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Glycemic Indices, Vitamins of Flour and Sensory Properties of Stiff Dough (Swallow) from Processed, Ripe and Unripe Breadfruits (*Artocarpus altilis*)

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Abstract This study investigated the glycemic indices, vitamins of flour and sensory properties of stiff dough (swallow) from processed, ripe and unripe breadfruits (*Artocarpus altilis).* Ripe and unripe breadfruits were processed (using five pre-treatments which include: blanching, steaming and fermentation at 12, 18 and 24 hours respectively) into ten flour samples which were evaluated for glycemic indices and vitamins. The flour were separately reconstituted into dough (swallow) and evaluated for sensory characteristics using standard methods. The glycemic index, glycemic load, beta-carotene and vitamin C content of the flour varied significantly (p>0.05) with values ranging from 31.25 to 71.50, 0.225 to 0.525, 0.503 to 4.827ug/100g, 0.002 to 0.015% except vitamin A (0.025 to 0.504 IU/100g) which had no significant difference. Sensory properties of the stiff dough showed significant (p>0.05) variations for texture (3.36 to 6.82) and consistency (4.19 to 7.08) but no significant variation in appearance (3.94 to 5.97), moldability (4.61 to 7.25), taste (4.22 to 6.72) and general acceptability (4.47 to 6.51). The work concluded that blanched, ripe breadfruits produced flour with the highest beta-carotene and vitamin A as well as stiff dough with the best overall acceptability while 12 hours treatment (fermentation) of unripe breadfruit produced flour with the lowest glycemic index and glycemic load.

Keywords: *breadfruit, glycemic indices, vitamins, sensory, stiff dough*

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1. Introduction

The problem of hunger has ravaged human civilization since pre-history till date due to exponential increase in population, overall food price index increase of 184% for cereals [1] and root crops despite the world food summit held in Rome 1996, where 185 delegates representing their countries pledged to reduce world hunger to 50% by the year 2015. These cereals and root crops which are the major staples have their limitations like high glycemic index, presence of natural toxins, poor yield among others which have contributed to health challenges and increase the number of undernourished people to an estimated number of about 1.02 billion [2] due to unaffordability and poor knowledge of what else to eat by health challenged victims like the over-weight, obsessed, diabetic among others caused by poor eating habit or excessive consumption of cereals and root crops which may have been the major cause or contributed to their health challenges.

These health challenges, according to (pre) history of humanity started when there was a steady rise in the daily uptake of carbohydrates in all industrialized and most developing countries of the world due to the switch from the primitive nutrition consisting the consumption of animals (meat, fish, and insects) and a range of plant products (fruits, seeds, nuts, bulbs). Primitive nutrition led to 15% decrease in carbohydrate intake for hunter-gatherers living in the Tundra and Northern Coniferous forest, [3]; and the energy intake from carbohydrate in the diets of most hunter-gatherer societies was lower than the quantities currently recommended by human nutrition (45 – 65%) [4].

These limitations have raised controversy over the recommended carbohydrate intake and studies indicate that where the intake of low carbohydrate diet (LCD) is limited to 26% in the daily energy balance, it may result in improved glucose metabolism and enhance insulin sensitivity, [5]. The debate on the quality of carbohydrate cannot ignore the importance of glycemic index (G.I) because the rising cases of chronic diseases such as diabetes mellitus have attracted global interest of carbohydrate rich foods on blood sugar responses which can be measured in terms of glycemic index. The increase in the cases of chronic diseases may be due to excessive consumption of some major staples high in glycemic index such as wheat flour (71.92), cassava dough (fufu – 93.26), cassava flakes (garri – 95.92) and cassava chips (tapioca – 91.94), [6].

Glycemic index (G.I) is an indicator of the dynamics of hydrolysis and absorption of carbohydrates into the bloodstream and glycemic load (G.L) is the value that estimates the impact of carbohydrate consumption using the glycemic index while considering the amount of carbohydrates consumed in a serving, [7]

However, 70% of the undernourished population live in the rural areas of developing countries like Nigeria where they depend primarily on agriculture for their livelihood, [8]; and one of the agricultural product common in Nigeria is breadfruit. Breadfruit (*Artocarpus altilis)* is not only a fruit (that is, when ripe), it is also a vegetable, (when it is unripe) [9]. It is a seedless, nutrient dense fruit commonly called ukwa in the south-south region of Nigeria and have been identified under the International Treaty on Plant Genetic Resources for Food and Agriculture for its potential to positively impact food security in under developed region of the world, [10]. Breadfruit is underutilized, underexploited, affordable and readily available. It is relatively a good source of calcium, potassium, phosphorus and have been reported in relatively good quantities although amount may vary between cultivars. Compared to other tropical starchy foods, it is an acceptable source of vitamin C at all stages of maturity [9]. Minerals found in breadfruit include: Copper, Magnesium, Phosphorous, Potassium, Calcium, Cobalt, Iron and Manganese but amounts are highly variable due to stages of growth, location and cultivar [11].

Breadfruit contains significant amount of carotenoids ranging from $1050\mu g/100g$ to $3540\mu g/100g$ depending of the cultivar and carotenoid content has been investigated to alleviate Vitamin A deficiency in malnourished part of the world. Ripe breadfruit contains higher levels of carotenoids than mature unripe breadfruits [12]. Even though the colour of the fruit is intense and rich yellow as it continues ripening, it does not correspond with higher carotenoid contents [13].

Breadfruit has the potential to trigger low blood glucose and insulin response because according to [9] breadfruit starch contain high amylose and starch food with high amylose content have been reported to exhibit lower digestibility, [14]. According to [1]; breadfruit is categorized as a medium glycemic index food but this study will examine the glycemic indices, vitamins of breadfruit flour and sensory properties of processed breadfruit stiff dough.

2. Materials and Methods

All samples of seedless breadfruits (*Artocarpus altilis*) were collected from ten breadfruit trees located in Ikot Akpa Nkuk community in Akwa Ibom State, South-South, Nigeria. Enzymes used in this analysis were of German origin and sourced from Bristol Scientific Company Limited. Other chemicals were gotten from Food Science and Technology Analytical Laboratory, Rivers State University, Port-Harcourt.

2.1. Sample Preparation

Breadfruit flour was extracted using a method described by [15] with some modification in fermentation time. Hundred unripe, sizeable breadfruits were sorted, washed with clean water to remove dirt and adhering latex, wiped with clean cotton cloth and peeled manually with stainless knife into sodium-metabisulphite solution (2.5g/10,000ml water) in order to control browning.

The peeled breadfruit samples where homogenized and measured. One (kg) was sliced, blanched and oven dried into chips, one (kg) each was immersed in water at ratio 1:3 (W/V) for twelve hours, eighteen hours and twenty-four hours respectively to undergo fermentation using the method described by [16] with modifications in fermentation time and dried into chips while two kilogram was steamed. One (kg) out of the steamed breadfruits were sliced and oven-dried at 60°C for 24 hours into chips while one (kg) was pounded into stiff porridge (swallow). All the breadfruit chips were milled into fine flour using ken-wood heavy duty-multipurpose blender. The process was repeated with ripe breadfruits.

Stiff dough from breadfruit (*Artocarpus altilis*) flour was prepared according to the modified method as described by [17]. 500ml of distilled water was poured into a stainless-steel pot. The water was allowed to boil at 100°C. 250g of each flour sample was added to the boiling water while stirring vigorously and continuously with a wooden paddle until a soft gelatinized paste devoid of lumps was achieved. The paste was covered and left on the fire for about 5minutes to cook. It was further stirred, packed and wrapped with a thin polythene wrap.

2.2. Determination of Starch Hydrolysis and Glycemic Indices

The rate of starch digestion was expressed as a percentage of total starch hydrolysed at different times (0, 30, 60, 90, 120, 180 minutes) and predicted glycemic index was carried out using the modified [18] method as described by [19].

2.3. Determination of Vitamins

The method described by [20] was used for determination of vitamin C in breadfruit flour. Beta-carotene was determined using the method described by [21] as reported by [22]. Vitamin A content was determined using the method described by [23] as reported by [22]; where the concept of retinol equivalent (RE) was established following relationships among food sources of vitamin A.

2.4. Sensory Evaluation

Sensory evaluation of all breadfruit stiff dough was carried out with the method described by [24]; using 20 panelist consisting of male, female, staff and students of Food Science and Technology Department, Rivers State University who were neither sick nor allergic to breadfruit and it products. The samples was evaluated for the following organoleptic characteristics: appearance, texture, consistency, mouldability and taste. The overall acceptability was determined by mean value of the other sensorial parameters. Water was provided for panelists to rinse their mouth after evaluating each sample.

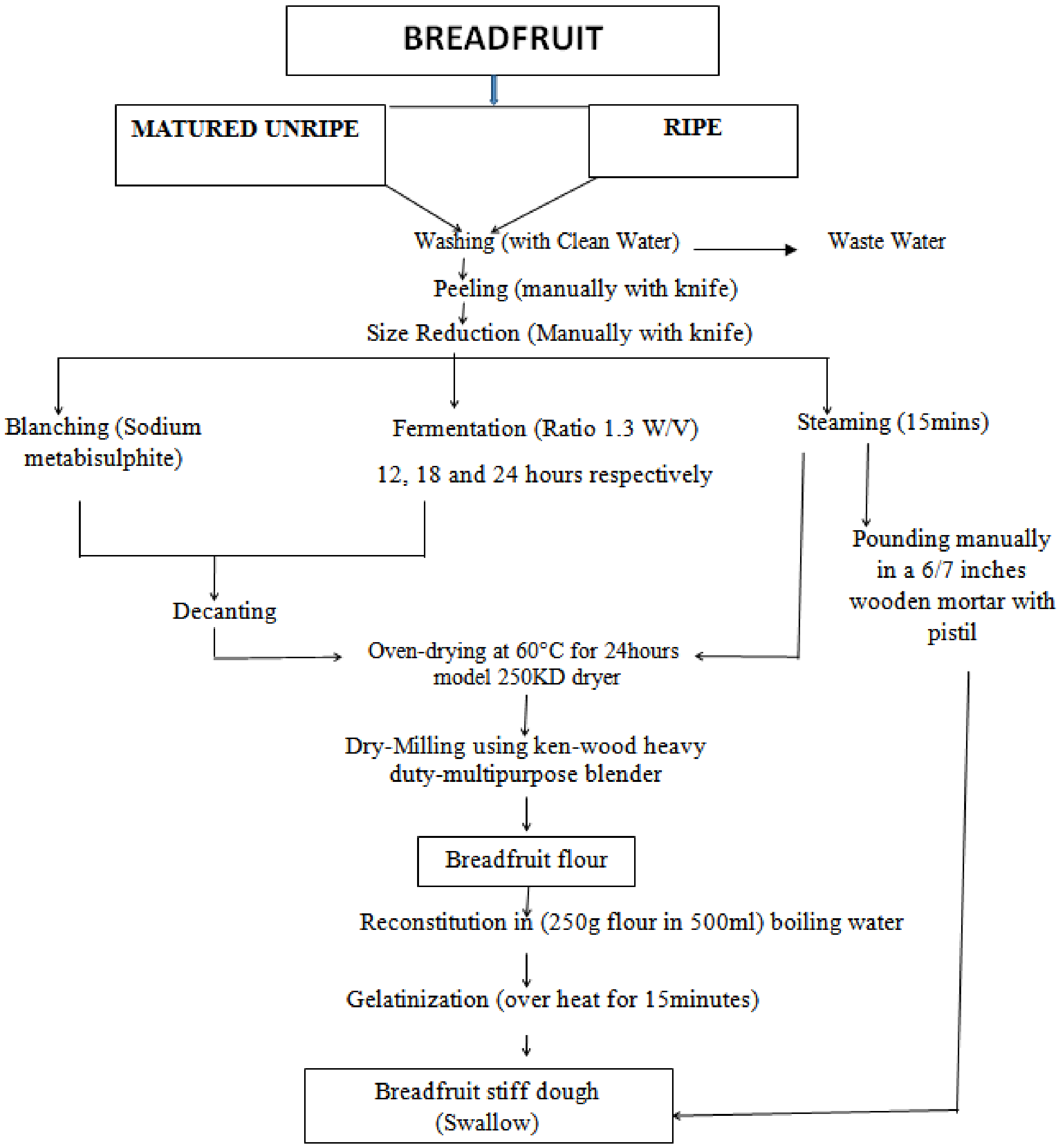

Figure 1. Production of Breadfruit flour and stiff dough (swallow) using different treatments (Source: Ragone, (2011))

2.5. Statistical Method

All analysis was carried out in duplicate. Mean score of two independent trials was reported. The variations between treatments was assessed. Data collected was subjected to one way analysis of variance (ANOVA) using JMP SAS ®, version 16.2 software and Principal Compact Analysis (PCA). Turkey's test was used to separate the mean where significant difference existed.

3. Results

3.1. Glycemic Indices, pH and Vitamin Composition from Unripe and Ripe Breadfruit Flour Processed with Different Treatments

Table 1 shows the results for glycemic index, glycemic load and vitamin composition of flour processed from ripe and unripe breadfruits with different treatments. The glycemic index values for unripe breadfruit flour ranged from 31.25 – 53.75 with sample B, (12hours fermented unripe breadfruit flour 12FUBF) having the lowest glycemic value and sample E, steamed unripe breadfruit flour (SUBF) having the highest glycemic value while the ripe breadfruit flour recorded glycemic index values ranging from 49.85 – 71.50 with sample J, steamed ripe breadfruit flour (SRBF) having the lowest glycemic value and sample H, (18 hours fermented, ripe breadfruit flour 18FRBF) having the highest glycemic value.

Glycemic load for unripe breadfruit flour ranged from 0.225 – 0.380 with sample B (12FUBF) recording the lowest and sample E (SUBF) having the highest. The ripe breadfruit flour recorded glycemic load ranging from 0.355 – 0.525 with sample F, blanched ripe breadfruit flour and G, 12 hours fermented ripe breadfruit flour (UTRBF and 12FRBF) recording the lowest and sample H (18FRBF) having the highest glycemic load.

Table 1. Glycemic indices, pH and vitamin values from unripe and ripe breadfruit flour processed using different treatment

S/N	Sample Code	B-Carotene (mg/kg)	Vitamin A (IU/100g)	Vitamin C (IU/100g)	pH	G.I (predicted)	G.L (predicted)
A	UTUBF	1.21^{bc}±0.15	0.06^{a}±0.01	0.01^{c}±0.00	5.45^{ab}±0.007	39.25^{bc}±2.58	0.275^{cd}±0.02
B	12FUBF	0.77^{c}±0.11	0.05^{a}±0.01	0.01^{c}±0.00	5.53^{ab}±0.035	31.25^{d}±2.58	0.225^{d}±0.02
C	18FUBF	0.68^{c}±0.00	0.04^{a}±0.01	0.01^{c}±0.00	4.93^{ab}±0.68	47.50^{bc}±2.58	0.360^{bc}±0.02
D	24FUBF	0.50^{c}±0.09	0.03^{a}±0.00	0.01^{c}±0.00	4.78^{abc}±0.014	45.70^{bc}±2.58	0.355^{bc}±0.02
E	SUBF	1.11^{bc}±0.11	0.06^{a}±0.00	0.00^{c}±0.00	5.64^{a}±0.028	53.74^{b}±2.58	0.380^{b}±0.02
F	UTRBF	4.83^{a}±0.15	0.24^{a}±0.01	0.01^{b}±0.002	5.23^{ab}±0.007	51.20^{bc}±2.58	0.355^{bc}±0.02
G	12FRBF	4.02^{a}±0.49	0.20^{a}±0.02	0.01^{a}±0.00	5.00^{abc}±0.007	50.90^{bc}±2.58	0.355^{bc}±0.02
H	18FRBF	2.04^{b}±0.69	0.10^{a}±0.03	0.01^{c}±0.002	4.73^{bc}±0.007	71.50^{a}±2.58	0.525^{a}±0.02
I	24FRBF	0.87^{bc}±0.19	0.0^{A}±0.01	0.65^{c}±0.004	4.29^{c}±0.00	54.40^{b}±2.58	0.410^{b}±0.02
J	SRBF	2.07^{b}±0.00	0.5^{A}±0.55	0.01^{c}±0.00	5.46^{ab}±0.007	49.85^{bc}±2.58	0.360^{bc}±0.02

Values are means of duplicate determination ±SD, means having different letters within a column are significantly different (p<0.05).

KEYS

A UTUBF – Unripe Blanched breadfruit flour
B 12FUBF – 12hours fermented unripe breadfruit flour
C 18FUBF – 18hours fermented unripe breadfruit flour
D 24FUBF – 24hours fermented unripe breadfruit flour
E SUBF – Steamed unripe breadfruit flour
F UTRBF – ripe blanched breadfruit flour
G 12FRBF – 12hours fermented ripe breadfruit flour
H 18FRBF – 18hours fermented ripe breadfruit flour
I 24FRBF – 24hours fermented ripe breadfruit flour
J SRBF – steamed ripe breadfruit flour

pH value of unripe breadfruit flour ranged from 4.78 -5.64 with sample D, twenty-four hours fermented unripe breadfruit flour (24FUBF) having the lowest pH (more acidic) and sample E, steamed unripe breadfruit flour (SUBF) having the highest (less acidic) while the pH of the ripe breadfruit flour range from 4.29 -5.46 with sample I (24hrs fermented ripe 24FRBF) having the lowest (more acidic) and sample J (steamed ripe breadfruit flour SRBF) having the highest (less acidic).

Beta-carotene content of unripe breadfruit flour ranged from 0.503 - 1.209ug/100g with sample D (24FUBF) having the lowest value of B-carotene and sample A (UTUBF) having the highest B-carotene content while the ripe breadfruit flour recorded B-carotene content ranging from 0.870 - 4.827ug/100g with sample I (24FRBF) having the lowest value and sample F (UTRBF) having the highest B-carotene content. The content of vitamin A in unripe breadfruit flour ranged from 0.025 - 0.056IU/100g with sample D (24FUBF) having the least and sample A (UTUBF) having the highest Vitamin A while the ripe breadfruit flour recorded Vitamin A content ranging from 0.044 - 0.504IU/100g with sample I (24FRBF) having the least value and sample J (SRBF) having the highest Vitamin A content. Vitamin C content for both ripe and unripe breadfruit flour ranged from 0.002 - 0.015% with sample D (24FUBF) having the lowest and sample F (UTRBF) having the highest Vitamin C.

Table 2. Sensory evaluation of stiff dough (swallow) from ripe and unripe breadfruit flour processed using different treatment

S/N	Sample Code	Appearance	Texture	Consistency	Moldability	Taste	General-Acceptability
A	UTUBF	4.44^{a}±1.73	5.00^{ab}±0.63	6.56^{ab}±0.86	5.81^{a}±0.75	5.58^{a}±0.83	5.48^{a}±0.31
B	12FUBF	3.83^{a}±2.44	5.56^{a}±0.47	5.72^{ab}±0.79	5.89^{a}±0.86	5.08^{a}±0.20	5.22^{a}±0.10
C	18FUBF	4.11^{a}±1.34	5.72^{a}±0.08	5.78^{ab}±0.24	5.69^{a}±0.51	4.83^{a}±1.26	5.23^{a}±0.48
D	24FUBF	4.22^{a}±1.73	6.17^{a}±0.24	6.14^{ab}±0.04	6.03^{a}±0.04	5.22^{a}±0.47	5.56^{a}±0.38
E	SUBF	3.94^{a}±2.67	5.47^{a}±0.90	5.92^{ab}±0.43	5.92^{a}±0.59	5.69^{a}±0.12	5.39^{a}±0.13
F	UTRBF	4.86^{a}±2.08	6.64^{a}±0.59	7.08^{a}±0.04	7.25^{a}±0.20	6.72^{a}±0.55	6.51^{a}±0.46
G	12FRBF	4.33^{a}±1.41	6.22^{a}±0.31	6.28^{ab}±0.47	5.78^{a}±0.39	5.25^{a}±1.22	5.57^{a}±0.45
H	18FRBF	4.47^{a}±2.87	6.83^{a}±0.00	6.22^{ab}±0.08	6.08^{a}±0.04	5.58^{a}±0.43	5.84^{a}±0.68
I	24FRBF	4.72^{a}±1.26	5.78^{a}±0.31	5.50^{ab}±0.31	6.28^{a}±0.63	5.19^{a}±0.67	5.49^{a}±0.39
J	SRBF	5.17^{a}±2.99	5.58^{a}±0.12	5.94^{ab}±0.24	5.53^{a}±0.35	5.53^{a}±0.43	5.55^{a}±0.37
K	SPBF	5.97^{a}±2.24	3.36^{b}±0.90	4.19^{b}±1.77	4.61^{a}±2.36	4.22^{a}±1.26	4.47^{a}±1.71

Values are means of duplicate determination ±SD, means having different letters within a column are significantly different (p<0.05).

KEYS

A UTUBF – Unripe Blanched breadfruit flour
B 12FUBF – 12hours fermented unripe breadfruit flour
C 18FUBF – 18hours fermented unripe breadfruit flour
D 24FUBF – 24hours fermented unripe breadfruit flour
E SUBF – Steamed unripe breadfruit flour
F UTRBF – ripe blanched breadfruit flour
G 12FRBF – 12hours fermented ripe breadfruit flour
H 18FRBF – 18hours fermented ripe breadfruit flour
I 24FRBF – 24hours fermented ripe breadfruit flour
J SRBF – steamed ripe breadfruit flour

3.2. Sensory Evaluation Result of Stiff Dough (Swallow) from Ripe and Unripe Breadfruit Flour Processed with Different Treatments

Table 2 shows the sensory result of breadfruit stiff dough (swallow) of unripe and ripe breadfruit flour processed from different treatments.

Sensory evaluation of the stiff dough samples prepared from unripe and ripe breadfruit flour was carried out about six hours after production using the 9 points hedonic scale where 1= dislike extremely and 9 = like extremely as described by [24]. A total of 19 semi-trained panelists aged twenty (20) years and above were involved in the evaluation for appearance, texture, consistency, mouldability and taste. The samples were coded with alphabets A to K, served to the panelist with water to wash their hands and rinse their mouth after every sample taste in a randomized order.

The sensory session was divided into two and panelist were made to analyze six (6) samples per session to avoid confusion. The panelist were instructed to analyze the samples first, without an accompaniment in both sessions and repeat the process with an accompaniment. They were also instructed to rate the samples on a scale ranging from slightly tender to extremely tough for texture, slightly rough to extremely smooth for consistency, slightly viscous to extremely sticky for moldability, slightly tasteless to extremely sweet for taste as stated in the sensory sheet.

Sensory evaluation result showed that all the stiff dough samples were liked very much by at least 1 panelist with sample A blanched unripe breadfruit stiff dough (UTUBF) having the highest number. Seven (7) samples (A, B, E, F, G, H and K) were liked extremely with sample F, blanched ripe breadfruit stiff porridge (UTRBF) having the highest number. The texture of samples A – J ranged from neither tough nor tender to slightly tough with sample K, steamed pounded breadfruit stiff dough (SPBF) having a tender texture. The consistency of the samples ranged from neither smooth nor rough to moderately smooth except sample K which was extremely rough due to the manual pounding method used. The moldability of the samples ranged from neither sticky nor viscous to slightly sticky but sample K was extremely viscous for moldability. The taste of the samples ranged from extremely tasteless to moderately sweet with sample A being extremely tasteless but sample K was moderately sweet. Samples A to E had a creamy appearance and samples F to J had a brownish appearance but sample K had a yellowish appearance.

4. Discussion.

4.1. Glycemic Indices, pH and Vitamins of Breadfruit Flour from Ripe and Unripe Breadfruits Processed Using Different Treatments

Glycemic index compares the potential of foods containing the same amount of carbohydrates to raise blood glucose, [25]. According to FAO/WHO, the glucose reference scale for glycemic index classifies products with glycemic index of 55 or less as low, 56 – 69 as moderate, 70 and above as high, [26]. The American Diabetes Association (ADA) explains that the GI indicates the way food raises blood sugar level compared with a reference food, usually glucose with GI score of 100 or white bread with a GI score of 71 [27].

The glycemic index of unripe and ripe breadfruit flour reported in this research ranged from 31.25 – 54.4. This values is within the range of low glycemic index on the glucose reference scale except sample H (18FRBF) with high glycemic index value of 71.5 close to the result of [28] who reported 60, 71 and 62 for glycemic index of breadfruit, Irish potatoes and white yam respectively. The GI of other breadfruit flour samples in this study is a little lower than 55 for *Tannia* as reported by [28] and lower than predicted glycemic index (PGI) of 80.79% and 80.45% for cake and bread as reported by [19].

According to previous studies, fermentation has dual effect on G.I. Studies from [29]; reported increased G.I while studies from [30] reported decreased G.I after fermentation. According to [31]; increase in fermentation time may bring about release of more glucose and therefore increase post prandial glycemic responses. However, the effect of fermentation on G.I of food largely depend on the following factors: the acid produced, starch hydrolysis, digestibility of fibre, [32] and amylose to amylopectin ratio [33]. In other words, during fermentation, if more acids are produced, fermented food will have low G.I due to lowered rate of gastric emptying and suppression of starch digesting enzymes, [32] but when digestibility of fibre and hydrolysis of starch dominates during fermentation, G.I increases according to [29] as reported by [31]. This may have been the case of sample H (18FRBF) which recorded high G.I at 18 hours fermentation but low G.I at 24 hours fermentation. This may have been possible due to the presence of more anaerobic microorganism that supported the production of amylase enzyme which could have increased hydrolysis of sugar at 18 hours but at 24 hours it was also possible that the time could not support the existence of those microorganism. The high G.I value of sample H (18FRBF) may have also been attributed to the ripe breadfruits used, suggesting that there was ease of digestion and absorption of glucose. According to [33], starch food with high amylose content triggers low blood glucose, insulin response and vice versa because the straight chain of glucose molecules makes amylose more compatible due to it linear nature thereby making glucose difficult to release as well as slowing down absorption.

According to [34]; maltose formed during fermentation is converted to D-glucose when hydrolysed in aqueous solution in the order: starch – dextrin – maltose – glucose. The low G.I from the other flour samples may be attributed to high amylose to low amylopectin ratio reported by [9] and the production of short chain organic acid (evident in the pH values) like lactic acid, acetic or propionic acid that dominated during fermentation, [35]. This result is in agreement with [36] who stated that breadfruit flour is gluten free with low glycemic index. The production of acid during fermentation is confirmed by the pH values of the flour which shows that all the flour samples have acidic pH ranging from 4.29 – 5.64.

Glycemic load (G.L) is the value that estimates the impact of carbohydrate consumption using the glycemic index. One unit of G.L approximates the effect of consuming one gram of glucose [37]. Since the glycemic index does not consider the number of carbohydrates in a food, glycemic load may be a better indicator of how a carbohydrate food will affect blood glucose [25].

The University of Sydney defines glycemic load of 0 to 10 as low, 11 to 19 as medium and 20 above, as high. The glycemic load of blanched, fermented and steamed breadfruit flour in this study all range between 0.225 - 0.525. Sample H (18FRBF) which has a high glycemic index records a low glycemic load emphasizing the importance of glycemic load. Glycemic index tells the potential of a food to raise blood glucose in the blood stream but glycemic load tells how much blood sugar per serving could go into the blood stream when the food is eaten. Glycemic load gives a more accurate picture of a food real-life impact on blood sugar [38].

The pH value of breadfruit flour ranged from 4.78 -5.65 in the unripe and 4.29 -5.46 in the ripe. Samples D, (24 hours fermented unripe breadfruit flour 24FUBF) and I, (24 hours fermented ripe breadfruit flour 24FRBF) having the lowest pH of 4.78 and 4.29 were fermented for 24 hours in the unripe and ripe stage, suggesting that acids were produced during fermentation, increased with prolonged time, reduced with blanching and steaming.

Vitamins

The absence of polar group in carotenoid structure makes them practically insoluble in water but more susceptible to degradation and isomerization in the presence of oxygen and heat, [39]. Food processing like heat treatment and storage have been reported to have a major effect on B-Carotene retention because of the nature of un-saturated, unstable carotenoids that are easily degraded by light, oxygen and ultra-violet heat leading to significant losses, [40]. Beta-Carotene values reported in this study was higher in the blanched ripe samples UTRBF (4.83mg/kg) confirming that ripening develops more Beta Carotene content due to the loss or degradation of phytol morety exposing the chlorophyll, leading to the exposure of carotenoids than in the blanched unripe sample UTUBF (1.21mg/kg) which still contained part of its chlorophyll component, but Beta Carotene significantly decreased with fermentation and steaming, confirming that Beta-Carotene is not stable at temperature between 65 – 70 degree-Celsius as reported by [40]. The yellowish appearance of the ripe raw breadfruit is suggestive of higher carotenoid content which is confirmed in the results of [13,41] who reported that ripened breadfruit contains higher levels of carotenoids than mature breadfruits. This report relates with the result of [42] who reported that processing of yellow fleshed cassava into consumable products resulted in major and minor losses of carotenoids caused by the breakdown of trans-carotenoids to their cis-isomers (isomerization) due to the increased contact with moisture, heat treatment and exposure to light.

Converting dietary B-Carotene into vitamin A is catalyzed by the enzyme Beta-Carotene 15, 15-dioxygenase (BCMOI) located in the intestinal enterocytes. The central cleavage of B-Carotene with BCMOI from the internal enterocytes produces two molecules of retinal which can be reversibly converted to retinol and irreversibly oxidized to retinoic acid. BCMOI only cleaves carotenoids with a non-substituted B-ionine ring, thus making pro-vitamin A the only substrate. Vitamin A value of plant is determined by the conversion efficiency of pro-vitamin A into Vitamin A (retinol) in the body. The vitamin A value for breadfruit flour reported in this study is less than 1 lU/100g and there is no significant difference $p<0.05$ among all the flour samples. The low content of vitamin A may have been as a result of the instability of B-Carotene when it was exposed to fermentation (moisture), isomerization and heat treatment. There was a significant difference ($p<0.05$) in B-Carotene and vitamin C but the level of Vitamin A was significantly the same in all the flour samples.

4.2. Sensory Properties of Breadfruit Stiff Dough (Swallow) from Ripe and Unripe Breadfruit Flour Processed with Different Treatments

Sensory evaluation is a set of techniques used to accurately evoke, measure, analyze and interpret the human responses to food products as perceived through the senses of sight, smell, touch and hearing, [43]. The aim of sensory evaluation of food is to minimize the potential bias effects of brand identity and other information that may influence consumer's perception.

The optical appearance of food is very important because colour of food surface (appearance) is the first quality parameter evaluated by the consumer and it is critical to product acceptability [44]. In this research, the appearance of eleven (11) samples of breadfruit stiff porridges evaluated by semi- trained panelist were described as creamy, light brown, brownish and yellowish. Unripe blanched, fermented and steamed breadfruit flour (UTUBF, 12FUBF, 18FUBF, 24FUBF and SUBF) had variations of creamy appearance. Ripe blanched, fermented and steamed breadfruit flour (UTRBF, 12FRBF, 18FRBF, 24FRBF and SRBF) had variations of brownish appearance. Only sample K, steamed pounded breadfruit flour (SPBF) had a yellowish appearance. The brownish appearance common among the ripe breadfruit stiff dough may have been as a result of maillard or caramelization reaction due to increased sugar content in the ripe stage.

Texture was used to describe the tenderness or toughness of the stiff dough (swallow). Most of the stiff dough were neither tough nor tender while some were moderately tough. The consistency of some stiff dough were smooth while some were neither rough nor smooth, some were viscous while some were slightly sticky for mouldability but sample K, steamed pounded breadfruit stiff dough was tender, moderately sticky and sweet. Stiff dough described to be sweet were processed in the ripe stage and ripening may have impacted sweetness since starch is converted to sugar during ripening. Significantly, there was no difference at $p<0.05$ among all the stiff dough for appearance, moldability, and taste except for texture and consistency

5. Conclusion

This study revealed that processing methods (blanching, fermentation, steaming and drying) and pH had effect in lowering the glycemic index and glycemic load of breadfruit flour because according to [1]; the glycemic index / glycemic load of raw breadfruit (*Artocarpus altilis*) is reported to be 68 (medium) and 18.36 (medium) respectively. There was an inverse relationship between G.I, amylose to amylopectin ratio because according to [9] breadfruit starch is reported to have high amylose content of 22.20-25.25%, [14]; reports that starch with high amylose content exhibit lower digestibility, [33] reports that it triggers low blood glucose and insulin response and these inverse relationship may had been the reason for the low glycemic index values of all the breadfruit flour except sample H (18FRBF) where starch hydrolysis may had dominated during fermentation but further studies on this is recommended.

It also revealed that unripe breadfruit flour may be more suitable in diabetic diets due to its low G.I but the treatments contributed to the general quality characteristics and stability of the stiff porridges (swallow) as blanched ripe breadfruit flour (UTRBF) produced stiff dough with overall sensory acceptability while 12 hours fermentation produced flour with the lowest predicted glycemic index. However, there was a loss of carotenoid appearance found in the raw breadfruits which may be due to fermentation or breakdown of their trans-carotenoids to their cis-isomers due to contact with moisture, heat treatment and exposure to light.

Conclusively, processing methods had diverse effect on G.I, vitamins and sensory properties of both unripe (vegetable) and ripe (fruit) breadfruit flour and stiff dough but 12 hours unripe breadfruit flour is considered most preferred due to its low G.I and G.L suggesting that it could be suitable for diabetics because according to [45], low consumption of energy from saturated fatty acids in favour of carbohydrates with low G.I is associated with lower risk of myocardial infarction (blockage of arteries/obstruction of blood flow to the heart and according to [46], carbohydrate contained in products with low G.I. should be the main source of energy in the diet of diabetics as it allows for control of post-prandial glucose and insulin release [47].

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