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Full Length Research

Physio-chemical properties of sugar syrup produced from two varieties of yam (*Dioscorea dumetorum* and *Dioscorea alata*) using exogenous enzymes

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ABSTRACT: Physio-chemical properties of sugar syrup produced from two varieties of yam (*Dioscorea dumetorum* and *Dioscorea alata*) using exogenous enzymes were studied. Starch and flour samples of two yam varieties (*Dioscorea dumetorum* and *Dioscorea alata*) were converted into sugar syrup by enzyme hydrolysis using exogenous enzymes. The sprouted and unsprouted tubers were processed into dried starch by washing, peeling, and milling; stirring, settling for about 6 hours; the supernatant was decanted and the sediment which contained the starch was filtered with muslin cloth and oven-dried at 70^{o}C for 30minutes to produce the dry starch. The sprouted and unsprouted tubers were also processed into fine flour by drying, milling and sieving with a 0.8 mm sieve. Alpha and Beta amylase enzymes were used in the syrup production. Physiochemical analysis was carried out on the syrup and results obtained were subjected to statistical analysis using analysis of variance (One-way ANOVA). The results obtained show that the pH values ranged from 4.45 to 5.65 while the moisture content values ranged from 67.42 to 72.25%; the dextrose equivalent results for the samples were 26.68, 26.47, 29.64, 27.13, 29.56, 26.34, 30.15 and 24.79% for the un-sprouted *Dioscorea dumentorum* flour (UD), sprouted *Dioscorea dumetorum* flour (SD), un-sprouted *Dioscorea alata* flour (UA), sprouted *Dioscorea alata* flour (SA), un-sprouted *Dioscorea dumetorum* starch (UDS), sprouted *Dioscorea dumetorum* starch (SDS), un-sprouted *Dioscorea alata* starch (UAS) and sprouted *Dioscorea alata* starch (SAS) respectively. This indicates that sample UAS had the highest level of hydrolysis. For the sugar syrups; sample SD had the highest viscosity value (950.05cp) while sample UA had the lowest value (835.10cp). The specific gravity of the sugar syrup samples ranged from 1.16 to 1.29 with sample SDS having the highest value and sample UD having the lowest value. Result from the analysis on sugar concentration (disaccharides) showed that the highest maltose concentration was recorded in sample SDS (57.27%) and the lowest was obtained in sample UA (51.65%). The glucose concentration of the sugar syrup samples ranged from 1.55 to 2.05%; sample SA recorded the lowest value of 1.55% while UAS recorded the highest value of 2.05%. The maltotriose, raffinose and starchyose concentrations of the sugar syrup samples ranged from 7.39 to 7.76%, 0.12 to 023% and 0.93 to 1.15% respectively. Results of this work suggest that sugar syrup can be made from underutilized yam species.

Keywords: Exogenous enzymes, sugar syrups, yam varieties.

INTRODUCTION

Sugar syrups are defined as aqueous solutions of sugars or starch which can be produced from any carbohydrate materials. Corn is the major raw material for its production, and is used for various purposes such as in fruit drink industry, confectionery, pharmaceutical and brewing (IFIS, 2005). Starch (corn) is a major raw material for syrup production but can equally be made from cassava, potato and sorghum according to some research works (Akpa,

2014), but unfortunately, most of our indigenous crops are not utilized for industrial syrup production.

Yam is the common name for some plant species in the genus *Dioscorea* that form edible tubers. The most economically important ones are white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis),* winged or purple yam (*Dioscorea alata),* bitter yam (*Dioscorea dumetorum),* etc (Calverly, 2003). Bitter yam and purple yam is gradually going into extinction as a result of underutilization, this is as a result of the anti-nutritional properties they possess, but are good sources of protein, lipid, crude fiber, starch, vitamins and minerals, they also contain anti-nutritional substances like total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitors but it can be inactivated by moist heat treatments and soaking followed by cooking before consumption (Mohan et al., 2011).

Native starch granules are semi-crystalline and can resist hydrolysis by amylases. When gelatinized, they are readily hydrolyzed and converted to sugars and dextrins, thereby reducing the molecular weight of starch molecules (amylose and amylopectin) (White et al., 2003; Tester et al., 2006). Dextrins are starch hydrolysis products produced by acid hydrolysis, enzyme hydrolysis, or a combination of both (White et al., 2003). Dextrin is one of several carbohydrates having the same general formula as starch, but dextrin and starch are structurally different as dextrin is a smaller and less complex molecule (Lotfy, 2009). The extent of hydrolysis is normally expressed in terms of the dextrose equivalent (DE): a quantity usually determined by titration and a measure of the total reducing power of the sugars present relative to a dextrose (D-glucose) standard, on a dry mass basis. The DE value is inversely related to molecular weight, *i.e.*, the degree of polymerization (DP), and is an indicator of the degree of hydrolysis. Thus, glucose has a DE value of 100, while intact starch maybe has an effective DE of zero (Sun et al., 2010). Starch hydrolyzates with DE values below 20 are referred to as maltodextrins. Dextrins with the same DE can have different properties and molecular compositions, depending on the starch and how it is digested (Sun et al., 2010) and this may greatly affect the properties of dextrins such as hygroscopicity, fermentability, viscosity, sweetness, stability, gelation, solubility and bioavailability and so on.

Though partial hydrolysis of starch has traditionally been carried out by using acids, acid hydrolysis is being replaced by enzymatic hydrolysis for the production of maltodextrins (Sun et al., 2010). The most widely used enzymes for production of maltodextrins using partial hydrolysis of starch are α-amylase from *Bacillus* spp. (Gupta et al. 2003). Enzyme hydrolysis with α-amylase efficiently hydrolyzes α-(1→4) linkages, but not α-(1→6) linkages, leaving behind a small amount of high-molecular-mass residues (Sun et al., 2010). The starch-degrading enzyme, alpha amylase (1,4-α-D-glucanohydrolase, E.C. 3.2.1.1) is widely distributed in nature. This extracellular enzyme hydrolyses α-1,4 glycosidic linkages randomly throughout the starch molecule in an endo-fashion, producing oligosaccharides and monosaccharides including maltose, glucose and alpha limit dextrin (Nigam and Singh, 2011).

The main objective of this work is to produce sugar syrup from two varieties of yam (*Dioscorea dumetorum* and *Dioscorea alata)* using exogenous enzymes as well as to determine the physio-chemical properties and sugar profile of the sugar syrup and this will result to proper utilization of these yam species that are going into extinction.

MATERIALS AND METHODS

Source of sample collection

The two varieties of yam used for the syrup production; *Dioscorea dumetorum* and *Dioscorea malata* were obtained from the National Root Crops Research Institute (NRCRI), Umudike, Abia State in Nigeria. The exogenous enzymes used for the syrup production was a combination of α &β-amylase, and was obtained from Nigeria Breweries Ltd, Awommamma, Imo State, Nigeria.

Sprouting of the yam tubers

The sprouted samples were produced by keeping the yam tubers (*Dioscorea dumetorum* and *Dioscorea alata)* separately separately (Plates 1 and 2) in a shaded, humid environment for 15 days and allowed to sprout naturally (Subramanian et al., 1992).

Yam flour production

The yam flour was produced according to the method described by Subramanian et al. (1992), where each sample of fresh yam tubers as well as the sprouted yam tubers of *Dioscorea dumetorum* and *Dioscorea alata* was peeled, washed and sliced into chips. The yam chips were sun dried for 6 hours after which they were oven-dried at 70^{o}C for 30 minutes using an electric single oven (model: LRE4211ST). The drying continued until the weight did not change significantly between two weighing successions. The dried yam chips were then milled and sieved to obtain fine flour (0.8 mm sieve) as shown in Figure 1. Images of flour samples are shown in Plates 3 to 6.

Starch extraction

The method of Osuji and Anih, (2011) was employed. Starch extraction was carried out from the fresh yam tubers. Properly washed and peeled tubers were milled into slurry; stirred and allowed to settle for about 6 hours.

Plate 1. Image showing sprouted *Dioscorea alata.*

Plate 2. Image showing sprouted *Dioscorea dumetorum.*

After settling, the supernatant was decanted and the sediment which contained the starch was filtered with muslin cloth and oven-dried at 70^{o}C for 30minutes to produce the dry starch.

Syrup production

The method of Osuji and Anih, (2011) involves weighing 100 g of the flour or starch samples into clean pots and a slurry was made by adding 450 ml of mash water (pH 11 using CaOH). The temperatures of the slurries were raised to 45^{o}C and 0.4 ml of α &β-enzymes were added, stirred and maintained at this temperature for 20 minutes. The temperature was gradually raised to 55^{o}C, stirred and rested for 10 minutes. Iodine test were carried out on the samples and then 0.4 ml of the enzymes was added into the slurries and their temperatures were further raised to 65^{o}C and maintained for 1 hour. Another set iodine tests were carried out and temperatures were raised to 90 to 93^{o}C after which 0.4 ml of the enzymes was added and temperatures were maintained for another 1 hour. The slurries were then boiled for 5 minutes, after which iodine tests were carried out. The samples were then cooled to 60^{o}C by placing them in an ice water bath. The pH of each sample was checked, and then the temperatures were maintained for an hour after the addition of 0.4 ml enzyme. After hydrolysis, the liquors were boiled for 10 minutes to denature enzymes. The converted slurries were then filtered across a double layered muslin cloth. The samples were then concentrated through evaporation using a water bath, and then packaged (Zheng et al., 2010).

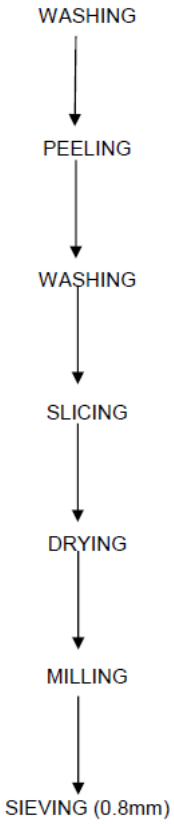

Figure 1. Flow diagram showing the method of yam flour production.

Determinations of sugar analysis composition and dextrose equivalent

Sugar analysis composition was carried out by the method described by Montesano et al. (2016) while dextrose equivalent was obtained by the procedure described by Akinola and Ayanleye (2004) and Hull (2010). HPLC grade acetonitrile (ACN), chloroform ($CHCl_3$), and analytical grade reference compounds, D- (−)-fructose (≥99% GC), D-(+)-glucose (≥99.5% GC), and D-(+)-sucrose (≥99.5% GC), were purchased from Sigma-Aldrich (Milano, Italy), whereas deionized water (>18MX cm resistivity) was obtained from Milli-Q SP Reagent Water System (Millipore, Bedford, MA, USA).

Preparation of standard solution

Stock solutions of fructose, glucose, and sucrose were prepared in bi-distilled water by weighing 2.5231, 2.5120, and 2.5363 g, respectively, and bringing the volume to 100 ml. The standard solution was diluted to five appropriate concentrations ranging from 2.50 to 0.31 mg/ml. Stock solutions of the sugars were stable for 1 month at 4°C in the refrigerator. The working standard solutions were prepared as needed by appropriate dilutions of the concentrated stock solutions in the bi-distilled water. Standard solutions were prepared fresh daily (Montesano et al., 2016).

HPLC instrumentation and chromatographic condition

The HPLC analyses were carried out using a LC-10ADvp pump (Shimadzu Corp., Kyoto, Japan) and ELSD (Sedex 55, S.E.D.E.RE., France), operating at 60°C and nitrogen pressure of 230 kPa. Standard and sample solutions (20 μl) were directly injected on a Platinum Amino column (5 μm, 250mmx4.6mm i.d.; Grace, Lokeren, Belgium), maintained at a temperature of 20°C in a column oven (CTO-10ASvp, Shimadzu). HPLC analysis was carried out by isocratic elution for 20 minutes using the mixture ACN: H_2O (80:20, v/v) at a flow rate of 1.2 ml/min. The mobile phase was degassed by ultrasonic bath (Astrason Heat Systems, New Highway, Farmingdale, NY) prior to use. After each analysis, the column was washed with water. The chromatograms were acquired and the data handled using the Class-VP software (Shimadzu). All solutions of samples were filtered through 0.45 nylon membrane (Advanced Microdevices Pvt. Ltd., Ambala, India) before use (Karioti et al., 2014).

Sample preparation for the determination of sugars

The extraction of sugars from yam starch/flour samples was adapted from a method described by Montesano et al. (2016). For this, 5 g of starch/flour was homogenized in blender (Oster, model 869-50R, USA) for 2 minutes using 50 ml of bi-distilled water; after that an equal volume of $CHCl_3$ (50 ml) was added. The obtained mixture was vortexed for 5 minutes and then incubated at 50°C for 30 minutes under magnetic stirring (F80 Model, FALC Instruments s.r.l., Treviglio, Bergamo, Italy).The extract was followed by centrifugation at 6500 rpm for 10 minutes; then the supernatant was separated and transferred to 250ml flask and subjected to Rotavapor (B-480 Model, Büchi, Italy) for 5 minutes and successively to nitrogen flow for 10 minutes for removing $CHCl_3$ traces. All solutions of samples were filtered through 0.45 nylon membrane (Advanced Microdevices Pvt. Ltd., Ambala, India) and then analyzed in HPLC (Montesano et al., 2016).

Preparation of Dextrin

Yam starch/flour (50 g) was mixed with distilled water (150 ml) and stirred for 10 minutes. This solution was mixed with 0.1 mol/l NaOH to pH 6.0 and 0.1 % (w/v) $CaCl_2$ successively. Then, common neutral α-amylase and thermostable α-amylase were added into the above solution to hydrolyze the starch. After enzyme denaturing by high pressure (Shanghai Tocan Science and

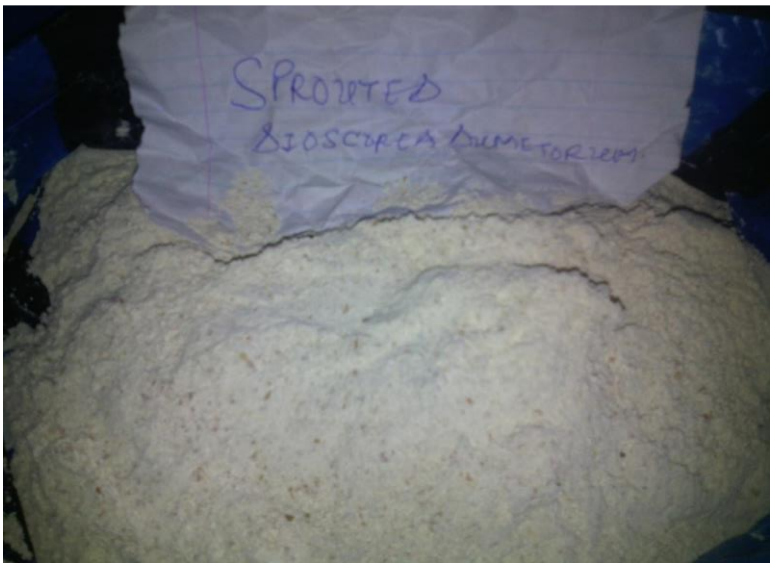

Plate 3. Image showing sprouted *Dioscorea dumetorum* flour.

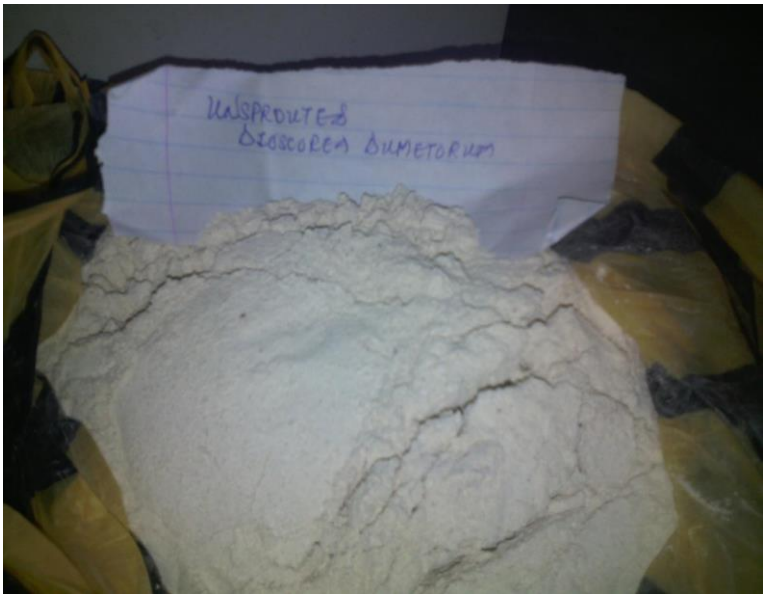

Plate 4. Image showing unsprouted *Dioscorea dumetorum* flour.

Technology Co. Ltd) and cooling, the DE-value of the product was determined (Sun et al., 2010). Obtained products were centrifuged, freeze-dried and used to property evaluation.

Determination of Dextrin's DE-value

The sample (1 g) was diluted to 50 ml and filtered. Then the above solution (0.5 ml) was mixed with 3, 5-dinitrosalicylic acid to measure the content of reducing sugar with glucose as standard (Sun et al., 2010). DE value was calculated in the following formula:

$$\mathrm{DE-Value} = \frac{\text{Reducing Sugar Content (glucose)}}{\text{Total Solids Content}} \times 100\%$$

Physico-chemical analysis

The method of Onwuka (2018) was used for the physic-chemical analysis of the sugar syrup and the parameters determined were as follows: viscosity, total titrable acidity, total solids, pH and specific gravity. The standard method of AOAC (2005) was used for moisture content

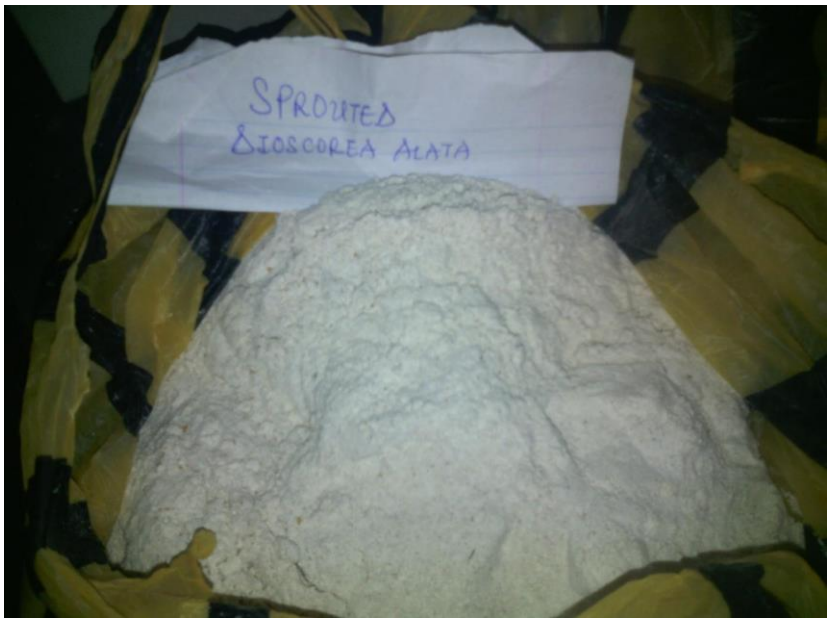

Plate 5. Image showing sprouted *Dioscorea alata* flour.

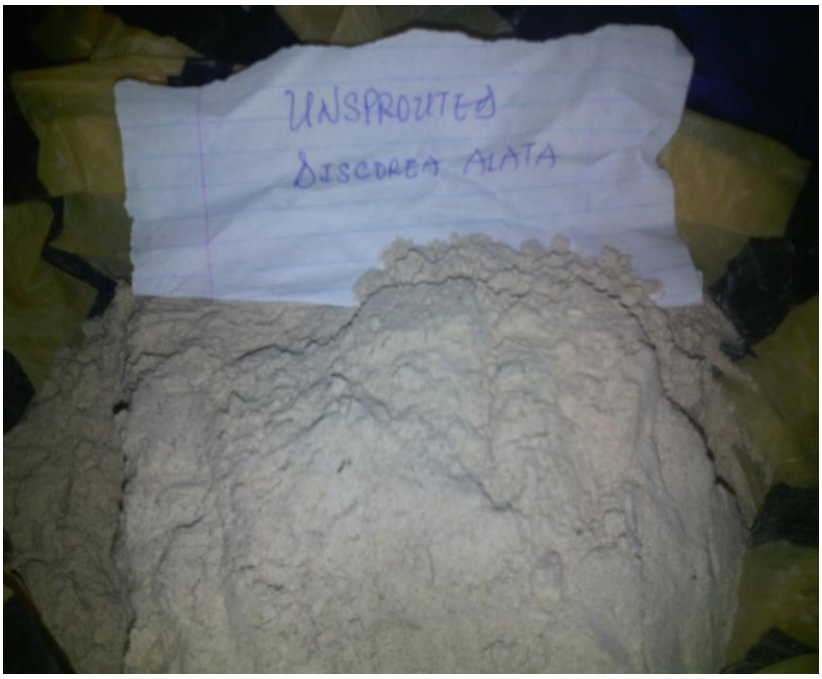

Plate 6. Image showing unsprouted *Dioscorea alata* flour.

determination. The apparent ^{o}Brix was determined using Montanez-Soto et al. (2013), where a digital refractometer was cleaned with a clean wiper and standardized with distilled water at 20^{o}C until the brix value reads zero. Two (2) drops of syrup sample at 20^{o}C was dropped on the lens (sensitive surface) of the refractometer and measured (Mikulic-Petkovsek et al., 2012).

Statistical analysis

Triplicate data obtained were subjected to statistical analysis using SPSS software of version 21. Mean values were determined and ANOVA was done as well as Fisher's Least Significant Difference (Pallant, 2004) was used to determine the separation of the means at ($p \leq 0.05$).

Table 1. Physico-chemical composition of syrup produced from two varieties of yam flour at different treatments using exogenous enzymes.

Sample	Physico-chemical Properties							
	Dextrose Equivalent (%)	Viscosity (cp)	Specific Gravity	pH	Total Solids (mg/ml)	Brix (°B)	Total Titratable Acidity (%)	Moisture (%)
UD	26.68±0.01^{c}	840.21±0.01^{c}	1.16±0.01^{d}	4.65±0.07^{b}	3.25±0.01^{a}	12.58±0.01^{c}	0.19±0.01^{b}	72.25±0.01^{a}
SD	26.47±0.01^{d}	950.05±0.07^{a}	1.23±0.01^{b}	4.65±0.07^{b}	2.86±0.01^{b}	12.64±0.01^{b}	0.14±0.01^{d}	69.56±0.01^{b}
UA	29.64±0.01^{a}	835.10±0.14^{d}	1.18±0.01^{c}	5.65±0.07^{a}	2.77±0.01^{c}	12.64±0.01^{b}	0.23±0.01^{a}	67.43±0.01^{d}
SA	27.13±0.01^{b}	840.31±0.04^{b}	1.26±0.01^{a}	5.65±0.07^{a}	2.56±0.01^{d}	12.78±0.01^{a}	0.18±0.01^{c}	69.26±0.01^{c}
LSD	0.02	0.03	0.02	0.16	0.02	0.02	0.02	0.02

Means are duplicate determination. Means with the same superscript along the column are not significantly different (P<0.05).
Keys: UD – Unsprouted *Dioscorea dumetorum* flour, SA - Sprouted *Dioscorea alata* flour**,** SD - Sprouted *Dioscorea dumetorum* flour, UA – Unsprouted *Dioscorea alata* flour.

Table 2. Physico-chemical composition of syrup produced from two varieties of yam starch at different treatments using exogenous enzymes.

Sample	Physico-chemical Properties							
	Dextrose Equivalent (%)	Viscosity (cp)	Specific Gravity	pH	Total Solids (mg/ml)	Brix (oB)	Total Titratable Acidity (%)	Moisture (%)
UDS	29.56±0.01^{b}	835.64±0.01^{d}	1.24±0.01^{c}	4.65±0.07^{c}	3.25±0.01^{b}	12.24±0.01^{c}	0.24±0.01^{b}	69.46±0.01^{c}
SDS	26.34±0.01^{c}	930.44±0.01^{b}	1.29±0.01^{a}	5.65±0.07^{a}	2.79±0.01^{c}	12.68±0.01^{a}	0.16±0.01^{d}	68.35±0.01^{d}
UAS	30.15±0.01^{a}	850.24±0.01^{c}	1.27±0.01^{b}	4.45±0.07^{d}	3.28±0.01^{a}	12.18±0.01^{d}	0.25±0.01^{a}	70.46±0.01^{a}
SAS	24.79±0.01^{d}	940.21±0.01^{a}	1.27±0.01^{b}	5.35±0.07^{b}	2.47±0.01^{d}	12.48±0.01^{b}	0.17±0.01^{c}	70.23±0.01^{b}
LSD	0.02	0.03	0.02	0.16	0.02	0.02	0.02	0.02

Means are duplicate determination. Means with the same superscript along the column are not significantly different (P<0.05).
Keys: UAS – Unsprouted *Dioscorea alata* starch**,** UDS – Unsprouted *Dioscorea dumetorum* starch, SAS - Sprouted *Dioscorea alata* starch, SDS - Sprouted *Dioscorea dumetorum* starch.

RESULTS AND DISCUSSION

Physico-chemical properties of sugar syrup from the yam flour and starch samples

The physico-chemical properties of sugar syrup from the yam flour and starch samples are shown in Table 1 and 2 respectively. The result revealed that the pH of syrup from the two varieties of yam flours ranged from 4.65 to 5.65 while that from the two varieties of yam starches ranged from 4.45 to 5.65 and the results indicate that they were in medium acid region. The results of the pH were however lower than the values of 5.65 to 6.5 reported by Dziedzoave et al. (2004). The acidic nature of the syrups could be attributed to the presence of organic acids which can function synergistically with sugar to prevent spoilage (Pinto, 2009). However, the low pH values will help effectively to control and/or maintain the storage stability of the syrup at a longer period of time. Acids present in foods do not only improve its palatability, but also influences their nutritive value. The acid influences the flavor, brightness of color, stability, consistency and keeping quality of the product (Dziedzoave et al., 2004).

The dextrose equivalent (DE) with the highest value was recorded by sample UA (29.64%) for flour and sample UAS (30.15%) for starch while the least DE for flour was recorded by sample SD (26.47% and SAS (24.79%) for starch. Significant differences exist in the dextrose equivalent of syrups from starch and flour. The higher DE values of syrups obtained from un-sprouted *Dioscorea alata* starch and flour when compared to syrups from *Dioscorea dumetorum* could be due to

varietal effect as a result of the nature of its starch composition. It could also be an indication that sprouting may have enhanced accessibility of enzymes to the substrate during hydrolysis, thus reducing the DE of syrups (Osuji and Anih, 2011). However, the dextrose equivalents obtained from the sprouted samples were lower than the un-sprouted samples. Variations could be as result of differences in raw materials used and also as a result of the nature of enzymes used during hydrolysis.

The results of the viscosity indicate that SD (950.05cp) and SAS (940.21cp) had the highest value while the samples with the lowest value are UA (835.10cp) and UDS (835.64cp). There were significant differences ($p<0.05$) in the apparent viscosity of syrups from starch and flour. There was an observable increase in the apparent viscosity of syrup from sprouted samples when compared to un-sprouted samples of the two yam varieties. The variations might be due to varying solid contents and to a lesser extent varietal differences and types of treatment. The results obtained in this study are lower than 2300 to 2480cp reported by Ahure and Ariahu (2013). This could be as a result of the starting raw material, enzyme used, or method of hydrolysis.

Total titrable acidity (TTA) is the present acid in a sample determined by titration with a standard base and stated in terms of the predominant acid in the sample (George, 2002). The results obtained indicate that sample UA (0.23%) and UAS (0.25%) have the highest value while the least was recorded in SD (0.14%) and SDS (0.16%). There were significant differences ($p<0.05$) in the TTA of syrups from starch and flour and these variations could be as a result of varietal differences with regards to the acidity level of the soil where these tubers were cultivated. The results obtained were higher than the values of 0.08 to 0.10% reported by Akonor et al. (2014).

Specific gravity of the syrup is the density of the syrup compared to that of water at equal volumes (Pratt and Cornley, 2013). The results obtained indicate that samples SA (1.26) for flour and SDS (1.29) for starch had the highest value while the lowest value was recorded in samples UD (1.16) and UDS (1.24). There were significant differences ($p<0.05$) in the specific gravity of syrups from starch and flour. These differences from the two varieties of yam might have been due to principally varying levels of solid content in the syrup which contributed to its density (Smith et al., 2005).

The highest total solid content was recorded in UD (3.25%) for flour and UAS (3.28%) for starch while the least total solid content for flour was recorded in SA (2.56%) and SAS (2.47%) for starch. The total solids of syrups from un-sprouted samples were significantly higher than their corresponding sprouted samples. Total solids are largely composed of soluble and insoluble constituents in the syrup such as sugars, dextrin, organic acid, amino acid and minerals. The observable total solids of syrups from sprouted samples when compared to syrups from un-sprouted samples could be due to the extent of partial degradation of endosperm starches and cell wall into lower molecular weight products as sprouting progresses because of increase in enzyme development (O'Keefe, 2004).

The highest degree brix content was recorded in sample SA (12.78) for flour and sample SDS (12.68) for starch while the least degree brix was recorded in UD (12.58) for flour and UAS (12.18) for starch. There were significant differences in the degree brix of syrups from starch and flour. These changes could be attributed to the inherent differences among the yam varieties and the type of treatment. The type and amount of sugars in the syrup and the source of variety of raw material can affect the apparent brix measurement as a result of changes in the refractive index of the solution due to different soluble substances in the solution. The resulting syrup from the two yam varieties had an apparent brix lower than the values of 24.00 to 28.00 B reported by Eke-Ejiofor (2015) after hydrolyzing starches from cassava and different potato varieties.

The moisture content with the highest value was recorded by sample UD (72.25%) for flour and UAS (70.46%) for starch while the least moisture content for flour was recorded by UA (67.43%) and SDS (68.35%) for starch. Significant differences ($p<0.05$) exist in the moisture content of syrups from starch and flour (Lee et al., 2004).

Sugar profile of syrup samples produced

The result of the sugar profile is shown in Table 3 and Table 4. The syrups produced different combinations of sugars, such as maltose, glucose, maltotriose, sucrose, raffinose and starchyose in various proportions. There were significant differences ($p<0.05$) in the sugar composition of syrups from starch and flour. From the results, syrups obtained from different yam varieties of flour and starch showed that maltose was the most abundant sugar in the syrup (Dziedzic and Kearsley, 2012). The high maltose concentration in the syrup could be due to the nature and quality of enzyme used in the production of these syrups.

According to Hull (2010), α-amylase enzyme randomly attacks gelatinized starch at 1-4 linkages to produce glucose and maltose but unable to hydrolyze the 1-6 linkages. However, in this study, the enzyme used was a combination of both α & β-amylase. Hull (2010) reported that β-amylase attacks the 1-4 linkages of liquefied starch to produce predominantly maltose with lesser amounts of glucose. This provides an explanation for the high maltose concentration as compared to other sugars produced in the syrup, maltotriose concentration was considerably high but second to maltose. There was an observable increase in the maltose and maltotriose content of syrups from flour and starch of sprouted yam of different varieties, which could be attributed to the sprouting action of the tubers.

Table 3. Mean values of sugar profile of sugar syrup produced from two varieties of yam (*Dioscoreadumetorum* and *Dioscoreaalata*) flour at different treatments using an exogenous enzyme.

Sample	Sugar Profile					
	Maltose (%)	Glucose (%)	Maltotriose (%)	Sucrose (%)	Raffinose (%)	Stachyose (%)
UD	53.27±0.01^{c}	1.85±0.01^{b}	7.26±0.01^{c}	0.38±0.01^{b}	0.15±0.00^{b}	1.05±0.01^{b}
SD	55.58±0.01^{b}	1.74±0.01^{c}	7.46±0.01^{b}	0.27±0.01^{c}	0.13±0.01^{c}	0.95±0.01^{c}
UA	51.65±0.01^{d}	1.94±0.01^{a}	6.95±0.01^{d}	0.42±0.01^{a}	0.17±0.01^{a}	1.09±0.01^{a}
SA	56.58±0.01^{a}	1.55±0.01^{d}	7.56±0.01^{a}	0.22±0.01^{d}	0.07±0.01^{d}	0.82±0.01^{d}
LSD	0.03	0.02	0.03	0.02	0.02	0.02

Means are duplicate determination. Means with the same superscript along the column are not significantly different (P<0.05).
Keys: UD – Unsprouted *Dioscorea dumetorum* flour, SA - Sprouted *Dioscorea alata* flour, SD - Sprouted *Dioscorea dumetorum* flour, UA – Unsprouted *Dioscorea alata* flour.

Table 4. Mean Values of sugar profile of sugar syrup produced from two varieties of yam (*Dioscoreadumetorum* and *Dioscoreaalata*) starch at different treatments using an exogenous enzyme.

Sample	Sugar Profile					
	Maltose (%)	Glucose (%)	Maltotriose (%)	Sucrose (%)	Raffinose (%)	Stachyose (%)
UDS	56.59±0.01^{c}	2.05±0.01^{a}	7.53±0.01^{c}	0.44±0.01^{b}	0.23±0.01^{a}	1.15±0.01^{a}
SDS	57.27±0.03^{a}	1.93±0.01^{c}	7.76±0.01^{a}	0.47±0.01^{a}	0.17±0.01^{c}	1.12±0.01^{b}
UAS	54.48±0.01^{d}	2.01±0.01^{b}	7.39±0.01^{d}	0.33±0.01^{d}	0.22±0.01^{b}	1.12±0.00^{b}
SAS	57.24±0.01^{b}	1.75±0.01^{d}	7.69±0.01^{b}	0.42±0.00^{c}	0.12±0.01^{d}	0.93±0.01^{c}
LSD	0.03	0.02	0.03	0.02	0.02	0.02

Means are duplicate determination. Means with the same superscript along the column are not significantly different (P<0.05).
Keys: UAS – Unsprouted *Dioscorea alata* starch, UDS – Unsprouted *Dioscorea dumetorum* starch, SAS - Sprouted *Dioscorea alata* starch, SDS - Sprouted *Dioscorea dumetorum* starch.

This is in line with the reports of Hui and Sherkat (2005), which states that maltose and maltotriose are the most abundant sugars produced in germinated grain when the grain starch is modified. The action of sprouting could have promoted enzymic changes leading to breakdown of starch into simpler sugars which include maltotriose (Smith, 2001). Also, the significantly higher maltotriose concentration when compared to other sugars except maltotriose, could have resulted from the enzymic activity during mashing.

There was a significant reduction in glucose and sucrose concentration of syrup produced from flour and starch of different yam varieties. The results showed that starchyose and raffinose from sprouted samples were significantly lower than their corresponding un-sprouted samples. The decrease in the concentration of raffinose and starchyose could be attributed to the sprouting action and mashing process leading to degradation of macromolecules. During sprouting, oligosaccharides are degraded by the action of two distinct types of α-galactosidase that differ in their optimum pH of catalysis (Lee et al., 2004).

Conclusion

The results obtained show that the production of sugar syrup from two varieties of yam using an exogenous enzyme by hydrolysis was feasible and effective and could equally be stored at a longer period of time is consistency and keeping quality of

the product. The syrups obtained were high maltose syrups as they contain more than 50% maltose which is the reason for the low viscosity.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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