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Production and Evaluation of Instant Breakfast Cereals Using Whole Corn, Millet, Sorghum and Rice

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Abstract:
This research investigated the production and evaluation of instant breakfast cereals from blends of whole corn, millet, sorghum and rice. Commercial Quaker oat was used as control. Two pre-cooking methods were adopted: steaming at 104°C for 55 minutes and toasting at 250°C for 55 minutes. The grains were milled into individual grits prior to formulation. A total of sixteen samples were formulated, eight were steamed (100:0 = SC, SM, SR, SS; 50:50 = SCR, SCM, SCS; 25:25:25:25= SBG), and the other eight were toasted (100:0 = TC, TM, TR, TS, and 50:50 = TCR, TCM, TCS; 25:25:25:25 = TBG). The samples were assessed for their functional properties, reconstitution time, solubility and sensory attributes. The result of the functional properties revealed the following: pH (5.15 to 6.60), bulk density (0.43 to 3.55 g/ml), oil absorption capacity (0.24 to 3.02 %), water absorption capacity (1.13 to 188.5 g/g), gelation temperature (50.95 to 124°C), wettability (15.60 to 80.20 seconds), and emulsion capacity (15.15 to 35.15%). The reconstitution time and solubility test values ranged from 20.6 to 49.4 s and 2.20 to 17.55% respectively. The appearance, consistency, aroma, taste, mouth feel and overall acceptability of the breakfast cereals differ significantly ($p<0.05$) when assessed for their sensory attributes. Samples developed from toasted 25% corn + 25% rice + 25% millet + 25% sorghum was best accepted and preferred. Conclusively, acceptable instant breakfast cereals with improved nutrition could be developed from blends of whole corn, millet, sorghum and rice.

Keywords: Breakfast Cereal, Functional Properties, Reconstitution Solubility, Sensory Evaluation

1. Introduction

Breakfast cereals are simply defined as foods obtained by swelling, grinding, rolling or flaking of any cereal (Sharma and Caralli, 2004). They can be categorized into traditional (hot) cereals that require further cooking or heating before consumption and ready-to-eat (cold) cereals that can be consumed from the box or with the addition of milk (Fast, 2000). Traditional flour milling process produces refined flour. During this process, the bran and germ layers of grain are removed in order to stabilize the raw material and to increase the keeping quality. If the bran, germ and endosperm components are retained during the milling process, the resulting flour is classified as whole grain (Franz and Sampson, 2006). Whole grains contain all the essential parts and the same balance of nutrients that are found in the original grain seed. Compared to refined flour, whole grains are nutritionally superior; they are richer in dietary fibre, protein, antioxidants, dietary minerals and vitamins.

Maize or corn (*Zea mays*) is a staple food for an estimated 50% population. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. More than 40 different ways of consuming maize had been recorded in many countries in Africa (Nago *et al.*, 1990). Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer. Maize has various health benefits. The B-complex vitamins in maize are good for skin, hair, heart, brain, and proper digestion. They also prevent the symptoms of rheumatism because they are believed to improve the joint motility. The presence of vitamins A, C, and K together with beta-carotene and selenium helps to improve the functioning of thyroid gland and immune system. Potassium is a major nutrient present in maize which has diuretic properties.

Millets are small-seeded cereals having excellent nutritional quality. They are comparable or superior to some commonly consumed cereals like wheat and rice (Ragaee *et al*. 2006). Despite its superior nutritional quality, it has received less attention compared to the major cereals. A few studies have focused on the nutrient quality of pearl millet however documentation on the other types is limited. Millets are also preferred to be decorticated to improve sensory quality and bioavailability of nutrients (Lestienne *et al.* 2007).

Sorghum (*Sorghum bicolor*) is a known by a variety of names (such as great millet and guinea corn in West Africa, kafir corn in South Africa, jowar in India and kaoliang in China) and is a staple food in many parts of Africa, Asia, and parts of the Middle East.

Rice is the main staple food for more than half of the world's population. The cereal was also utilized as a popular remedy since ancient times for several therapeutic purposes. Rice or rice-based products were also well documented in the traditional medicines of different Asian countries. The well-known popular uses are anti-diabetic, anti-inflammatory for the airway, ailment of gastrointestinal disorders and diarrhoea, diuretic, source of vitamins and skin preparations (Umadevi *et al*., 2012). Traditional flour milling process produces refined flour void of the bran and germ; with reduced nutritional value. This research would stimulate the establishment of using whole local grains in producing breakfast cereals which would help decrease risk of cardiovascular disease, diabetes, obesity and certain cancers (McKeown *et al*., 2002). Thus, this work is aimed at producing and evaluating instant breakfast cereals using whole corn, millet, sorghum and rice.

2. Research Methods

Material

Whole corn (Plate 1), millet (Plate 2), sorghum (Plate 3) and rice (Plate 4) were purchased from Ubani main market Umuahia Abia State, Nigeria. The raw materials were processed at the laboratory of the Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, Nigeria for further processing.

Figure 1. Material used in the research: whole corn grain (a), whole millet grain (b), whole sorghum grain (c), whole rice grain (d)

Methods

The experimental design was laid on a completely randomized design (CRD) with heating methods and analyses being the treatments. Equal treatments were assigned to all the samples. The design was modelled according to Hinkelmann (2012) as:

$$X_{ij} = \mu + \quad + €_{ij}$$

Where:
X_{ij} = Independent Observation
$€_{ij}$ = Experimental error

The data obtained were evaluated and statistically analyzed using analysis of variance (ANOVA) and means separated using Tukey's test of the Statistical Package for Social Sciences (SPSS) version 20 (SPSS, 2003). The level of significance will be accepted at 0.05 probability level.

Research Procedures

Processing of Whole Grains Into Grits

Corn (yellow), millet (pearl), sorghum (red) and rice (brown) grain seeds were properly cleaned and sorted to remove stones, dirt, chaff, and other extraneous matters, before they were used for further processing. The method as described by Okaka (2005) was used. Each of the grains was divided into two parts; one part was steamed (at 104 ^{o}C for 55 minutes) and the other toasted (at 250^{o}C for 55 minutes). The steamed part was further oven dried (at 80^{o}C) until constant weight was obtained. Both the steamed and toasted grains were milled using attrition milling machine into grits (Figure 3 and 4). The flow diagram for the production of whole cereal grits is shown in Figure 2. The resulting grits were used to formulate samples as shown in Table 1, which were further used to make the breakfast cereals by reconstitution.

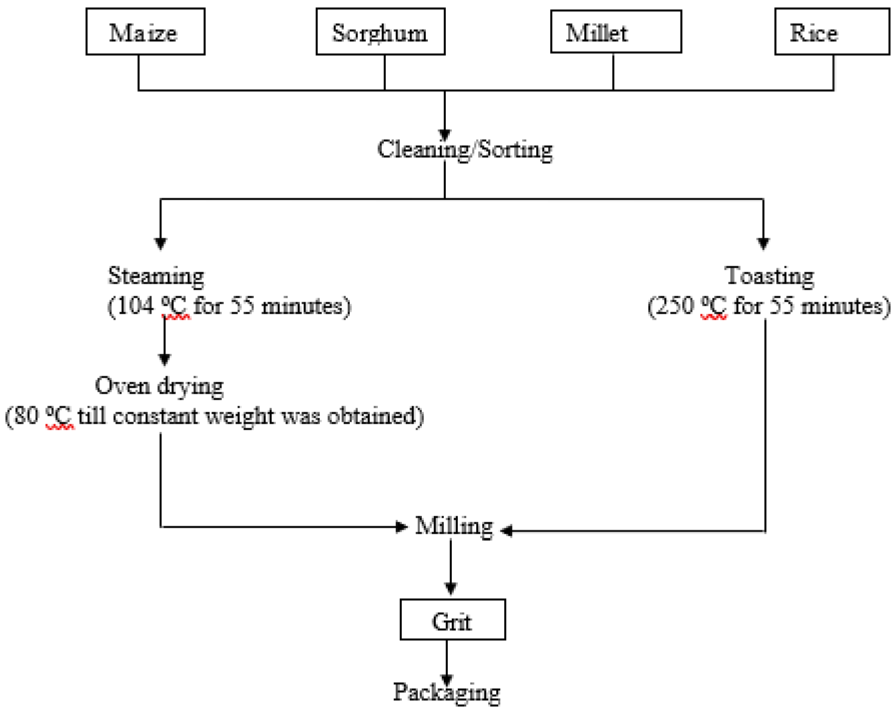

Figure 2. Flowchart for the production of whole breakfast cereal

Whole Millet Grits Whole Rice Grits Whole Corn Grits Whole Sorghum Grits

Figure 3. Steamed samples of whole grain grits

Whole Millet Grits Whole Rice Grits Whole Corn Grits Whole Sorghum Grits

Figure 4. Toasted samples of whole grain grits

Table 1. Blend formulation for breakfast cereal production

Samples	Ratio	Samples	Ratio
QM	100:0	TC	100:0
SC	100:0	TM	100:0
SM	100:0	TS	100:0
SS	100:0	TR	100:0
SR	100:0	TCR	50:50
SCR	50:50	TCM	50:50
SCM	50:50	TCS	50:50
SCS	50:50	TBG	25:25:25:25
SBG	25:25:25:25		

Keys**:** S = steamed, T = toasted, C = Corn (maize), M= Millet, S = Sorghum, R = Rice, QM = Quaker Oat (Control sample), SC = 100% steamed whole corn, SM = 100% steamed whole millet, SS = 100% steamed whole sorghum, SR = 100% steamed whole rice, SCR = 50% steamed corn:50% steamed rice, SCM 50% steamed corn:50% steamed millet, SCS = 50% steamed corn:50% steamed sorghum, SBG = 25% steamed corn:25% steamed rice:25% steamed millet:25% steamed sorghum, TC = 100% toasted whole rice, TM = 100% toasted whole millet, TS = 100% toasted whole sorghum, TR = 100% toasted whole sorghum, TCR = 50% toasted corn:50% toasted rice, TCM 50% toasted corn:50% toasted millet, TCS = 50% toasted corn:50% toasted sorghum, TBG = 25% toasted corn:25% toasted rice:25% millet:25% sorghum.

Determination of pH

The pH of the food samples was measured with a Mettler Delta 350 pH meter using the method described by Onwuka (2018). The sample homogenates was prepared by blending 10 g sample in 100 ml of deionized water. The mixture was filtered and the pH of the filtrate was measured. Triplicate readings were taken for each sample.

Determination of Bulk Density

Bulk density was determined for each of the formulated samples using the method described by Onwuka (2018). Each sample was slowly filled into 10 ml measuring cylinder. The bottom of the cylinder was gently tapped on a laboratory bench until there is no further diminution of the sample after filling to 10 ml mark. Bulk density was estimated as mass per unit volume of the sample (g/ml). Triplicate measurements were taken.

Oil and Water Absorption Capacity (OAC/WAC)

The Water and Fat absorption capacities of the formulated samples were determined using the method described by Onwuka (2018). One (1) g of each of the samples was weighed into a conical graduated centrifuge tube, and then a warring whirl mixer was used to thoroughly mix the sample with 10 ml of distilled water or oil for 30 minutes. The mixture was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000 xg for 30 minutes. The volume of free water or oil (supernatant) was read directly from the graduated centrifuge tube. The absorption capacity was expressed as gram of oil or water absorbed (or retained) per gram of sample.

Gelation Capacity

The gelation capacity was determined using the method described by Onwuka (2018). Two to twenty (2 – 20) % W/V suspension of each of the samples was prepared in 5 ml distilled water in test tubes. The sample test tubes were heated for 1 hour in a boiling water bath which was followed by rapid cooling under running cold tap water. The test tubes were further cooled for 2 hours at 4^{o}C. The least gelation concentration was determined as that concentration at which the sample from the inverted test tube did not fall down or slip visually.

Wettability

The method described by Onwuka (2018) was adopted. One gram of sample was added into a 25 ml graduated cylinder. It was inverted and clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was removed to allow the test to be dumped. The wettability is the time (seconds) required for the sample to become completely wet.

Determination of Reconstitution Time (s) of The Breakfast Cereals

Reconstitution time (in seconds) was determined by the method described by Nwanekezi *et al*. (2001). Two grams of each sample flour was spread on the surface of 50 mL of distilled water at room temperature (28±1ºC) in 150 ml cylinder. The time taken for the flour to completely disperse was recorded as the reconstitution time.

Solubility Test of The Breakfast Cereal

Water solubility index was determined by the method of Onwulata *et al*. (1998). Two grams of each sample flours was weighed into a porcelain dish and hydrated with 10 ml of distilled water. The hydrated flour was heated in a water bath at 100°C for 30 minutes and allowed to cool to room temperature. The supernatant was decanted, weighed, evaporated to dryness and weighed. Water solubility index was calculated as the weight percent of the dry supernatant.

Determination of The Sensory Attributes of The Breakfast Cereals

The method described by Iwe (2010) was adopted in conducting the sensory evaluation of the breakfast cereals. Twenty (20) panelists were selected from Michael Okpara university of Agriculture

Umudike, including staff and students. The panelists were given orientation and were partially trained. The semi-trained panelists were served the breakfast cereal samples. They were asked to rate the samples for appearance, aroma, taste, consistency, mouth feel and general acceptability based on the 9-point Hedonic scale; where 9 is 'extremely like', through 5 'neither like nor dislike', to 1 'dislike extremely'.

3. Results and Discussion

Functional Properties of The Breakfast Cereals

The functional properties of the instant breakfast cereals are presented in Table 2. The pH values of the samples ranged from 5.15 to 6.60. There was no significant difference (p>0.05) between the control sample (Quaker oat) and steamed samples (100 % steamed millet, 50% steamed corn:50% steamed rice, 50% steamed corn:50% steamed millet). This implies that both the 100% steamed millet and blended steamed samples showed no significant difference (p<0.05) with the control. The 100% steamed corn recorded highest pH value for unblended samples, while steamed 50% corn + 50% millet recorded highest pH value in terms of blended samples. The pH values of the steamed samples were in agreement with that of Oladapo *et al.* (2017) who obtained 6.20 for maize grain flour. There was significant difference (p<0.05) between the toasted breakfast cereals and the Quaker oat, but no significant difference (p>0.05) among the toasted samples. Agunbiade and Ojezele (2010) reported pH of 4.88 for fortified breakfast cereals from maize, sorghum, African yam bean and soybeans. The low acidity obtained especially in the steamed samples may be as a result of the imbibing of water molecules during steaming of the products. Food products developed with whole grains provide health benefits like lowering of blood cholesterol, reducing high blood sugar or preventing cancer, aside from its nutritional contribution (Capanzana *et al.*, 2013). The low acidic value of these breakfast cereals will help to balance the consumer's body pH (McCarron, 2011).

Table 2. Physical properties of instant breakfast cereal produced from corn, millet, rice and sorghum

Sample	pH	BD (g/ml)	OAC (%)	WAC (g/g)	GT (^{o}C)	Wett (seconds)	EC (%)
QM	$6.45^{a}\pm0.71$	$0.84^{b}\pm0.07$	$0.24^{g}\pm0.14$	$6.35^{c}\pm0.42$	$80.60^{d}\pm0.10$	$32.55^{g}\pm0.07$	$20.45^{i}\pm0.07$
SC	$6.10^{b}\pm1.40$	$3.55^{a}\pm0.07$	$0.75^{ef}\pm0.07$	$1.61^{e}\pm0.01$	$59.0^{jk}\pm0.00$	$44.04^{e}\pm0.56$	$35.15^{a}\pm0.05$
SM	$6.55^{a}\pm0.71$	$0.91^{b}\pm0.14$	$1.35^{b}\pm0.14$	$1.52^{e}\pm0.28$	$89.5^{b}\pm0.71$	$20.65^{j}\pm0.21$	$18.20^{j}\pm0.28$
SS	$5.65^{cd}\pm0.21$	$0.53^{b}\pm0.07$	$3.02^{a}\pm0.28$	$5.23^{d}\pm0.14$	$60.10^{j}\pm0.14$	$29.62^{h}\pm0.14$	$25.30^{j}\pm0.14$
SR	$6.51^{a}\pm0.21$	$0.92^{b}\pm0.28$	$1.24^{cd}\pm0.21$	$188.5^{a}\pm2.1$	$57.80^{k}\pm0.28$	$25.50^{i}\pm0.28$	$27.15^{ef}\pm0.07$
SCR	$6.40^{a}\pm0.00$	$0.82^{b}\pm0.07$	$1.25^{cd}\pm0.07$	$1.81^{e}\pm0.14$	$60.15^{j}\pm0.14$	$60.22^{c}\pm0.28$	$29.70^{cd}\pm0.28$
SCM	$6.60^{a}\pm0.14$	$0.96^{b}\pm0.21$	$1.21^{d}\pm0.07$	$1.72^{e}\pm0.21$	$70.15^{g}\pm0.71$	$60.27^{c}\pm0.01$	$26.15^{fg}\pm0.21$
SCS	$6.05^{bc}\pm0.70$	$0.83^{b}\pm0.21$	$0.82^{e}\pm0.07$	$1.71^{e}\pm0.14$	$50.95^{l}\pm0.71$	$33.20^{f}\pm0.28$	$28.65^{d}\pm0.07$
SBG	$6.35^{b}\pm0.70$	$0.61^{b}\pm0.14$	$0.61^{f}\pm0.14$	$1.64^{e}\pm0.14$	$70.15^{g}\pm0.21$	$60.41^{c}\pm0.01$	$29.05^{d}\pm0.07$
TC	$5.75^{cd}\pm0.71$	$0.43^{b}\pm0.07$	$0.45^{fg}\pm0.01$	$1.81^{e}\pm0.14$	$80.50^{d}\pm0.21$	$16.45^{k}\pm0.07$	$30.25^{bc}\pm0.21$
TM	$5.90^{cd}\pm0.00$	$1.01^{b}\pm0.14$	$1.01^{e}\pm0.14$	$1.63^{e}\pm0.14$	$124.0^{a}\pm1.42$	$16.75^{k}\pm0.07$	$15.15^{k}\pm0.21$
TS	$5.15^{f}\pm0.71$	$0.54^{b}\pm0.12$	$1.04^{e}\pm0.14$	$7.31^{c}\pm0.14$	$77.50^{d}\pm0.11$	$15.60^{l}\pm0.14$	$20.15^{i}\pm0.21$
TR	$5.50^{de}\pm0.14$	$0.56^{b}\pm0.07$	$0.58^{f}\pm0.01$	$21.3^{b}\pm0.14$	$64.0^{i}\pm1.41$	$16.80^{k}\pm0.14$	$21.30^{ij}\pm0.14$
TCR	$5.70^{de}\pm0.14$	$0.50^{b}\pm0.71$	$0.53^{f}\pm0.01$	$1.13^{e}\pm0.35$	$66.50^{h}\pm2.12$	$20.25^{j}\pm0.71$	$22.20^{h}\pm0.14$
TCM	$5.55^{de}\pm0.14$	$0.74^{b}\pm0.14$	$1.51^{f}\pm0.01$	$1.94^{e}\pm0.14$	$74.15^{f}\pm1.48$	$65.15^{b}\pm0.21$	$27.50^{e}\pm0.07$
TCS	$5.70^{cd}\pm0.14$	$0.63^{b}\pm0.21$	$0.71^{ef}\pm0.01$	$1.88^{e}\pm0.21$	$83.05^{c}\pm0.17$	$80.20^{a}\pm0.21$	$31.0^{b}\pm1.41$
TBG	$5.40^{e}\pm0.14$	$0.77^{b}\pm0.70$	$0.94^{e}\pm0.14$	$1.84^{e}\pm0.42$	$70.35^{g}\pm0.71$	$45.30^{d}\pm0.14$	$35.0^{a}\pm0.14$

Means ± standard deviation of duplicate determinations $^{a-l}$. Means with the same superscripts within the same column are not significantly different (p>0.05).

Keys: BD = Bulk density, OAC= Oil absorption capacity, WAC= Water absorption capacity, GT= Gelation temperature, Wett= Wettability, EC= Emulsion capacity.

There was no significant difference (p>0.05) in the bulk density of the breakfast cereal samples except 100% steamed corn which had a bulk density value of 3.55 g/ml. This might be attributed to the different proportion used in the formulation of the samples. This result is higher than that of Agunbiade and Ojezele (2010) who in their findings reported the bulk density range of 2.45 to 2.60 g/ml for fortified breakfast cereals made from maize, sorghum, African yam bean and soybeans. This might be as a result of those legumes incorporated in their formulation. The differences in the bulk density suggest that the samples may require different packaging space. The less the bulk density, the more packaging space is required (Agunbiade and Ojezele, 2010). However, Rao and Rao (2007) in their study observed that considerable variation in the magnitudes of bulk densities could be as a result of vibration, different particle sizes, and other factors. The low values of bulk densities make the flour suitable for high nutrient density formulation of foods. Bulk density is generally affected by the particle size and density of the flour and it is very important in determining the packaging requirement, material handling and application in wet processing in food industry (Karuna *et al.*, 1996). The lower the bulk density, the higher the amount of flour particles that can bind together leading to higher energy values (Onimawo and Egbekun 1998).

The oil absorption capacity (OAC) of the breakfast cereals values ranged from 0.24 to 3.02% with the highest value recorded in 100% steamed sorghum, while the oat (control sample) had the lowest value. The OAC of the samples were very low compared to that of Oladapo *et al.* (2017) who obtained 82.00 % for maize grain flour. There was significant difference ($p<0.05$) among the OAC of the steamed samples. The toasted samples ranged from 0.45 to 1.51% with the blend of 50% toasted corn:50% toasted millet having the highest value while 100% toasted corn had the lowest value. There was significant difference ($p<0.05$) among toasted samples except samples TM, TS, TCS and TBG which showed no significant difference ($p<0.05$) with mean values of 1.01%, 1.04%, 0.71%, and 0.94% respectively. The hydrophobicity of proteins is known to play a major role in fat absorption. This helps to resist physical entrapment of oil by the capillary of non-polar side chains of the amino acids of protein molecules (Chau and Cheung, 1998).

The water absorption capacity (WAC) of the formulated breakfast cereals ranged from 1.13 to 188.50 g/g with 100% steamed rice having the highest WAC value, while 50% toasted corn:50% toasted rice had the lowest value. All the steamed blended samples had no significant difference ($p>0.05$). However, the toasted samples had significant difference ($p<0.05$) ranging from 1.13 to 21.3%. This result also shows that the WAC increased with increase in whole rice grits inclusion. This may be due to the hygroscopic properties of rice, thus, swelling on exposure to moisture (Wasserman, 2010). The high WAC value could be attributed to the heat treatment (steamed) method which expose the starch granules. Similar values were recorded from treated and untreated sorghum and pigeon pea breakfast cereals (Mbaeyi, 2005). On the other hand, water absorption capacity of the breakfast cereals may equally be associated with the nature of starch granules after toasting. The difference in water absorption is mainly caused by the greater number of hydroxyl group which exists in the fibre structure and allows more water interaction through hydrogen bonding (Nassar *et al.,* 2008). Hence, water absorption capacity can be said to be influenced by the degree of disintegration of native starch granules. Therefore, damaged starch is likely to increase and will require more fluid such as water or milk on reconstitution.

The gelation temperature of the breakfast cereals is ranged from 50.95 to 124 ^{o}C. All the samples showed a significant difference. Steamed samples ranged from 50.95 to 89 ^{o}C with sample SM (100% steamed millet) having the highest value, while sample SCS had the lowest. There was no significant difference ($p>0.05$) in the blended and unblended samples except samples SCR and SS with mean values of 60.15 and 60.10 ^{o}C respectively. There was a significant difference ($p<0.05$) among the toasted samples. The values ranged from 64.0 to 124.0 ^{o}C with sample TM having the highest value, while TR had the lowest value. The mean values obtained from both methods showed a close relationship with existing literatures. The control sample QM (100% oat) and sample TS (100% sorghum) showed no significant ($p>0.05$) difference. The value obtained in sample (TM) (100% toasted millet) is within the range of gelation temperature (121^{o}C to 157^{o}C) obtained by Okafor and Usman (2015) on breakfast cereals from blends of maize, African yam bean, defatted coconut cake and sorghum extract. However, the other samples were also in line with a study carried out by (Usman, 2009) who reported gelation temperature range of 75.32 to 89.66 ^{o}C in a breakfast cereal from blends of African yam bean, maize and defatted coconut. Gelatinization is an important processing step determining the physical properties of starch-based products. During gelatinization, the molecular order of the starch granules is irreversibly destroyed by structural changes which involve changes of shape and size of granules, absorption of water and swelling, crystallite melting, and leaching of amylose (amylopectin) from the granules (Spigo and Faveri, 2004). A gel represents a transitional phase between solid and liquid states. In food systems, the molecular net consists of proteins, polysaccharides or a mixture of both, while the liquid is usually water (Wasserman, 2010).

The wettability result showed that the particles of the formulated samples were totally hydrated between 15.60 to 80.20 seconds. The steamed samples showed a wettability range of 20.65 to 60.41 seconds, with sample SBG having the highest wettability value while steamed whole millet had the least wettability value. The control sample showed no significantly different ($p>0.05$) from sample 100% steamed whole millet. However, the wettability range values of the whole toasted samples are shorter than that of other samples followed by the whole steamed samples. This variations might be attributed to the different proportions of the samples. The toasting process and continuous stirring which helped to dehydrate and agglomerate the particles upon gelatinization into small aggregates may also contributed in making them to be readily absorbed fluid during rehydration. The particles sank, absorbed water and dispersed upon stirring. Hence, the characteristics such as wettability, sinkability, dispersibility, and solubility required from instant products were met within some seconds (Hogekamp and Schubert, 2000).

The emulsion capacity (EC) of the instant breakfast cereals produced from corn, millet, sorghum and rice showed values ranging from 15.15 to 35.15%, with the highest value recorded for 100% steamed whole corn and lowest for 100% steamed whole millet. There was significant difference ($p<0.05$) in all the samples except 100% steamed whole corn and 25% toasted corn:25% toasted millet:25% toasted sorghum:25% toasted rice which showed 35.15 and 35.00 % respectively. Both the steamed and toasted samples showed significant difference ($p<0.05$) in the EC value. The disparity in the EC values could be a reflection of their content of protein molecules that hangs oil and water droplets. The EC is the ability of proteins to diffuse at the oil-water interface and to develop inter linkages with water and hydrophilic amino acids and oil with hydrophobic amino acids simultaneously (Ashraf *et al.,* 2012).

The Reconstitution Time and Solubility Test of Instant Breakfast Cereal

The reconstitution time of the breakfast cereal and their composites is presented in Table 3. The mean values ranged from 20.6 to 49.4 seconds. The steamed samples ranged from 27.10 to 42.05 seconds. The control sample (Quaker oat) showed the least value when compared with steamed samples with mean value of 20.60 seconds. The blended samples showed a higher mean score when compared with the unblended. There was significant difference ($p<0.05$) among blended except for blended steamed samples (50% steamed corn:50% steamed millet and 50% steamed corn:50% steamed sorghum) which showed mean values of 31.85 and 32.20 seconds respectively. The toasted samples showed mean value range of 28.80 to 49.40 seconds with 50% toasted corn + 50% toasted rice having the highest mean value while 100% toasted whole corn had the lowest mean value. The improved reconstitution time was more evident in the steamed samples which took 25.0 to 42.05 seconds than in the toasted samples that took 28.80 to 49.40 seconds to reconstitute. The reason could probably be as a result of weakening the hydrophilic bonds and the glycosidic linkages between starch molecules during steaming, thereby allowing the imbibition of water and allowing easy dissolution and reconstitution. The reconstitution times obtained in this study were within the range of reconstitution time (20.0 to 92.5 seconds) reported by Mbaeyi (2005) on breakfast cereals made from sorghum and pigeon pea. These values obtained in this study showed that little energy would be required for reconstitution.

The result of solubility of the instant breakfast cereals produced from corn, millet, sorghum and rice is also presented in Table 3. The solubility increased from 2.20 to 17.55%. This implied that there was significant difference ($p< 0.05$) among the samples. The solubility of the steamed samples ranged from 2.20 to 16.40%, with 25% steamed corn:25% steamed rice:25% steamed millet:25% steamed sorghum being the highest while 100% steamed whole sorghum had the lowest. The steamed blended samples showed higher solubility than the unblended. The toasted samples ranged from 4.23 to 17.55% with 50% toasted corn:50% toasted sorghum having the highest mean value while 100% toasted whole sorghum had the lowest mean value. There was significant difference ($p<0.05$) among the toasted samples. Blended toasted samples had higher solubility values when compare with unblended (100% samples). The solubility values obtained in this study partially agreed with that of Eke-Ejiofor *et al.* (2016) who reported the solubility value range of 23.07 to 25.18% in a breakfast cereals substituted with Maize and Coconut. However, the solubility values obtained in this study were not in agreement with that of Oladapo *et al.* (2017) who reported the solubility value of 1.01% in a composite flour. Lower values of flour solubility indicate the existence of strong bonding forces within the flour granules arising from coagulated protein or fat that form complexes with amylose preventing it from leaching from the granules (Sung and Stone, 2003). Factors capable of influencing the solubility of flours/grist include flour composition and particle size, density and pH, processing conditions and storage conditions (Mirhosseini and Amid, 2013). Solubility of flours/grits are influenced by the extent to which water is absorbed and retained within starch granules and the increase in solubility values could be attributed to increase leaching of solubilized amylose molecules from swelled starch granules promoted by destruction of the starches (Pomeranz, 1991).

The Sensory Evaluation of Breakfast Cereal

The mean sensory scores of the breakfast cereals are shown in Table 4. The sensory results revealed that the appearance of all the breakfast cereal samples ranged from 5 to 7 according to the 9-point hedonic scale. The steamed samples were moderately liked more than the toasted samples and the control. This showed that there was significant difference ($p<0.05$) between the steamed samples and other samples in terms of appearance. This might be as a result of the different heating methods given to those samples or the varying proportions used in the formulation. Appearance of any food in terms of the size, shape, colour, temperature and texture can influence consumer’s reactions or impressions about the food.

Table 3 : Reconstitution Time and Solubility Test of Instant Breakfast Cereal Produced From Corn, Millet, Rica and Sorghum

Samples	Reconstitution Time (seconds)	Solubility Test (%)
QM	20.60^{j}±0.14	15.15^{c}±0.21
SC	25.05^{i}±0.21	11.10^{f}±0.01
SM	27.95^{h}±0.21	9.14^{h}±0.28
SS	27.10^{h}±0.14	2.20^{l}±0.03
SR	38.35^{e}±0.21	5.98^{j}±0.01
SCR	42.05^{c}±0.35	14.10^{d}±0.01
SCM	31.85^{f}±0.21	12.45^{e}±0.01
SCS	32.30^{f}±0.14	10.55^{g}±0.01
SWG	38.20^{e}±0.14	16.40^{b}±0.01
TC	28.80^{g}±0.14	12.05^{ef}±0.01
TM	32.25^{f}±0.21	9.71^{h}±0.02
TS	29.20^{g}±0.14	4.23^{k}±0.04
TR	42.50^{b}±0.14	7.17^{i}±0.02
TCR	49.40^{a}±0.14	16.35^{b}±0.01
TCM	42.30^{b}±0.42	12.83^{e}±0.04
TCS	42.30^{b}±0.42	17.55^{a}±0.01
TWG	40.15^{d}±0.21	11.60^{ef}±0.14

Means ± standard deviation of duplicate determinations $^{a-l}$. Means with the same superscripts within the same columns are not significantly different ($p>0.05$)

Table 4 : Sensory Scores of The Breakfast Cereals

Samples	Appearance	Consistency	Aroma	Taste	Mouth feel	Overall Acceptability
QM	6.29^{b}±0.02	5.50^{c}±0.00	7.10^{a}±0.01	5.89^{b}±0.00	5.90^{a}±0.01	7.90^{a}±0.12
SC	5.67^{b}±0.01	5.45^{c}±0.21	5.90^{b}±0.01	6.01^{b}±0.28	5.89^{a}±0.01	6.01^{b}±0.01
SM	5.57^{c}±0.13	6.90^{b}±0.14	5.91^{b}±0.14	6.70^{a}±0.01	5.15^{b}±0.01	5.90^{b}±0.04
SS	6.72^{a}±0.01	6.11^{b}±0.21	5.55^{b}0.63	6.02^{b}±0.28	6.49^{a}±0.01	6.17^{b}±0.21
SR	6.59^{a}±0.12	4.17^{c}±0.14	5.89^{b}±0.01	5.72^{b}±0.21	5.09^{b}±0.01	5.67^{b}±0.14
SCR	6.79^{a}±0.01	6.10^{b}±0.14	6.00^{b}±0.01	6.01^{b}±0.01	5.50^{b}±0.01	6.30^{b}±0.14
SCM	6.58^{a}±0.01	6.73^{a}±0.14	5.45^{b}±0.14	5.79^{b}±0.28	5.79^{a}±0.01	6.69^{a}±0.14
SCS	5.20^{c}±0.01	5.47^{b}±0.01	5.66^{b}±0.01	6.00^{b}±0.01	6.31^{a}±0.01	5.35^{b}±0.01
SBG	6.01^{b}±0.02	6.80^{a}±0.01	5.67^{b}±0.01	6.88^{a}±0.01	6.49^{a}±0.01	5.90^{b}±0.01
TC	7.08^{a}±0.01	6.19^{b}±0.01	6.01^{b}±0.01	6.88^{a}±0.01	6.25^{a}±0.01	6.10^{b}±0.01

Samples	Appearance	Consistency	Aroma	Taste	Mouth feel	Overall Acceptability
TM	$5.80^{b}\pm0.01$	$5.78^{b}\pm0.01$	$6.21^{b}\pm0.01$	$6.07^{b}\pm0.02$	$7.23^{a}\pm0.14$	$5.98^{ab}\pm0.01$
TS	$5.70^{b}\pm0.02$	$5.28^{c}\pm0.21$	$5.30^{b}\pm0.01$	$6.11^{b}\pm0.01$	$6.90^{a}\pm0.01$	$5.78^{ab}\pm0.21$
TR	$5.70^{b}\pm0.01$	$5.12^{c}\pm0.01$	$6.67^{ab}\pm0.02$	$5.87^{b}\pm.001$	$6.15^{a}\pm0.01$	$5.72^{ab}\pm0.01$
TCR	$6.01^{b}\pm0.01$	$6.01^{b}\pm0.01$	$6.23^{ab}\pm0.01$	$6.12^{b}\pm0.01$	$6.78^{b}\pm0.01$	$6.01^{b}\pm0.01$
TCM	$6.01^{b}\pm0.01$	$5.98^{b}\pm0.14$	$6.53^{ab}\pm0.01$	$6.14^{b}\pm0.01$	$6.12^{a}\pm0.01$	$5.98^{b}\pm0.14$
TCS	$5.50^{b}\pm0.01$	$5.90^{b}\pm0.01$	$6.22^{ab}\pm0.01$	$5.86^{b}\pm0.10$	$6.23^{a}\pm0.01$	$5.97^{b}\pm0.01$
TBG	$7.37^{a}\pm0.21$	$6.19^{a}\pm0.01$	$6.58^{b}\pm0.14$	$6.98^{a}\pm0.01$	$6.29^{a}\pm0.50$	$7.45^{a}\pm0.01$

Means ± standard deviation of duplicate determinations $^{a-c}$. Means with the same superscripts within the same columns are not significantly different (p>0.05)

In terms of consistency, the control sample and samples with the formulations – SBG, SCM and TBG (25% steamed corn:25% steamed rice:25% steamed millet:25% steamed sorghum, 50% steamed corn:50% steamed millet and 25% toasted corn:25% toasted rice:25% toasted millet:25% toasted sorghum) respectively showed no significant difference (p>0.05). This might be attributed to the chemical composition or the functional properties of the individual flours used in the formulations of the breakfast cereal samples.

Control sample (QBM) (Quaker oat) was ranked highest by the panelists in terms of aroma followed by sample SBG (25% steamed corn:25% steamed rice:25% steamed millet:25% steamed sorghum). There was slight significant difference (p<0.05) between the steamed and toasted samples used in the formulation. This could be attributed to the varying proportions of the flours used in the formulation, as well as precooking methods adopted in this study as toasting enhances flavour.

There was no significant difference (p>0.05) in all the samples except samples SBG, TC and TBG (25% steamed corn:25% steamed rice:25% steamed millet:25% steamed sorghum, 100% toasted whole corn and 25% toasted corn:25% toasted rice:25% toasted millet:25% toasted sorghum respectively) which the panelists scored highest based 9-point hedonic scale. Differences in taste could be attributed to molecular changes in the flour due to the different processing methods (steaming and toasting) that the raw materials were subjected to.

The mean score for mouth feel of the breakfast cereals showed that there was no significant difference (p>0.05) among the samples except samples SM, SR, SCR and TCR (100% steamed millet, 100% steamed rice, 50% steamed corn:50% steamed rice and 50% toasted corn:50% toasted rice respectively) which the panelists scored highest based 9-point hedonic scale. This result implied that the consumers neither like nor dislike these samples (SM, SR, SCR and TCR). Thus, had no impact on the mouth feel of the products.

In terms of overall acceptability, none of the samples was rejected by the consumers; however the commercial control was the most acceptable probably because the panelists were accustomed to the product. The sensory scores showed that the toasted samples were moderately preferred to the steamed samples based on the 9-point hedonic scale. All the sensory scores showed that the new products developed were generally accepted by the consumers, which is an indication that the product had good chances of being patronized by consumers when launched in the market.

Conclusion

This research showed that formulation with the 100% steamed rice obtained relatively the highest values amongst the functional properties (pH, Water absorption capacity, Oil absorption capacity and bulk density). Thus, the dispersibility and solubility required from instant products were met within some seconds. The rate of reconstitution of the steamed whole samples was observed to be faster as a result of their corresponding lower solubilities than the toasted samples. Thus, the steamed whole samples showed similar reconstitution time with the control sample. Sensory analysis using hedonic scales showed that the 25% toasted corn:25% toasted rice:25% toasted millet:25% toasted sorghum had the best sensory characteristics and the most acceptable by consumers, indicating its market potentials. Therefore, this research showed that acceptable instant breakfast cereals could be produced from whole corn, millet sorghum and rice, and the prepared breakfast cereals from the flours had acceptable sensory properties.

However, further research should be carried out to ascertain the shelf life and the best packaging recommended for the formulated samples. These, along with other factors would make the product compete globally and influence the commercialization of the products for National sustenance.

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