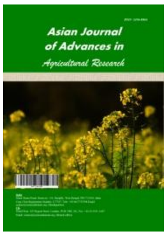

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Production of Glucose Syrup and Energy Bar from Blends of Malted Sorghum and Cocoyam Flour

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Authors' contributions

This work was carried out in collaboration among all authors. Author RNA designed and supervised the study. Authors JIA and WAO conducted literature searches, managed the laboratory analysis and performed the statistical analysis of the study. All authors read and approved the final manuscript.

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ABSTRACT

Background and Objective: Roots and tuber crops such as Cassava (*Manihot esculenta* Crantz), yam (*Dioscorea alata)*, taro (*Colocasia esculenta) etc* are highly grown in tropical Africa and processed into staples such as garri, fufu, lafun etc. which only bring marginal income to the farmers. Reports showed that these tubers may be used as novel substitutes for industrial production of glucose syrups, modified starches and malto dextrins etc. This study evaluated the potentials of using cocoyam flour and malted sorghum in making glucose syrup and the application of the glucose syrup in energy bars production as sweetener.

Materials and methods: The cocoyam cormels were processed into flour while sorghum grains were malted and milled into flour. Glucose syrup was produced from cocoyam and malted sorghum flours mixed at ratios of 90:10, 80:20, 70:30, 60:40 respectively. The energy bars were produced using a composite of cocoyam flour and malted sorghum at the same ratio with the glucose syrup. The glucose syrup was used as sweetener. The products were evaluated for proximate; functional and sensory properties. Data obtained were analyzed statistically.

Results: The results showed that the glucose syrups had dextrose equivalent 26.36-36.64%; brix^0 15.05-16.35; energy bars calorific value 364.35-367.065 kJ/100g. The sensory evaluation showed that the energy bars performed satisfactorily as rated by the panel in taste and overall acceptability.

Conclusion: Based on the result, cocoyam flour could be usefully employed in production of glucose syrup and further applied as sweetener in the production of biscuits and energy bars.

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Keywords: Glucose syrup; cocoyam cormels; malted sorghum; energy bars.

1. INTRODUCTION

The raw material for the production of glucose syrup and high fructose syrup in the US and in many other parts of the world is corn starch. However, alternative starch sources have been reported as potential raw materials in Europe, South America and Asia. Nowadays, glucose syrup is only produced from a variety of starch raw materials including, such as cassava, sago, rice, sorghum, wheat, corn, etc [1]. Roots and tuber crops such as Cassava (*Manihot esculenta* Crantz), yam (*Dioscorea alata)*, Sweet potato (*Ipomoea batatas*) and taro (*Colocasia esculenta)* are competitively grown in abundance in tropical Africa. These carbohydrate foods are processed into staples such as garri, fufu and lafun etc. which only bring marginal income to the farmers.

Most often, high postharvest losses are recorded because of poor storage infrastructure. There is urgent need to diversify the usage, industrial applications and markets for roots and tuber crops. This can be achieved by conversion of flour or starch from roots and tubers into many industrial products such as glucose syrup, modified starches, malto dextrins, gums, adhesives, bio ethanol etc [1-3].

Energy bars are supplemental bars containing cereals and other high energy foods targeted at people who require quick energy but do not have time for a meal. They are different from energy drinks, which contains contain high contents of caffeine and sugar, in addition to other ingredients such as taurine, *Ginkgo biloba* leaf extract, ginseng, guarana, vitamins, amino acids, and herbal ingredients [4], whereas bars provide food energy. Most energy bars come in the form of biscuits and are one of the bakery products regularly consumed by people of all social class and age group. Biscuits generally are all made from flour (usually wheat flour) and all have low moisture content and therefore have long shelf-life if protected from moisture and oxygen in the atmosphere. It should be recognized that the degree of substitution and the type of substitute may vary from year to year depending on the availability of local raw materials and the types of products desired.

In Nigeria and the rest of tropical Africa, tuber and root crops are produced in abundance but there are limited technologies to transform them into high foreign exchange earners. Presently, Nigeria occupies the number one position as the world's foremost producer of cocoyams as reported by Alfred [5] and cocoyam constitute one of the six most important root and tuber crops worldwide [6]. Despite this, most third world countries, Nigeria inclusive, still face the problem of producing cocoyam at a subsistent level [7] and moreso, post harvest losses of this food commodity as millions of tonnes of cocoyam are either destroyed through pest infestation, physical injury or poor handling facilities. Besides, the food and pharmaceutical companies spend huge revenues to procure glucose syrup which otherwise could be produced locally. Glucose syrup is at present imported into the country and takes a large chunk of the nation's scarce foreign exchange.

Cocoyam which is a starch food material has limited value hence there is need to add value to cocoyam and increase the income of cocoyam farmers. Also, replacement of wheat flour with cocoyam and malted sorghum flour will enhance better flavor and encourage the use of locally grown crops as flour to produce high quality food products in an economic way. This serves as a means of diversifying and upgrading local agricultural food products, thereby improving the economy of the nation. This study was aimed at exploiting the relative abundance of starchy raw materials especially cocoyam for production of glucose syrup and the glucose being produced alongside with the blends of flour for the production of energy bar biscuits.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in the Department of Food Science and Technology Laboratory. Madonna University, Nigeria, Akpugo Campus Enugu from January, 2016 to August 2016.

2.2 Sample Procurement

The cocoyam, sorghum, wheat flour, fat, baking powder used for this study were purchased from Ogige market, Nsukka, Enugu State, Nigeria.

2.3 Chemicals

All the chemicals used for analysis were of analytical grade and were obtained from the

Food Chemistry Laboratory of Food Science and Technology Department Madonna University Nigeria, Akpugo Campus, Enugu.

2.4 Cleaning and Weighing of Cocoyam Cormels and Sorghum Grains

The cocoyam cormels were washed in excess water to remove adhering contaminants and mucilage. After the cleaning, 1000 g of the cocoyam cormels were weighed out. The sorghum grains were sorted and 1000 g of the cleaned grains weighed out.

2.5 Production of Cocoyam Flour

The cocoyam flour was produced by the method described Okpala et al. [8]. One thousand grams (1000 g) of the cleaned cocoyam cormels were sliced to 1mm thick with a kitchen knife. The slices were blanched in boiling water for 5 min, after which the blanched samples were sundried properly, milled and sieved using a 400 micro mesh.

The sorghum malt was produced using the method described by Hallen et al. [9]. One thousand grams (1000 g) of the cleaned Sorghum grains were soaked in potable water in a ratio of 1:2 (w/v) for 48 h at 25^{0}C, during this period the water was changed every 4 h, the grains were air rested for 2 h and re-steeped. The grains were spread inside a jute bag at a thickness of 2- 3 cm and kept in the cupboard whose chamber has been disinfected with 1500 ppm formaldehyde solution to discourage mold growth. The malting was done for 48 h. The malts were oven dried at 50^{o}C for 48 h to a constant weight, then cooled, and milled with MC AC 2105 blender. The resultant flour was sieved using 400 micro mesh and packaged in an air tight plastic container. Five different proportions of cocoyam flour : sorghum malt flour were prepared as shown in Table 1.

2.6 Production of Glucose Syrup

Glucose syrup was produced following the method described by Bello-Perez [10]. Initially the pH of the mash water was adjusted to pH 11.0 using Ca $(OH)_2$. The grist (which consist of a composite flour of cocoyam flour and malted sorghum at different ratio as shown in Table 1) was introduced into the mash water at a ratio of 1:5 (w/v) and temperature was raised to 45^{o}C (protein rest). 0.2 ml of enzymes (amylose glucosidase) was added and was rested for 30minutes. The temperature was raised to 55^{o}C and rested for 20 min. The temperature was raised to 65^{o}C and 0.2 ml of enzyme (amylose glucosidase) was added and allowed to rest for 1hour. The temperature was further raised to 90-93^{o}C and 0.2 ml of the enzyme (amylose glucosidase) was added and allowed to rest for 1hour.The substrate was boiled for 2mins and cooled to 60^{o}C by adding ice water.

Then 0.2 ml of enzyme was added for saccharification. It was filtered and the wort was concentrated. The glucose syrup were analyzed accordingly.

2.7 Production of Energy Bar

The energy bar were produced according to the creaming method described by Akubor [11], using the flour blends as shown in Table 1 along with the corresponding glucose syrup obtained. A ratio of 1: 0.2: 0.3: 0.04:0.08:0.06 of flour, glucose syrup, fat, baking powder, egg, milk. During biscuits making, sugar and fat were initially creamed in a Kenwood mixer at medium speed until fluffy. The milk and beaten egg were added and mixed for 30 min. The baking powder and composite flours in each case were slowly added into the mixer and mixed thoroughly until uniform smooth and hard consistent dough was obtained. The dough was rolled on a flat rolling board, sprinkled with the same flour to a uniform thickness of (2 mm) using a wooden rolling pin.

2.8 Analysis

The moisture content of the glucose syrups were determined using the oven method described by the William et al. [12]. The dextrose Equivalent of the samples were determined by the AOAC Official Method 923.09, 2005, followed [13]. The pH and total solids of the glucose syrup were determined by method described by William et al. [12] while the brix value of the samples were determined using a hand held refractometer. The proximate composition of the energy bars was determined by the method described by William et al. [12] while the caloric value was calculated in kilo-calories per 100 g (kCal/100 g) by multiplying the percentages of crude protein, fat and carbohydrates by the Atwater factor of 4,9,4, respectively and adding the figures together [14]. The individual analyses were determined in triplicates.

Table 1. Ratio of materials used for the production of glucose syrup

Sample ratio	Cocoyam (g)	Malted sorghum (g)
100:0	1000	0
90:10	900	100
80:20	800	200
70:30	70	300
60:40	600	400

2.9 Sensory Evaluation of the Energy Bar

A twenty man panelist consisting of students of Madonna University Akpugo Campus was used to evaluate the energy bars for consumer acceptance, preference and likeness (likeability test) as described by Lawless and Heymann [15], using the 9-point hedonic scale, in ascending order of preference. The panelists were asked to rinse their mouths after tasting each sample.

2.10 Statistical Analysis

Data obtained were statistically analyzed and mean separation carried out by Least Significant Difference (LSD) at P = .05.

3. RESULTS AND DISCUSSION

The result of the proximate composition of the glucose syrup produced from various blends of cocoyam and sorghum flours is shown in Table 2. The knowledge of proximate composition of the food is fundamental to the assessment of its nutritive quality [16]. The moisture content ranged from 66.36 to 68.06 % with sample A_3 having the highest. The values however differ significantly at P = .05. The moisture contents of the all the samples were high when compared with the specification by FAO which ranged from 15 % - 20 %. The high moisture content of the products was attributed to inadequate heating carried out during concentration of the syrup. The low moisture though desirable from the stand point of product stability, it, however, will affect the color of the glucose syrup.

The dextrose equivalent of glucose syrup ranged from 26.36 - 36.64% with sample A_4 {Cocoyam (70%), Sorghum (30%)} having the highest dextrose equivalent while sampleA_1= Cocoyam (100%) had the least, 26.36%. There were significant (P=.05) differences in values obtained for the dextrose equivalent. The highest mean dextrose equivalent obtained for sample A_4 showed that blending at the ratio of cocoyam (70%) and sorghum (30%) would give the best yield of dextrose sugar. The dextrose equivalent values obtained were lower when compared to the standard specified by FAO which is 45%.

Hence there is need for further modification of the process in order to achieve a higher dextrose equivalent. Dextrose equivalent is the measure of the amount of reducing sugars present in a sugar product indicating the degree of hydrolysis of starch into glucose. Pure glucose has 100% dextrose equivalent [16].

The functional properties of the glucose syrup are presented in Table 3. The pH of the samples ranged from 6.0-6.3 with sample A_3 having the lowest while sample $A_{1\ \text{and}}$ A_4 had the highest. However, there were no significant differences among the sample. These values were within the range specified by FAO (5.5 – 6.5). pH is the commonest analytical measurement in industrial food processing. It measures the degree of acidity and alkalinity and plays vital role in shelf stability of foods.

The brix values of the samples ranged from 15.05 - 16.35 brix^0. The brix^0 values of the glucose syrups were significantly different (p= 0.05). Sample A_4 had the highest brix^0 (16.35) while sample A_1 had the least (15.05). The values for the brix^0 was in consonance with earlier report for the dextrose equivalent 3.0 – 16.0 brix^0 by Okafor et al. [17] for glucose syrups produced from cassava, water yam and sweet potato flours using sorghum malt. Brix is the food industry's standard of identifying the sugar concentration in syrups or liquids. It is related to percentage total soluble solids in syrups including juices.

The total solids content of the glucose syrup samples ranged from 88.95-89.84 with A_3 having the lowest and A_4 having the highest. Total solid contributes to bulk of the glucose syrup. Thus all the samples gave comparable mean values of total solid.

Table 2. Proximate composition of glucose syrups from blends of cocoyam and sorghum

Samples	Moisture Content (%)	Dextrose Equivalent (%)
A_1	67.74 ^{b}±0.007	26.36 ^{e} ±0.014
A_2	66.47 ^{d} ±1.556	33.36 ^{d} ±0.007
A_3	68.06 ^{a} ±0.007	34.0 ^{c} 6±0.007
A_4	67.47 ^{c} ±0.282	36.64 ^{a} ±0.007
A_5	66.36 ^{d} ±0.014	35.59 ^{b} ±0.007

Values are means of duplicate determinations. Values with different superscript in the same column are significantly differentP<0.05.KEY:A1=Cocoyam(100%),A2=Cocoyam(90%),Sorghum(10%),A3=Cocoyam(80%), Sorghum (20%),A4=Cocoyam (70%), Sorghum (30%), A5= Cocoyam (60%), Sorghum (40%)

Table 3. Functional properties of glucose syrup produced from blends of cocoyam and sorghum flours

Samples	Ph	Total solids	Brix ^{0}C
A_1	6.3^{b} ± 0.009	89.37^{b}±0.013	15.05^{e}±0.014
A_2	6.2^{ab} ±0.043	89.66^{c}±0.021	15.58^{c}±0.007
A_3	6.0^{a} ±0.051	88.95^{a}±0.005	15.45^{d} ±0.007
A_4	6.3^{b} ±0.032	89.84^{d}±0.097	16.35^{a} ±0.007
A_5	6.2^{ab} ±0.003	89.56^{c}±0.012	15.86^{b} ±0.001

Values are means of duplicate determinations. Values with different superscript in the same column are significantly different p<0.05 KEY:A1=Cocoyam(100%),A2=Cocoyam(90%),Sorghum(10%),A3=Cocoyam(80%), Sorghum (20%),A4=Cocoyam (70%), Sorghum (30%),A5= Cocoyam (60%), Sorghum (40%)

Table 4. The proximate composition of the energy bars

Sample codes	Moisture Content	Crude Protein	Ash	Fat	Crude Fibre	CHO	Energy
AA	10.64^{b}±0.007	10.85^{b}±0.014	2.57^{d}±0.007	3.86^{e}±0.007	1.69^{e}±0.014	70.41^{b}±0.009	364.35^{d}±0.050
AB	10.34^{c}±0.014	10.67^{e}±0.007	2.45^{e}±0.014	4.13^{d}±0.007	1.83^{c}±0.021	70.60^{a}±0.002	366.65^{b}±0.000
AC	11.05^{a}±0.007	10.71^{d}±0.014	2.60^{c}±0.007	4.46^{c}±0.007	1.79^{d}±0.282	69.34^{d}±0.031	364.42^{d}±0.000
AD	10.16^{d}±0.007	10.80^{c}±0.007	2.73^{b}±0.007	4.54^{b}±0.007	2.06^{b}±0.000	69.73^{c}±0.022	367.07^{a}±0.919
AE	10.44^{c}±0.014	10.94^{a}±0.007	2.81^{a}±0.007	4.73^{a}±0.014	2.10^{a}±0.64	69.81^{e}±0.010	366.15^{c}±0.149

Values are means and standard deviations of duplicate determinations on the energy bar. Values with different superscript/letter in the same column are significantly different (P<0.05)

Key:AA=Cocoyam (100%), AB=Cocoyam (90%), Sorghum (10%), AC=Cocoyam (80%), Sorghum (20%), AD=Cocoyam (70%), Sorghum (30%), AE= Cocoyam (60%), Sorghum (40%)

Table 5. Sensory evaluation scores for the energy bars

Sample Code	Appearance	Taste	Aroma	Crispness	Overall Acceptability
AA	$6.55^{ab}\pm1.395$	$6.45^{a}\pm1.432$	$6.80^{a}\pm1.473$	$6.85^{a}\pm1.725$	$7.10^{a}\pm1.518$
AB	$6.65^{ab}\pm1.460$	$3.95^{b}\pm1.731$	$5.05^{b}\pm1.605$	$6.20^{a}\pm2.353$	$4.70^{b}\pm2.340$
AC	$7.10^{b}\pm1.651$	$5.65^{a}\pm2.059$	$6.00^{ab}\pm1.806$	$7.00^{a}\pm1.521$	$6.05^{a}\pm2.114$
AD	$5.75^{a}\pm1.916$	$5.30^{a}\pm2.296$	$5.50^{ab}\pm1.906$	$6.65^{a}\pm1.348$	$5.85^{ab}\pm2.300$
AE	$7.20^{b}\pm1.321$	$6.05^{a}\pm2.139$	$6.00^{ab}\pm1.686$	$7.10^{a}\pm1.651$	$6.65^{a}\pm1.460$

The proximate composition of the energy bars were as shown in Table 4. The moisture content of the energy bars ranged from 10.16 to 11.05%. Samples AA and AB, AC, AD AE were significantly different at (P=.05) from each other. The differences in moisture content of the bars could be attributed particulate composition of the bars and the temperature distribution in the oven during baking. Moisture content determines the keeping quality of the foods. The mean moisture of 10.5 % observed in this study was slightly higher than the reports on moisture contents which stated that moisture level above 10% are likely to cause adverse effect on the keeping quality, (enhanced spoilage through microbial activity) [8].

The protein values range within (10.94%-10.67%). Sample AE (Cocoyam (30%), Sorghum (20%) had the highest while sample AB (Cocoyam (45%), Sorghum (5%)) had the least value. There were significant differences (p>0.05) found among the protein values of the bars.

Like the protein content, all the samples differ significantly in the ash, fiber, and carbohydrate values (p>0.05). However sample AE (2.81%) had the highest ash value and followed by sample AD (2.73%). Sample AE also had the highest fat content (4.73%) while sample AD had the highest fiber value (2.06%).

The highest carbohydrate value (70.60%) was obtained for sample AB and followed by sample AA (70.41%). The values are expected for the energy bars since the overriding function of energy bar is to provide instant energy.

The calorific energy content of the energy bar blends range from (367.065 kJ/100 g to 364.35 kJ/100 g). The highest calorific energy value of 367.07 kJ/100g was recorded for sample AD which did not differ from sample AC, but differ from the values obtained for samples AD and AB at P = .05.

The sensory scores for the energy bars are shown in Table 5. The result showed that there was significant (P = .05) difference among the panels scores for appearance, taste, aroma, crispiness and general acceptability (P = .05). The scores recorded for appearance range from 5.75 - 7.20.Sample AE was rated the highest while sample AD was rated the least. The taste scores range from 3.95 - 6.45. Sample AA received the highest rating (6.45) while sample AB was least preferred (3.95) by the panel. The aroma scores ranged from 5.05 - 6.80 and sample AA was most preferred while sample AB was the least preferred in terms of aroma. The crispness score ranged from 5.75 - 7.10.Sample AE was rated highest (7.10) while sample AB was least preferred 5.75. The overall acceptability score ranged from 6.20 -7.10, AA was rated the best in terms of overall acceptability.

4. CONCLUSION

The study has shown that cocoyam flour could be usefully employed in production of glucose syrup and energy bars. The study also showed that the best ratio of blending of cocoyam and sorghum is at the 70%: 30% ratio because it lead to the highest dextrose equivalent (DE). Energy bars made from that blend had the highest calorific energy value of 367.07 kJ/100 g and was rated the best in terms of overall acceptability. The sensory scores had good correlation with the results of the proximate analysis conducted on the samples. This study showed that the coco yam and sorghum will serve as source of glucose syrup for the food and pharmaceutical industries and save scarce foreign exchange.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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