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Production of Antidiabetic Modified Cassava Flour *Manihot Esculenta* Crantz, withα-Glucosidase and α-Amylase Activities as Measured by Post Prandial Blood Glucose Response, Glycemic Indices and Organoleptic Properties

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Abstract: *Modified Cassava flour production is a spinoff of biotechnology R&D initiatives of Akwa Ibom state University, tailored towards providing modified Cassava flour for individuals with certain metabolic disorders such as Diabetes Mellitus (type 2 diabetes). However, cassava flour modified with biomas was prepared into paste and consumed with sauce /soup. The effect of bioprocessing on the bioactive constituents and antidiabetic activities were investigated after consumption /digestion of the flour. Blood glucose concentration was measured after the consumption of the Test diets and the Control. The results showed a significant ($P < 0.05$) effect of treatment on the physicochemical parameters of the modified flour. However, post Prandial Blood Glucose contents and glycemic index decreased after digestion, with high **α**-Amylase and **α**-Glucosidase inhibitory activities observed, thus showing antidiabetic activities. Therefore, we recommend this modified cassava flour for its biological activities suitable for individuals with certain metabolic disorders.*

Keywords: modified cassava flour, glycemic indices, **α**-amylase and **α**-glucosidase

INTRODUCTION

Metabolic disorders such as diabetes, obesity, Alzheimer's, stroke or cardiovascular disease is commonly important diseases affecting significant portions of world population. Metabolic diseases have become global health problems with diabetes attaining high prevalence among others (Grochowski *et al,* 2017). Diabetes is a wasting disease of the metabolic disorder in which the body is incapable of using adequate amount of blood sugar resulting in a condition called hyperglycemia. This also could happen when the body is unable to produce adequate amount of insulin to

metabolized glucose in the body, thus resulting in the building up of blood sugar as also reported by Olugbuyi *et.al,* (2022).

WHO, (2020) reported that Diabetes affected 415 million people worldwide and Nigeria is not exempted. This number has been projected to rise to 642 million by the year 2040 (WHO, 2020). However, literatures have demonstrated that the bioactive compounds of plants origins have the potential to reverse or prevent this scenario depicted by diabetes, obesity and cardiovascular diseases (Burton *et. al,* 2016 and Ozer *et. al,* 2018). More importantly, dietary polyphenols and other constituents are known to contribute to low glycemic indices by inhibiting intestinal glucose transport proteins thus reducing the risk of type 2 diabetes. (Shamloo, *et. al,* 2018).

Cassava *Manihot esculentus*, Crantz is one of the staple foods in several tropical and sub-tropical countries of the world. According to FAO,(2009), the world's cassava production had been on the increase from about 176–277 metric tons per year from 2000–2013. Of these figures, Africa alone contributed between 54 and 58% of the world's cassava production within these periods (Shittu, et al., 2016). Nigeria is rated as the largest cassava producer in the world (Shittu, et al., 2016). The impacts of cassava on the economies of different countries have changed in recent times. Before now, in some economies, Cassava was regarded as merely a resourced poor farmers' crop, often castigated as an "inferior food crop"(Hahn and Janet,1985). Presently, Cassava has assumed a prominent position as domestic food crop, cash crop and as industrial raw materials used for numerous industrial applications through a series of technologies specifying chemical, physical and enzymatic modifications.

MATERIALS AND METHODS

Study Area and Sample Collection

The research was carried out in Akwa Ibom State University, Ikot Akpaden, (main campus). The main campus stretches over a distance of 12km from the East-West high way to the shoreline and is 4km wide. It has a tropical climate masked by two distinct seasons namely, dry season (November – March) and wet season (April-October). Average annual minimum and maximum temperature of the area is 23 ^{O}C and 31^{O}C respectively. The cassava pulps or tubers were procured from Ukam local market and was transported to department of biotechnology laboratory in Akwa Ibom state University, for further processing

Cassava Flour production technology

There has been a paradigm shift in the level of cassava processing technology, due to the changing status of cassava from resourced poor farmer's crop to an industrial or economically important food crop. Improved (mechanized) processing techniques were used instead of usual traditional manual operation. The greatest drudgeries of manual size reduction, pressing, drying and milling was

removed by the adoption of various mechanical devices that perform these operations. It has given an opportunity to increase the throughput of many products as well as improving their quality. The main processing steps in achieving modified Cassava Flour and the Control productions are summarized as shown in Fig.1A and B.

A. Harvested Cassava tubers → Peeling → Washing → Fermentation with Biomas for 24 h → Grating/Grinding → Dewatering or Pressing → pulverized/Sieving → dry (to moisture content below 12%) → Dry Milling (Flour)

B. Harvested Cassava tubers → Peeling → Washing → grating with Machine → Dewatering or Pressing → pulverized/Sieving→ dry to (Moisture content below 12%). → Dry Milling (Flour).

Fig.1 A= Processing steps in treated Cassava Flour and B. Processing steps in the cassava flour used as control.

Modification Procedure

To obtain a uniform size of cassava chips, cassava tubers were chopped or thinly sliced and shredded using a chopper or a grater. Cassava chips (1.0 kg) modified by soaking in 2.0 L of tap water at ratio of (1:2, v/v) mixed with 2.0 % (w/v) of an enzymatic Biomas solution containing extract crude enzymes of *Alpha Amylase* and *Alpha glucosidase* for 24 h. The mixture was stirred by hand and covered with aluminum foil and incubated at 25 °C for 24 to 48 h. Once enzymatic incubation was completed, the modified cassava chips were transferred onto aluminum trays of a dehydrator and dried at 50 °C for 2 to 4 h to reduce moisture content to between 10 to 12 %

Measurement of HCN Content

Hydrogen cyanide content of cassava flour (native, modified) was measured quantitatively by using alkali titration method as described by Obigbesan, and Fafunso, (1980). Starch slurry of 5 % concentrate (w/v) was prepared by soaking 10 g of cassava flour in 200 mL of distilled water for 4 h in a distillation flask. The solution was then distilled into 20 mL of 0.625 M NaOH using steam distillation until its volume became 150 mL. Distilled water was added and filled up to 250 mL with 8.0 ml of 5 % potassium iodine (KI) added into 100 mL of solution and titrated using 0.02 N silver nitrate solution. End point of titration was determined as colour of the solution turned to bright yellow.

Measurement of pH and Acidity

The suspension materials were prepared by mixing 5 g of modified cassava flours and the Control cassava samples with 50 mL of water, and the pH readings were measured with a glass electrode on pH meter. Alternatively, the titratable acidity was determined by titration with 0.1N NaOH to an end-point of pH 8.2. The titratable acidity was then expressed as the volume of sodium hydroxide solution required to neutralize 1 g of flour.

***In vitro* α-Glucosidase and α-Amylase Activities assay**

The *in vitro* α-Glucosidase Activity was carryout according to Alagbe & Malomo, (2024) with slight modifications. Briefly, the α-glucosidase activity was measured *in-vitro* by determining the presence of reducing sugar (glucose) arising from hydrolysis of glucose by α-glucosidase enzyme. Concisely, 100 µl of reaction mixture containing 70 µl of phosphate buffer Saline *PBS* (50 mM, pH 6.8), were filled in micro-plate wells and 10 µl of test extracts, and 10 µl (0.057 U) enzyme were

thoroughly mixed and thereafter, the mixture was preincubated in a water bath at 37°C for 10 min. and Absorbance read at 400 nm taken against the reagent blank. The reaction was initiated using 10 µl of 0.5 mM substrate (i.e., p-nitrophenol glucopyranoside *pNPG*). Acarbose was used as a positive control. After incubation at 37 ^{O}C for 30 min, optical absorbance at 400 nm was measured against the reagent blank.

α-Glucosidase inhibition % = [1- (A sample - A blank / A test - A control)] x 100
Where A sample is the absorbance of the mixture of sample, pNPG, enzyme solution; A blank is the absorbance of the mixture of sample, pNPG solution without enzyme; A control is the absorbance of the mixture of buffer, pNPG and without enzyme; A test is the absorbance of the mixture of buffer instead sample, pNPG and enzyme solution

The *in-vitro* α-amylase activity was measured by hydrolysis of starch in the presence of α-amylase enzyme according to Alagbe & Malomo, (2024). Briefly, α-amylase activity was carried out by starch-iodine method. 10 µL of α- amylase solution (0.025 mg/ml) was mixed with 390 µl of phosphate buffer saline *PBS* (0.02 M containing 0.006 M NaCl, pH 7.0) filled in microplate wells. Thereafter, the mixture was preincubated in a water bath at 37°C for 10 min.

Then, 100 µl of starch solution (1%) was added, and the mixture was re-incubated for 1 h. Afterwards, 0.1 ml of 1% iodine solution was added, and 5 ml of distilled water was added, before the absorbance was taken at 565 nm. The Sample, substrate and α-amylase blank observation were done under the same reaction conditions. Inhibitory action of enzyme activity was calculated as follows:

α – amylase inhibition (%) = (A-C) X100/ (B-C),

Where, A= absorbance of the sample,
B= absorbance of blank (without α-amylase), and
C= absorbance of control (without sample).
This process can also be quantified by using iodine, in which case blue colour with starch would be observed. The reduced intensity of blue colour indicated the enzyme-induced hydrolysis of starch in to monosaccharide. If the substance has α-amylase inhibitory activity, higher intensity of blue colour would be obtained. In essence, the intensity of blue colour in test sample is directly proportional to α-amylase inhibitory activity (Olugbuyi *et al*, 2022).

Postprandial Blood Glucose Measurement
Postprandial Blood glucose was measure according to Ludovic *et al*, (2004). The blood sample of each of the volunteers were taken by pricking fingertips using lancet and it was used to stain the test strips and the blood glucose level was checked using a fine test calibrated glucometer (Accu-Check) and the readings were recorded. The blood glucose responses were taken at zero minutes, 30 min, 60 min, 90 min, and 120 min.

Glycemic index evaluation
Glycemic index evaluation was done according to (Wolever *et al.*, 2001). Ten volunteers between the ages of 18 and 30 years were recruited from Akwa Ibom State University community members based on their consent and availability. The recruits were tested for their fasting blood sugar (FBS) levels very early in the morning before eating. Thereafter, prepared modified and Control (unmodified) cassava flour was presented to the recruits. Five ate modified and the other five ate the Control cassava flour respectively. Two hours later after eating, their random blood sugar (RBS) level was also tested and results was recorded, subjected to statistical analysis to check for difference in glucose levels.

The glycemic index of a food is calculated to know by how fast and to what extent it can raises blood glucose levels compared to a reference food and calculated using Incremental Area Under the Curve IAUC. Higher *IAUC* indicates higher Glycemic index classifying foods into low GI ≤ 55, medium 56- 69 and high GI ≥70.

$$\text{Glycemic index} = \frac{\text{IAUC for test food}}{\text{IAUC for reference food}} \times 100$$

Determination of Moisture Content
The moisture content was determined by oven method as described by AOAC (2005). A clean dry beaker was weighed and the weight was taken to be (a). 2.5g of the sample to the dry beaker and reweighed, the new weight was taken to be (b). The beaker and its content were properly dried in an oven at 1050c for 24hrs. At the end of 24hrs, they were removed from the oven and allowed to cool

in desiccators to room temperature and weighed again with minimum exposure to atmospheric air. The above procedure was repeated till a constant weight was obtained (c).

Calculation:

$$\% \text{ moisture content} = \frac{b - c}{b - a} \times 100$$

Where;

a = weight of beaker only
b = weighed beaker + sample before oven drying
c = weighed beaker + sample after oven drying

Determination of Ash and Organic Matter

The ash content was determined by the direct heating method as contain in AOAC (2005). Crucible with lid was ignited in a muffle furnace at the temperature of 1050c for an hour. It was transferred to desiccators to cool and weighed (a). Few grams (1-5g) finely ground dry sample was put into the pre-weighed crucible. The weight of the crucible and its content (sample) was taken (b). The crucible and its content were charred on a heater or Bunsen flame in a fume cupboard, to drive off most of the smoke (until smoking ceases).

Then it was transferred to a muffle furnace heated at (500- 6000c) to burn off all the organic matter and then it was allowed at this temperature for 2 hours.
The crucible was taken out after cooling, properly covered and placed in desiccators to cool and weighed (c).

Calculation:

$$\text{Ash \%} = \frac{\text{weight of ash}}{\text{Weight of sample}} \times \frac{100}{1}$$

$$\text{i,e} \quad \frac{c-a}{b-a} \times \frac{100}{1}$$

Where;

a = weight of empty crucible

b = weight of crucible + sample before ashing

c = weight of crucible + ash

N/B: The portion of sample which burnt off is organic matters

Organic Matter (%) = 100 - (%) Ash

Estimation of Crude Fibre

The crude fibre was determined using the procedure in AOAC (2005). It was determined as the fraction remaining after digestion with standard sulphuric acid and sodium hydroxide under careful controlled condition. In this method, 2g of material was defatted with petroleum for 2 hours. It was boiled under reflux for 5 minutes with 200ml of a solution containing 1.25g of H_2SO_4 per 100ml solution. The solution was properly filtered through linen or cotton cloth on a fluted funnel. It was properly washed with boiling water until the washing was no longer acidic.

The residue was transferred to a beaker and boiled for another 30 minutes with 200ml of a solution containing 1.25g of NaOH per 100ml. The final residue was filtered and washed with boiling water for several times until it is base (NaOH) free. The residue was finally washed twice with ethanol and qualitatively transferred into a pre-weight crucible; oven dried at 1500c (Io). It was incinerated in a furnace at 5500c and allowed to stand at this temperature for 2 hours. Then it was transferred to desiccators to cool and weighed (la) loss in weight).

Calculation:

1a – 1o / Weight of original sample taken x 100

Where:

Ia	=	weight of empty crucible
Io	=	weight of crucible and its content after incineration (ash fibre)

Determination of Crude Fat

The Soxhlet solvent extraction method as described by AOAC (2005) was used to determine the fat content. 2.0g of the sample was weighed into an extractor thimble, which has already been washed dried in an oven, lightly plugged with cotton wool. 150 ml of petroleum ether (at the boiling point of 60 - 80 0c) was poured into 250ml capacity round bottom flask. The Soxhlet extractor was fitted into round bottom flask which was seated on a heating mantle. The Soxhlet apparatus was assembled and allowed to reflux for 4 hours.

The extract was poured into a dried pre- weighted beaker (W1) and the thimble was rinsed with a little quantity of the ether back to the beaker. The beaker was heated on a steam bath or oven to drive off the excess solvent. The beaker was cooled in a desiccator and weighed (W2)**.**

Calculation:

$$\frac{\text{Weight gain in flask}}{\text{Weight of sample}} \times \frac{100}{1}$$

$$\frac{W2 - W1}{\text{Weight of sample}} \times \frac{100}{1}$$

Where:

W2 = weight of beaker + fat

W1 = weight of empty beaker only

Crude Protein Determination

The macro kjeldahl method as described by AOAC (2005) was used to determine the crude protein content. The method involves three major steps which are digestion, distillation and titration.

Digestion: In the first step, the protein is digested using concentrated sulphuric acid in presence of a catalyst. In this step all the organic material is oxidized except nitrogen, the reduced form of which is retained in digest as ammonium sulphate.

$$2N \text{ (food)} + H_2SO_4 \rightarrow (NH4)_2\ SO_4$$

$$(NH4)_2\ SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_20 + 2NH_3$$

Distillation: In the second step, ammonia is distilled off, collected in boric acid and titrated with standard acid. Boric acid provides the most convenient absorbent for ammonia. The boric acid did not involve in the titration but simply reacts with the ammonia to form an ammonium borate complex.

$$2NH_3 + 2H_3BO_3 \rightarrow 2NH_4H_2BO_3$$

Ammonium borate

Titration: The strongly basic ammonium- borate that is formed is titrated directly with acid in the presence of a methyl red indicator until the green distillate changes through colorless to pink (methylene blue indicator can also be used).

$$2NH_4H_2BO_3 \rightarrow NH_4Cl + HBO_3$$

I mole HCl = 1 mole of N = 14gN

In this Method:

1g of the sample was accurately weighed into a standard 250ml kjeldahl flask containing 1.5g CuSO4 and 1.5g Na2S04 as catalyst and 5ml concentrated H2S04.

The kjeldahl flask (digestion) was placed on a heating mantle and was heated gently to prevent frothing for some hours until a clear bluish solution was obtained.

The digested solution was allowed to cool and this was quantitatively transferred to 100ml standard flask and make up to the mark with distilled water.
20ml portion of the digest was pipette into a semi micro kjeldahl distillation apparatus and treated with equal volume of 40% NaOH solution.

The ammonia evolved was steam distilled into a 100ml conical flask containing 10ml solution of saturate boric acid to which 2 drops Tashirus indicator (double indicator) has been added. The tip of the condenser was immersed into the boric acid double indicator solution and then the distillation continued until about 2/3 of the original volume obtained.

The tip of the condenser was rinsed with a few millimeters of distilled water in the distillate which was then titrated with 0.1M HCl until a purple-pink end point was observed.
The blank determination was also carried out in the similar manner as described above except for the omission of the sample. The crude protein was obtained by multiplying the % Nitrogen content by a factor (6.25).

Crude protein = Nitrogen × factor

Calculation:

$$\frac{(\text{Sample titre - Blank titre} \times 0.1 \times 0.014 \times 20 \times 100 \times 6.25)}{\text{Weight of sample} \times 10 \times 1}$$

Note:

Most protein contain about 16% Nitrogen, so that 16mg N_2 = 100mg

$$1 \text{ mg } N_2 = \frac{100}{16} = 6.25\text{mg of protein}$$

The Nitrogen value is therefore multiplied by 6.25 to get the weight protein.

Determination of Carbohydrate Content

The content of carbohydrate was determined by difference as described by Pearson (1976).
CHO = 100 - % (ash + protein + fat + crude fiber + moisture),

Organoleptic or Sensory Analysis

Sensory Analysis was carried out following the method of Harry and Hildegarde, (2013). The organoleptic evaluation of the cassava flour sample was carried out to ascertain the

consumer acceptance and preference. The cassava flour sample was reconstituted into cassava paste (food) by cooking 500g of the sample in 500ml of boiling water while stirring vigorously for about 5 minutes and cooled for about 10 min.

The cooked sample was subjected to sensory evaluation using a 5 hedonic scale where 5= excellent, 4= very good, 3= good, 2= fair and 1= poor.
The 15 panelists evaluated for attributes such as colour, moldability, taste, odour and overall acceptability of the flour

Statistical analysis

All determinations were carried out in 4 replications. Data was subjected to analysis of variance (ANOVA) using SPSS (version 21, USA), while means was separated using New Duncan Multiple Range Test (NDMRT) at 5% level of significance ($p<0.05$). The results were expressed as means ± standard deviation.

RESULTS AND DISCUSSION

Results

Proximate composition of the Cassava flour

Table 1 showed the approximate compositions of both cassava flour samples i.e. the modified and the unmodified which in this case serves as the control. There was a variation in moisture content for modified sample- 11.67 %, when compared to the control samples, with 14.50%. This was not statistically significant ($P<0.05$). The protein concentrations in the cassava samples for the modified were 3.31 as the highest value when compared with that of the control with 1.30 as the lowest value. The total ash content of the modified cassava sample was 4.10 appearing as the highest value so far. This indicates that modified cassava exhibit other known macro elements including calcium, potassium, salt, and iron (Arise *et al*. 2021). The range of fiber contents in the modified samples was 6.83% to 5.04% in the control having the lowest fiber content The carbohydrate contents for modified sample from 67.00 % to 92.04%, in the control (unmodified) cassava sample as demonstrated in table 1. The proximate composition profile analysis from the cassava flour samples and the moisture, ash, proteins, fats, total carbohydrate, total dietary fiber, results revealed no significant difference in both samples. The moisture content of cassava flour (Table 1) and cassava is within 10 -13 % of the Codex/NIS Standards as reported by Eleazu and Eleazu (2012) for Quality Analysis of Flour Samples

Table 1: Proximate Analysis of modified and unmodified cassava flour compared to Codex Standard

Analysis	Average and Standard Deviation		
	Modified	Unmodified	Codex Standards
Carbohydrates	67.00±0.65	92.041±0.875	65–70
HCN mg/kg	2.6	5.0	10
Fat	2.12±0.0003	2.98±0.622	-
Protein	3.31±0.160	1.30±0.0341	-
Fibre	6.83±1.001	5.04±0.141	2 %
Ash	4.100 ±0.056	1.667±0.014	0.6%
Moisture	11.67 ±0.071	14.50±0.132	10 -13 %
Total acidity %	0.6	0.8	1.0
Finess/Solubility (%)	86±1.50	82±2.013	90

The problem of ensuring cassava product quality can only be settled by monitoring production parameters as shown in Table 1. Codex Standards for edible Cassava flour stipulated that Cassava flour be free from abnormal flavors, odors and live insects, filth - impurities of animal origin, including dead insects.

Table 2, showed the α-amylase inhibition potentials of the modified flour when compared with the Control diet of 2.75%. However, this was significantly ($p<0.05$), a higher α–amylase inhibition 6.62 % than the control samples with 2.75 %, Notably, the higher hydrophobic acid obtained might be accountable for its higher α–amylase inhibition (Fuentes-Zaragoza *et al*., 2010). Thus, this could

enhance the utilization of the test food as a potential anti-diabetic agent with no negative side-effect. Secondly, same table 2 and figure 2, showed the potential of the modified flour samples to exhibit α-glucosidase and α-amylase activities. Hence, this modified cassava samples have potentials to modulate the type 2 diabetes in human body in view of their high α- glucosidase and α-amylase activities (Table 2).

Table 2. α-glucosidase and α-amylase activity of modified cassava sample).

Sample	Modified cassava sample		Control cassava sample	
	α-glucosidase (mg/gm	α-amylase (mg/gm	α-glucosidase (mg/gm	α-amylase (mg/gm
1	1.87 ± 0.23	2.32 ± 0.05[a]	1.04 ± 0.25	1.09 ± 0.01
2	2.76 ± 0.11	3.41 ± 0.02[b]	1.18 ± 0.36	1.25 ± 0.03
3	2.98 ± 0.16	2.69 ± 0.15 [a]	1.08 ± 0.12	1.22 ± 0.04
Mean	5.62 ± 1.21[a]	6.62 ± 0.32 [b]	2.58 ± 0.14	2.75 ± 0.02

Values represent means ± standard deviation (n = 3); Values are expressed in milligram (mg) per kilogram dry weight (mg/g).

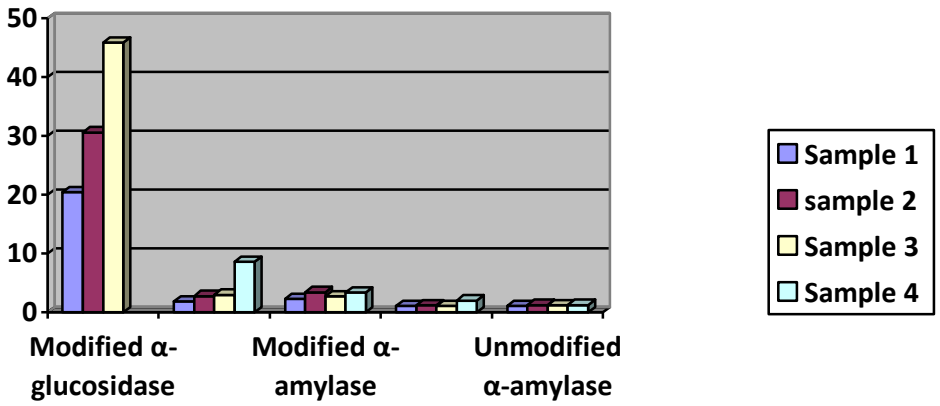

Fig. 2 Bar chart showing result of α-glucosidase and α-amylase activities of modified cassava sample.

The postprandial blood glucose response of the test food modified cassava flour and control diet are shown in Table 3. This showed the test food's rapid and slow release against the Control food's postprandial blood glucose at different times. The blood glucose responses were taken at zero min. and 120 min. The mean blood glucose response of the cassava flour (test food) was low as 25.6 and was increase in Control diet to 66.4 as shown in Table 3. The mean blood glucose response of the reference food (glucose) was shown as 68. Compared with the reference food, the GI of the Test four samples and the control diet had the blood glucose responses as 37.65 and 97.65 respectively at the 120 minutes and the reference food was 68 after the consumption (Table 3).

Table 3. Results of the Post Prandial Blood Glucose response from test Food and the controlled diet obtained using a glucometer

Subjects	Increase in blood glucose level after 120 minutes from Test food (mg/dl)	Increase in blood glucose level after 120 minutes from Control food (mg/dl)
A	22	65
B	27	82
C	20	57
D	29	64
E	30	64
Total	128	332
$\frac{\sum x}{n}$	25.6	66.4
Reference Food (Glucose)	68	68
G.I	37.65	97.65

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Table 4: Organoleptic (Sensory) attributes of the cassava samples

Samples	Appearance	Taste	Texture	Mouth feel	Crumblings	Aroma	Overall acceptance
Modified							
Panel 1	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Panel 2	4.00	5.00	5.00	5.00	5.00	5.00	5.00
Panel 3	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Panel 4	5.00	5.00	5.00	4.00	4.00	4.00	5.00
Mean	4.72	5.00	5.00a	4.72	4.72	4.72	5.00
Control							
Panel 1	4.00	4.00	3.00	3.00	4.00	5.00	4.00
Panel 2	4.00	3.00	4.00	4.00	4.00	5.00	5.00
Panel 3	4.00	5.00	5.00	4.00	5.00	4.00	3.00
Panel 4	5.00	4.00	4.00	3.00	3.00	4.00	4.00
Mean	4,20	4.00	4.00	3.50	4.00	4.50	4.00

DISCUSSION

Many processed foods go through various stages of modifications which may affect their digestibility, absorption and glycaemic index *G.I.* Processing of cassava involves methods such as cleaning, size reduction, drying, fermentation methods, heat treatment (pasteurization and sterilization) and many others [(FAO, 2011, Granfeldt, 2000]. These processes improve eating quality; reduce cyanogenic glucosides concentration and its toxicity **[FAO,** 2005]. However, their effects on glycaemic index need to be comprehensively studied. Processing of cassava flour

naturally raises concern regarding quality, abnormal flavors, odors, foreign matter content and output. Inarguably, these concerns could only be resolved by qualitative and quantitative study of the raw materials processing and the properties of the finished products. Moreover, mass production for commercialization purpose, makes the quality determination becomes very important.. Modification is the most prominent processing operation adopted to make edible finished products desirable. Codex Standards for edible Cassava flour stipulated that Cassava flour be free from abnormal flavors, odors and live insects, filth - impurities of animal origin, including dead insects (CAC, 1989; and ARS 2012). These have been closely monitored for compliance in this work as demonstrated in the evaluation of organoleptic attributes.

Pasting Properties The pasting properties of flour showed the behavior of the flour in hot water suspension when cooked. It indicates the potential use of the flour for eating purposes. The peak viscosity was attainable during cooking of flour suspension to near boiling point (95 ^{O}C). Viscosity also indicates the stability of the paste when subjected to prolonged heating. The pasting temperature is an index of ease of cooking and amount of energy required to cook the aqueous suspension of the flour. The particle size and relative composition of the flour, starch, protein, fiber and fat affected the pasting characteristics. The Cassava flour is known to have an intermediate thickening power, in agreement with Hossen *et al*. (2011). According to Hossen *et al*. (2011), potato showed the greatest paste viscosity, followed by cocoyam flour (Xanthosoma sagittfolium). Pasting viscosity of flour is slightly higher with the least hot paste stability among the different flours studied.

Total carbohydrate content values in test food (cassava flour) were within the range of 65% to 70% of the Codex/NIS Standards as reported by Eleazu and Eleazu (2012) for Quality Analysis of Flour Samples. This is also in agreement with what has been reported by Emmanuel *et al.,* (2012) while the dietary fiber as an indigestible part of carbohydrates remains relatively low for the sample investigated in this study. Dietary fiber is mainly carbohydrate, and its role as fiber is to keep the digestive system healthy. The total dietary fiber agreed with values reported by Infante *et al.* (2013). Dietary fiber is regarded as a crucial component of a healthy diet since it helps ease constipation or guard against colon cancer. They are essential to quantify the actual available carbohydrate. Therefore, starchy foods, including cassava flours are an important energy source. After being eaten, they are broken down into glucose as the body's main fuel, especially for cellular processes.

According to Oladunmoye *et al.* (2014), carbohydrates in cassava products is essential factors present in starchy foods, they influence how the starch is hydrolyzed and absorbed into blood stream. At the same time, test cassava flour products were significantly different from the control. This could be attributed to modification treatments used like fermentation, cyanogenic glucosides removal during the processing as affirmed by Bayata (2019).

Postprandial blood glucose response of the test food

The postprandial blood glucose response of the Control flour and the test food modified flour are shown in Table 3. The blood glucose response curves were used to show the test food's rapid and slow release against the reference food's postprandial blood glucose. The blood glucose responses were taken at zero min. and 120 min. The mean blood glucose response of the control food was observed to be similar to the reference food (glucose). This could be attributed to high starch content and the ratio of the amylose to amylopectin that made up the molecular matrix of the food starch. However, his was significantly lower, in comparison to the test flour, This could also be attributed to the enzymatic reactions of the modifications procedures and processing techniques of the food coupled with the physiological system of the volunteering participants as factors to be considered and as also observed by Raigond *et al.*, (2015).

High glycemic indices are not suitable for metabolic disorder diseases especially in the management of diabetic condition or obesity. The test flour showed a gradual decrease in releasing glucose into the blood from zero minutes and continues to descend until one hundred and twenty minutes. This might be as a result of the activities of modifications and the processing procedure as observed by Olusegun *et al.* (2017). Processing of cassava tubers can affect the nutritional value of cassava products through processing value chain, involving grating, fermenting, drying, and storage (Granfeldt *et al.* 2000).

Anti-diabetic inhibitory activities

α-glucosidase inhibitory activity of modified cassava flour

Table 2 showed the α-glucosidase and α-amylase inhibition potentials of the modified Cassava flour as compared to the Control (Unmodified). The higher α-glucosidase and α-amylase inhibitory effect observed in modified Cassava flour (15.62 ± 1.21 and 6.62 ± 0.32) respectively, are clear indication which showed that this sample has potentials to modulate the type 2 diabetes in humans. Principally, the α-amylase is a prominent enzyme found in both saliva and the pancreatic juice with the capacity to hydrolyzed carbohydrates to oligosaccharides. In the other hand, the enzyme α-glucosidase is found in the mucosal lining of the gastro intestinal tract that hydrolyzed oligosaccharides to glucose and other monosaccharides (Kazeem *et al*., 2013; Rege & Chowdhary, 2014). The present findings revealed that the modified cassava flour has potential property for the control of blood glucose as well as their acceptability by people with metabolic disorder.

Organoleptic property

Sensory evaluation of the Control (unmodified) cassava flour showed strong consumer preference, with mean scores of 4.0 (very good) for taste and aroma, 4.2 (very good) for appearance, and an overall appreciation of 4.0 (very good). This acceptability underscores cassava flour's versatility and palatability, supporting its potential as a wheat flour substitute (Okafor, 2014). The slightly lower

crumblings score may reflect the flour's heavy-starch nature, which can affect texture in certain preparations, a limitation noted in the problem statement.

Interestingly, the organoleptic profile of the modified cassava flour mirrored that of the unmodified flour, with identical mean scores across all parameters. This consistency suggests that the modification process, while altering nutritional composition, did not compromise sensory qualities, a critical factor for consumer's product acceptability. However, the data implies that sensory testing was conducted similarly for both flours, as the finding explicitly showed for both unmodified modified flours in Table 5. It reinforces the conclusion that fermentation maintains its palatability, a promising outcome for scaling up production of value-added cassava products.

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The data supporting this study's findings are available on request from the corresponding author.

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