2.8 x 10^5 CFU /g (Table 3). From the results, Ice cream samples stabilized with CMC and those stabilized with a mixture of hydrocolloids of *achi* and *ofor*, were within the acceptable limit of Public Health safety because their Total Viable Count did not exceed the limit (1 x 10^5 CFU / ml) permitted under regulation [25]. However, ice cream samples stabilized with hydrocolloid extracts of *achi* (samples I+A) at concentrations 0.2%, 0.3%, 0.4% and those samples stabilized with hydrocolloids of *ofor* (sample I+O) at 0.1% and 0.2% concentrations, were not within the permissible limit. Inadequate processing such as improper cooling of the hot ice cream mix leading to the multiplication of microorganisms present in ice cream immediately after pasteurisation, might have resulted to this [26].

3.3.2 Coliform count

The Coliform count of the ice cream samples ranged from 0.0 – 20.0 CFU / g (Table 3) which did not exceed the permissible limit (1.0 × 10^2 CFU / g) according to [27]. It has been reported that Coliform count could be used as a yardstick to determine the hygienic nature of ice cream.

Table 3. Total viable count, coliform count and mould count of the ice cream samples

Sample	Conc. (%)	Total viable count (CFU/g)	Coliform count (CFU/g)	Mould count (CFU/g)
I	0.0	3.6×10^4	NG	NG
I + C	0.1	8.1×10^4	NG	NG
I + C	0.2	1.8×10^4	1.0×10^1	NG
I + C	0.3	4.8×10^4	NG	NG
I + C	0.4	3.4×10^4	1.3×10^1	NG
I	0.0	8.2×10^4	NG	NG
I + O	0.1	1.4×10^5	1.0×10^1	NG
I + O	0.2	1.6×10^5	NG	NG
I + O	0.3	3.9×10^4	NG	NG
I + O	0.4	3.2×10^4	NG	NG
I	0.0	3.0×10^4	1.3×10^1	NG
I + A	0.1	3.5×10^4	2.0×10^1	NG
I + A	0.2	2.8×10^5	1.5×10^1	NG
I + A	0.3	1.3×10^5	1.8×10^1	NG
I + A	0.4	3.7×10^5	2.0×10^1	NG
I	0.0	6.3×10^4	1.0×10^1	NG
I + B	0.1	3.3×10^4	NG	NG
I + B	0.2	5.2×10^4	NG	NG
I + B	0.3	3.1×10^4	NG	NG
I + B	0.4	4.8×10^4	NG	NG

Values are means from two replicate readings.

Keys: I + A = Ice cream + hydrocolloids from achi; I + B = Ice cream + hydrocolloids from Both achi and ofor; I + C = Ice cream + CMC; I + O = Ice cream + hydrocolloids from ofor; I = Ice cream without any stabilizer (Control); NG = No Growth

[28] found out that squalid conditions of processing as well as contamination in the course of processing the raw materials, production, packaging and merchandising, might be attributed to high coliform counts in ice cream. Poor sanitation of the equipment, environment within which the production is carried out, poor sanitary practices from the handlers during preparation and/or at warehouses, could lead to high coliform counts [29].

3.3.3 Mould count

There was no mould growth in all the ice cream samples. Possible reason for no detectable growth in those samples was the antifungal effects of *Detarium microcarpum* and *Brachystegia eurycoma* [30,31].

4. CONCLUSION

From the results, the incorporation of local stabilizers significantly improved the physicochemical, sensory and microbial qualities of ice cream produced. hydrocolloid extracts of *Detarium microcarpum* (Ofor), plant-based natural stabilizer is a capable replacer of CMC in ice cream production because of its higher viscosity than other stabilizers and CMC, agreeable consistency, better consumer preference than other stabilizers, enhanced qualities – slow melting rate i.e. high melting resistance, commendable pseudo-plasticity, effectual overrun which will yield more profits for ice cream manufacturers, bring about a new variety of ice creams that are safe for consumption. Hydrocolloid extracts of *Detarium microcarpum*, at 0.3%, showed more desirable similar effects on the physicochemical, sensory and microbial qualities of ice cream samples formulated compared to CMC and could, therefore be recommended as a replacer of CMC in ice cream production. For further development, we recommend improvement in the hygienic status, quality of the raw materials used and good hygienic practices prior, during and after production in order for the product to meet the microbiological requirements for safety. It is then concluded that commercialization of ice creams with *Detarium microcarpum* hydrocolloid extracts as stabilizers can be a reality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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