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Effect of different processing conditions on quality of cassava

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ABSTRACT

Sweeteners play a vital role in the food industry serving either as preservative or as addition to consumables. The high intake of sweetener brought about production of artificially synthesized sweetener which has, in turn, given a reason of concern for health on a long term. Cassava is one of the mostly cultivated crops in Nigeria with cassava possessing the highest level of starch compared to other crops. This research explores the abundance of cassava, converting its starch into sweetener (glucose). An extraction test rig was developed as part of the study to extract sweetener from cassava. A 2x3x3 factorial experiment was used to carry out the experiment and the factors considered were cassava varieties (*Manihot dulcis and Manihot palmatal*), delay period (15, 30 and 45 minutes) and quantity of starch (1, 2 and 4 kg). The SPSS 20.0 was used to carry out the Analysis of Variance (ANOVA) for the measured parameters. The sugar concentration analysis carried out on the cassava sweetener (*Manihot dulcis*) and (*Manihot palmatal),* gave values 13.02 and 17.57 mg/mL, respectively which were in line with the established cassava sweetener with value of 12.43 mg/mL. The ANOVA showed the interactive effect of cassava variety, delay period and quantity of starch on the nutritional composition of the sweetener on a 5% confidence level. The result revealed the highest extraction efficiency of which full hydrolysis for cassava variety (*Manihot palmatal*), 45minutes delay period and 2 kg quantity of starch compared with cassava variety (*Manihot dulcis*) 45 minutes delay period and 2 kg quantity of starch that gave the extraction efficiency of 76.93% and 78.03%, respectively. In nutritional value and sugar concentration comparison, the cassava sweetener obtained gave values closer to the established cassava sweetener and, as such, is a proper replacement for artificial sweetener.

Introduction

Cassava (*Manihot esculenta*) is a root crop cultivated and consumed as a staple in many regions of the developing world. Cassava, once termed the neglected crop of the down-trodden, is fast becoming an elite food crop in sub-Saharan Africa (Phillips et al., 2006). Cassava (*Manihot esculenta*) has a great potential to be used in Africa as an industrial base. This is due to the fact that cassava starch can perform most of the functions maize, rice and wheat starches are currently used for. Industrial application of starch has evolved into a multibillion dollar business worldwide and as such, many more industries, mostly within Africa, have now developed multipurpose applications for starch, especially cassava starch (Tonukari et al., 2015).

Sweetener, which is referred to as sugar substitute, is any of various natural and artificial substances that provide a sweet taste in food and beverages. In addition to their sweetening power, they may be used for processes such as food preservation, fermentation (in brewing and wine making), baking (where they contribute to texture, tenderization, and leavening) and food browning and caramelization. Sweeteners are the compounds that interact with taste buds that evoke a characteristic response and enhance the perception of sweet taste. Sweeteners,

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therefore, have ability to impart sweet taste by masking the taste of material to which they are added (Mehtani et al. 2003). Artificial sweeteners are synthetic sugar substitutes. However, they may be derived from naturally occurring substances, such as herbs or sugar itself. Artificial sweeteners are also known as intense sweeteners, because they are many times sweeter than sugar. As a result, much less sweetener is required and energy contribution is often negligible. Artificial sweeteners are called sugar substitutes because they provide the sweetness of sugars without the added calories, thus reducing the risk for obesity and dental caries. Some common artificial sweeteners includeaspartame, sucralose and saccharin (Roberts et al., 2000). Natural sweetening agents are preferred over synthetic sweetening agents since they do not have any adverse impact on health. Non-saccharide natural sweetening agents are low calorific, nontoxic and super sweet (100 to 10,000 times sweeter than sugar) in nature and can overcome the problems of sucrose and synthetic sweeteners. Natural sweeteners are useful sugar substitutes for diabetic patients (Srikanth et al., 2011). Some common natural sweeteners include stevia, brown rice syrup, date sugar and honey (MFMER, 2018). Natural sweeteners may be both nutritive and flavourable and thus popular both as food and flavouring agents. However, because common sugar and other nutritive sweeteners, such as honey and corn syrup, are associated with health problems (such as obesity and tooth decay) or are even a threat to life (for diabetics), there have been efforts since the 19th century to produce non-nutritive sweeteners that are not subjected to metabolism and contain little or no caloric value. Non-nutritive sweeteners are zero or low calorie alternatives to nutritive sugars such as sucrose (table sugar). Non-nutritive sweeteners are much sweeter than sugar, so only a small amount is needed and are also referred to as high intensity sweeteners (Fitch and Keim, 2012). Non-nutritive sweeteners, which may be either artificial (synthetic) or derived from plants, include compounds as saccharin, aspartame, cyclamates and thaumatin.

Critics of artificial sweeteners say that they cause a variety of health problems, including cancer (Saad et al., 2014). However, according to the National Cancer Institute and other health agencies, there is no sound scientific evidence that any of the artificial sweeteners approved for general use cause cancer or other serious health problems. Numerous studies confirm that artificial sweeteners are generally safe in limited quantities, even for pregnant women (MFMER, 2018). Artificial sweeteners are regulated by the Food and Drug Administration (FDA) as food additives. They must be reviewed and approved by the FDA before being made available for sale. The FDA has established an acceptable daily intake (ADI) for each artificial sweetener. ADI is the maximum amount considered safe to consume each day over the course of a lifetime. ADIs are set at very conservative levels (MFMER, 2018).

Over centuries, sweetening to consumables at large has been found to be insatiable despite the high level of sugar production. This has brought about the advent of several artificial sweeteners which helped in the amelioration of this problem, but also on the long term they have been found to be associated with long-term weight gain and increased risk of obesity, diabetes, high blood pressure and heart disease. Hence, there is a need to replace artificial sweeteners with organic sweeteners. The importance of cassava in the agricultural economy of many tropical countries has grown remarkably in recent years and a great potential exists for cassava utilization as an industrial base raw material in Africa. In this research, the use of sweetener from cassava in consumables will ameliorate the level of health detriments associated to artificial sweeteners. Therefore, the aim of the study was to investigate the effect of different processing conditions on quality of cassava sweetener.

Materials and methods

Extraction of sweetener

Figure 1 shows the schematic diagram of the sweetener extractor.

Figure 2 and Figure 3 show the exploded and pictorial views of the sweetener extractor, respectively, used for the research.

Sample preparation

The steps during the sample preparation explain the procedure for making the cassava starch. Improved varieties of cassava root were harvested from National Center for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria. The varieties and date planted were acquired prior to harvesting. The procedures involved are according to IITA (2010) reference manual guidelines. The cassava mash was collected and processed into the next stage of starch conversion. Fig. 4 and 5 show the cassava variety *Manihot Dulcis* and *Manihot Palmatal,* respectively.

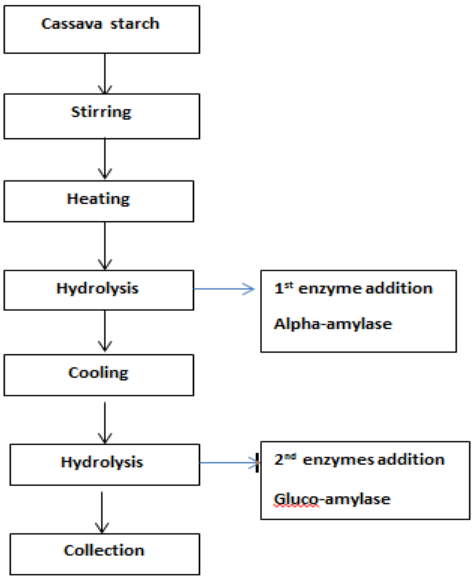
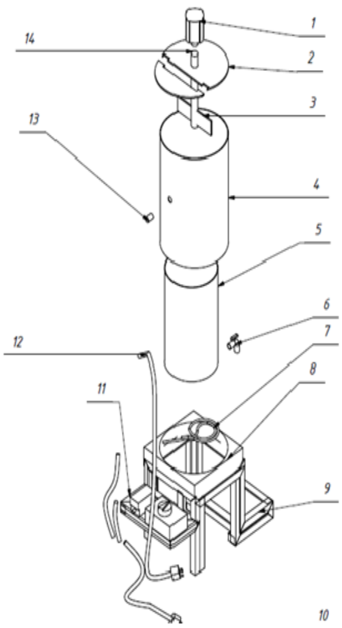


Fig. 1. Schematic diagram of sweetener extractor



S/N	PART LIST
1	Electric Motor
2	Cover
3	Stirrer
4	External Cylinder
5	Internal Cylinder
6	Tap
7	Heater
8	Base Support
9	Frame
10	Plug
11	temperature controller
12	Probe
13	Thermocouple Head
14	Shaft

Fig. 2. Exploded view of the sweetener extractor

Fig. 3. Pictorial views of the sweetener extractor

Fig. 4. *Manihot Dulcis* (okoiyawo)

Fig. 5. *Manihot Palmatal* (TME 419)

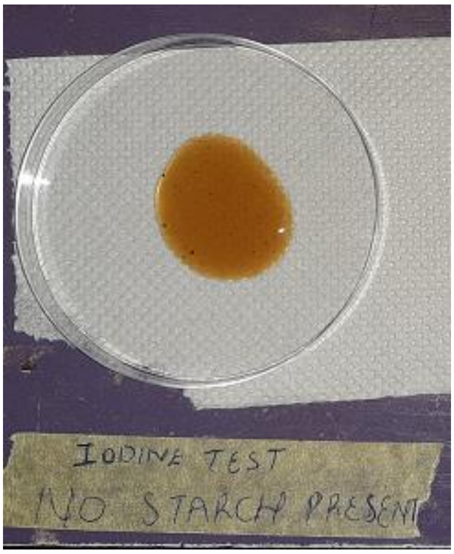


Fig. 6. Iodine test: starch absent

Fig. 7. Iodine test: starch present

Conversion and test confirmation

The cassava starch is poured into the stainless steel container and heated to 50-72 °C and the 1st enzyme, alpha-amylase (dextrolique), is added. Then, the starch temperature was raised to 80-85 °C and held for at least 60 minutes, while stirring is done. This brought about breakdown of carbohydrate molecule into smaller molecules called dextrin or complex sugar. The mixture is left to cool down to about 50-56 °C and the 2nd enzyme, gluco-amylase (sugarlique), is added. This breakdown complex sugar or dextrins into smaller molecules, i.e. simple sugars like fructose, glucose and sucrose, normally cool down within 55-50 °C, where the conversion takes place and it is stirred for 30 minutes to complete the conversion (AOAC, 2005). The mixture was allowed to stand for a while and then precipitation of a fluid floating on top of the solution was collected. A starch confirmation test was carried out by using an Iodine based starch indicator test in which in the presence of starch the fluid turned blue and colourless in the absence (Yukiko et al., 2016). Figs. 6 and 7 show the iodine-starch based test on cassava sweetener, respectively.

Sugar concentration analysis

The extract (cassava sweetener) was analyzed using the 6305 Spectrophotometer (visible range 190-1000 of absorbance. A graph of level of absorbance was plotted against the level of substrate absorbance.

nm, accuracy ± 2 nm). The spectrophotometer gave reading on the level of enzymatic activity and the level of absorbance. A graph of level of absorbance was plotted against the level of substrate absorbance.

Basic chemical expression of the reaction

$$E + S \underset{k_r}{\overset{k_f}{\rightleftharpoons}} ES \xrightarrow{k_{cat}} E + P \qquad (1)$$

Where: E = Enzyme S = Substrate (cassava starch), P = Product
ES = Enzyme-substrate complex, K_{cat} = Catalytic rate, $k_{f,r}$ = Forward and Reverse rate

Experimental design and layout

A 2×3×3 factorial experiment in a Completely Randomized Design (CRD) was used in this research. The factors thatwere taken into consideration are two levels of cassava variety (C) (C_1 and C_2), three levels of delay period (D) (D_1, D_2,,D_3) and three levels of starch quantity (Q) (Q_1, Q_2, Q_3). These values were individually tested and measured on the machine.

Determination of proximate composition of the cassava sweetener

These were determined in the laboratory using AOAC (2005) nutritional guideline.

The nutritional values determine were moisture content, crude protein, ash content, crude fibre, carbohydrate and crude lipid.

Results

Sugar concentration analysis and starch test confirmation on cassava sweetener

Starch test confirmation on cassava sweetener is carried out using Iodine-starch based test in which iodine was introduced into the cassava sweetener. This resulted in no colouration which indicates absence of starch and cassava starch. The whole process has undergone total hydrolysis.
The spectrophotometer was used to ascertain the level of absorbance of the cassava sweetener, which is then read from graph (Fig. 8). The graph presents the standard curve representing the level of absorbance against concentration in which extrapolation is done to established the sugar concentration of the cassava sweetener. Table 1 shows the summary of sugar concentration result of cassava sweetener obtained from the sweet cassava varieties**.**

Table 1. Sugar concentration values

Cassava varieties (C1, C2)	Sugar concentration (mg/mL)
Manihot Dulcis (okoiyawo)	13.02
Manihot Palmatal (TME 419)	17.57

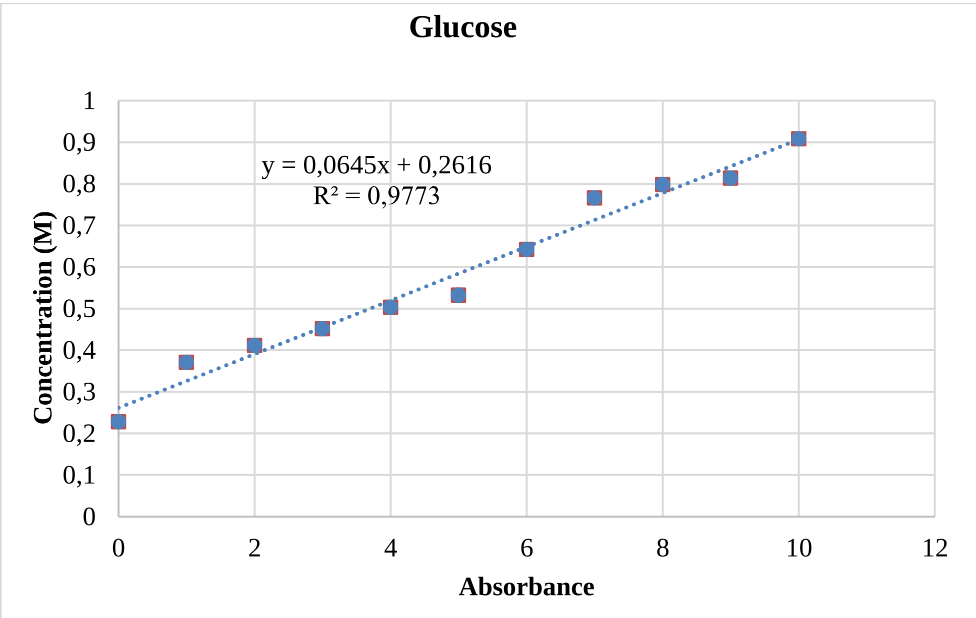


Fig. 8. The standard curve of absorbance against concentration

Analysis of variance test on the effect of cassava varieties, delay period and starch quantity on the proximate composition of sweeteners from cassava

Table 2 shows the analysis of variance for individual factors effect. The result shows the effect of cassava varieties, delay period and starch quantity are significant at $p \leq 0.05$ on moisture content, carbohydrate, crude protein, crude fibre and calorific value, while the effect of cassava varieties, delay period and starch quantity are not significant on ash and crude lipid. Also, delay period and quantity of starch had no significant effect on crude fibre and crude protein, respectively. From the essential regression analysis, the best equation was selected for the concentration of cassava variety based on the higher values of R^{2}.

The analysis of variance for two-way factor interaction between (cassava variety and delay period; cassava variety and quantity of starch; delay period and starch quantity)

The interaction (cassava varieties and delay period) was significant at $p \leq 0.05$ on moisture content, crude protein, crude fibre, while the effect of cassava varieties and delay period was not significant on carbohydrate, ash, crude lipid and calorific value. The interaction (cassava variety and quantity of starch) was significant at $p \leq 0.05$ on moisture content, carbohydrate, ash and calorific value, while the interaction had no significant effect on crude protein, crude fibre and crude lipid. The interaction (delay period and starch quantity) was significant at $p \leq 0.05$ on moisture content, carbohydrate, crude fibre and calorific value, while the effect of delay period and starch quantity showed no significant effect on crude protein, ash and crude lipid.

The analysis of variance for the three-way factor interaction between (cassava variety, delay period and quantity of starch) was significant at $p \leq 0.05$ on moisture content and crude fibre, while the interaction showed no significant effect on carbohydrate, crude protein, ash, crude lipid and calorific value.

Effect of delay period on extraction efficiency at various starch quantities for different cassava varieties

Figures 9 and 10 show the effect of delay period on extraction efficiency at various starch quantity for *Manihot dulcis* and *Manihot palmatal* varieties, respectively.

Table 2. Summary of analysis of variance for the effect of cassava variety, delay period and starch quantity on proximate composition of cassava sweetener

Source	df	Moisture Content	CHO	Crude Protein	ASH	Crude Fibre	Crude Lipid	Calorific Value
C	1	0.001*	0.000*	0.000^{*}	0.538^{ns}	0.000^{*}	0.318^{ns}	0.000^{*}
D	2	0.020*	0.034*	0.005^{*}	0.640^{ns}	0.092^{ns}	0.377^{ns}	0.028^{*}
Q	2	0.001*	0.004*	0.104^{ns}	0.224^{ns}	0.003^{*}	0.358^{ns}	0.006^{*}
C * D	2	0.001^{*}	0.202^{ns}	0.004^{*}	0.560^{ns}	0.004^{*}	0.464^{ns}	0.209^{ns}
C * Q	2	0.020^{*}	0.002^{*}	0.202^{ns}	0.042^{*}	0.096^{ns}	0.432^{ns}	0.005^{*}
D * Q	4	0.000^{*}	0.019^{*}	0.356^{ns}	0.645^{ns}	0.004*	0.551^{ns}	0.038^{*}
C * D * Q	4	0.010^{*}	0.288^{ns}	0.865^{ns}	0.299^{ns}	0.038^{*}	0.486^{ns}	0.635^{ns}

*Significant at $p \leq 0.05$; C = Cassava Variety, D = Delay period, Q = Starch quantity. ^{ns}Not significant at $p \leq 0.05$.

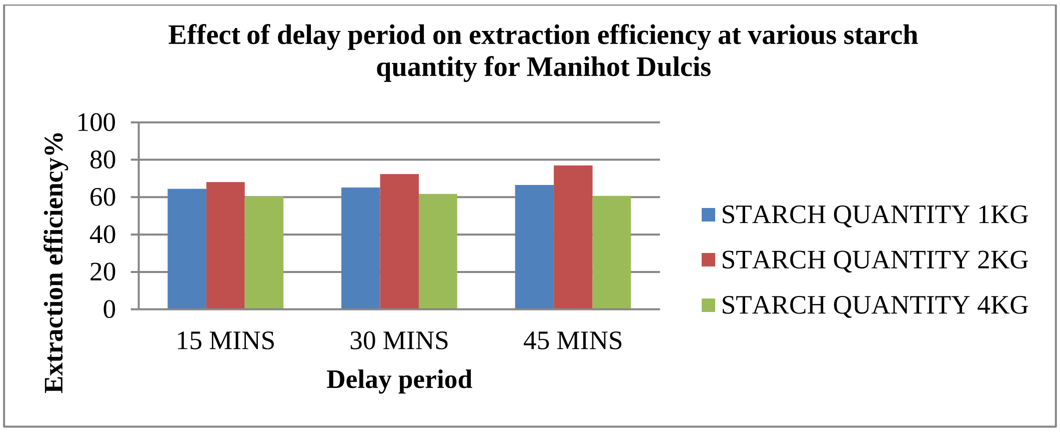


Fig. 9. Effect of delay period at various starch quantities for *Manihot Dulcis* on extraction efficiency

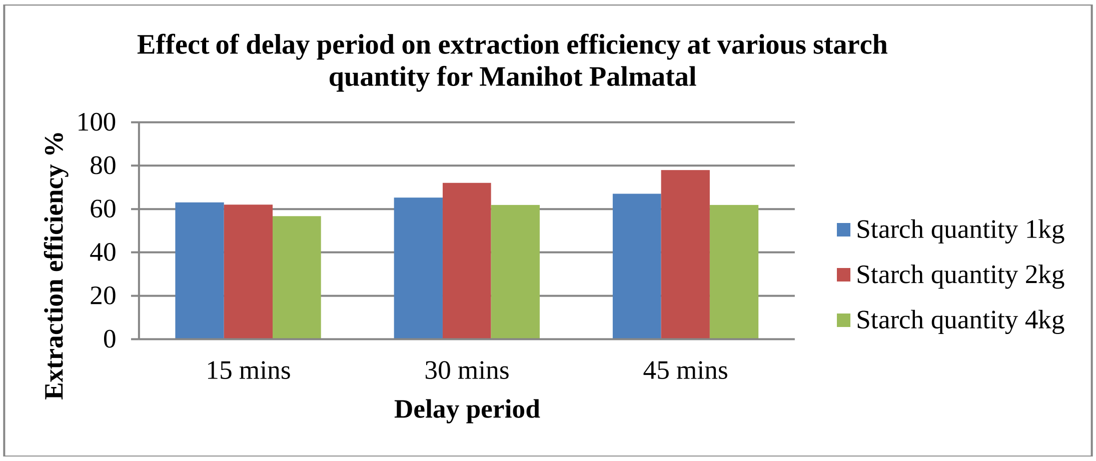


Fig. 10. Effect of delay period at various starch quantities for *Manihot Palmatal* on extraction efficiency

Table 3. Proximate composition and values comparison of cassava sweeteners

Parameters / ***Sources***	**Moisture Content%**	**Crude Protein %**	**Carbohydrate %**	**Crude Fibre%**	**Ash Content %**	**Crude Fat %**	**Calorific Value kJ/100 g**	**Sugar concentration mg/mL**
C1	14.067	6.804	73.848	2.651	2.547	0.083	1349.99	13.02
C2	15.468	6.409	69.761	5.375	2.757	0.179	1279.52	17.57
A.S		0.00	30.56	0.00	0.00	0.00	336.7	33.21
E. O .S	7.70	6.77	93.17	1.80	1.01	0.05	1547.35	12.43

C1 = *Manihot Dulcis*, C2 =*Manihot Palmatal*, A.S = Artificial sweetener (sucralose), E.O.S = Established organic sweetener (mahava cassava sweetener)

Comparison of organic sweetener with artificial and established sweetener

Table 3 shows the values obtained for the nutritional composition of sweeteners from different sources, including the sources of cassava varieties used for this research.

Discussion

Cassava variety C_1 was shown to have a higher sugar concentration. This is in line with the report of Reed (2012), who reported the sugar concentration of the *Manihot Dulcis* having 20 to 25% of starch and recommended the cultivation of this root for production ofglucose and tapioca.

The plot shows that 45 minutes delay period, the starch quantity 1 kg, 2 kg and 4 kg had the highest efficiency using cassava variety (*Manihot dulcis*), which decreased at 30 minutes delay period, starch quantity 1 kg, 2 kg and 4 kg and the least efficiency at 15 minutes delay period using starch quantity 1 kg, 2 kg and 4 kg using cassava variety (*Manihot dulcis*). Therefore, it shows that the delay period at 45minutes with starch quantity 2 kg using cassava variety *Manihot dulcis* revealed the highest efficiency, 78.03%. This efficiency is as a result of the delay period in which 30 minutes is the minimum delay period to achieve full hydrolysis with respect to the enzyme and starch quantity in line with Montañez Soto et al. (2012), where the author reported 50 minutes delay period using potato starch.

The plot (Figures 9 and 10) also shows the least efficiency at 15 minutes delay period using starch quantity 1 kg, 2 kg and 4 kg of cassava variety (*Manihot palmatal*), following an increase at 30 minutes delay period, starch quantity 1 kg, 2 kg and 4 kg. The 45 minutes delay period, the starch quantity 1 kg, 2 kg and 4 kg had the highest efficiency using cassava variety (*Manihot palmatal*). Therefore, it shows that the delay period at 45 minutes with starch quantity 2 kg using cassava variety *Manihot palmatal* revealed the highest efficiency 76.93%. The efficiency at 45 minutes gave full hydrolysis for the cassava starch at the weight owing to the enzyme used in which Montañez Soto et al. (2012) also used glucoamylase on rice starch and reported as close time of 50 minutes.

It can be inferred from the Table 3 that the organic sweetener from cassava varieties shows low crude fat, which is relatively close to the established organic sweetener (control). Thus, consuming crude fat from these sources control high blood pressure and obesity in humans as compared to the artificial sweetener (Bocarsly, 2010). The organic sweeteners from the cassava varieties are shown to have a lower sugar concentration owing to the absence of sucrose as compared to the artificial sweetener which is incorporated with sugar which can lead to the long term effect of diabetes (Srikanth, 2011). Also, the Table 3 shows that the organic sweeteners have higher crude fibre as compared to the established organic sweetener which is a result of the carbohydrate content in the cassava (Keating et al., 1981; Reed, 2012). The level of consumption of the organic sweetener can be quantified based on daily intake per calorie (men: 150 calories per day, 37.5 grams or 9 teaspoons; women 100 calories per day, 25 grams or 6 teaspoons) is set at conservative levels MRMER (2018). The organic cassava sweetener should be taken in moderation. It can as well still lead to diabetes, but not as much as when compared to the excessive intake of the artificial sweetener, e.g. sucralose.

Conclusions

The study focused on the development of organic sweeteners from cassava. The following conclusions were drawn from the study:

1. The extraction test rig was designed to be portable and efficient in the mixing of the sweetener.
2. Test confirmation using Iodine-Starch based test which revealed full hydrolysis of the cassava starch.
3. The sugar concentration analysis carried out on the organic cassava sweetener (*Manihot dulcis*), (*Manihot palmatal),* gave values which were in line with the established cassava sweetener 13.02 mg/mL, 17.57 mg/mL and 12.43 mg/mL, respectively.
4. The extraction efficiency of 76.925% was obtained for cassava variety (*Manihot palmatal*), 45 minutes delay period and 2 kg quantity of starch. The extraction efficiency of 78.025% was obtained for cassava variety (*Manihot dulcis*), 45 minutes delay period and 2 kg quantity of starch.
5. The organic sweetener obtained was compared to artificial and established cassava sweetener and was found to be of close nutritional composition as the established cassava sweetener. Hence, it is a suitable replacement for the artificial sweetener.

<ins>*Author Contributions*</ins>: **Musliu Sunmonu***:* Concieved the idea, developed and evaluated the apparatus performance, including the development of the design conceptand process conditions. **Mayowa Sanusi**: Developed the engineering drawings (exploded views of the machine). **Habeeb Lawal:** Provided the graphical representation of the results.

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