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RESEARCH ARTICLE

FUNCTIONAL PROPERTIES OF STARCHES, PHYSICO-CHEMICAL AND RHEOLOGICAL PROPERTIES OF GLUCOSE SYRUP MADE FROM CASSAVA AND DIFFERENT POTATO VARIETIES

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ABSTRACT

The physico-chemical and rheological properties of glucose syrup from cassava and different potato varieties were determined. Starches from sweet , Irish potato and cassava were processed and hydrolyzed using 30% of rice malt per 100g starch weight for the preparation of glucose syrup. Physico-chemical properties such as moisture content, mineral ash, Total Available Carbohydrate (TAC), Total Titratable Acidity (TTA), pH and dextrose equivalent (DE) were determined while viscosity at different speeds were also determined. Sweet potato starch had the highest moisture content while Irish potato had the least (39% and 67%, respectively). The ash content showed no significant difference in value for all three samples (0.23%) as well as dextrose equivalent (in ^{o}Brix) which ranged from 24 in Irish potato to 28 in sweet potato. The pH values of all three samples were acidic with cassava recording 4.4 and potato varieties with 4.9. At 6, 12 and 30 RPM, viscosity decreased with increase in speed with sweet potato been more viscous, recording 30.46pas^{-1} 21.34pas^{-1} and 12.96pas^{-1} respectively, while Irish potato was the least viscous recording 11.03pas^{-1}, 7.92pas^{-1} and 5.38pas^{-1} respectively as speed in rpm increased, but at 60 rpm viscosity of samples showed inconsistency as Irish potato was more viscous (4.040 pas^{-1}) and cassava least viscous (1.68 pas^{-1}). Relative bulk density (g/ml) was highest in Irish potato (45.66) and lowest in cassava starch (28.45). Solubility and dispersibility (%) for the three Starches recorded no significant difference ($p>0.05$) with solubility ranging from 12%-14% with cassava as the lowest and Irish potato as the highest. Other functional properties of starch such as relative bulk density, swelling power, least gelation concentration (LGC) and water absorption capacity (WAC) showed significant difference ($p<0.05$).

INTRODUCTION

Syrup is a thick viscous liquid consisting primarily of a solution of sugar in water, containing large amount of dissolved sugars but showing little tendency to deposit crystals (Hull, 2010). The viscosity arises from multiple hydrogen bonds between the dissolved sugar, which has many hydroxyl (OH) groups, and the syrups can be either medicinal or non-medicinal.

Glucose syrup is food syrup made from the hydrolysis of starch, in which case the syrup is called "corn syrup". It can also be described as aqueous solution of glucose, maltose and other nutritive saccharides from edible starch. Glucose or dextrose is found in nature in sweet fruits such as grapes or honey. Glucose syrup is also made from other starch crops including potato, wheat, barley, rice and cassava (Hull, 2010).
Corn syrup is made from the starch of maize and contains varying amounts of maltose and higher oligosaccharides, depending on the grade. Corn syrup is used in foods to soften texture, add volume, prevent crystallization of sugar and enhance flavor. They are also used in large quantities in fruits, liquors, crystallized fruits, bakery products, pharmaceuticals and brewery products. Depending on the method used to hydrolyze starch and on the extent to which the hydrolysis reaction has been allowed to proceed, different grades of glucose syrup are produced, which have different characteristics and uses (Norman *et al.*, 2001). The syrups are broadly categorized according to their dextrose equivalent (DE).

Starch is the major raw material for the production of glucose syrup and it is widely used in the food and pharmaceutical industries (Wallenstein, 1950; Newton, 1970). The syrup is obtained from the hydrolysis of starch to glucose, maltose, maltotriose and dextrins (Kunze, 1996). Cassava is a multipurpose root crop that is primarily used as a staple food in the tropical areas of the world especially in Nigeria and Ghana (Bokanga, 1992). It has several advantages compared with other roots crops which include high productivity under

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marginal climate and soil fertility conditions which results in low cost of raw materials (Ospina and Wheatley, 2005).

Potato are essentially a food security crop with steadily growing urban and domestic market (Eke-Ejiofor and Kiin-Kabari, 2010). Irish potato, *Solanum tuberasum* is a cool season vegetable that ranks as the world's fourth largest food crop, following rice, wheat and maize (UNFAO, 2011). Potato starch is used in the food industry as thickeners and binders of soups and sauces, in the textile industry, as adhesives for the manufacturing of papers and boards (Gopal 2006).

The nutritional potentials identified with sweet potato crop are still under exploited in Africa especially in Nigeria (Akoroda and Egeonu, 2009) as well as the use of rice for malt production.

Malting is the process in which cereals specifically barley are soaked and drained to initiate the germination of the plant from the seed (Padmaja, 1995). These grains are made to germinate by soaking in water and are then halted from germinating further by drying with hot air (Kirk-Othmer, 2007).

During malting, the grains are allowed to germinate in order to produce amylase which helps to modify the grains to an optimal level of brewers extract. Both alpha and beta-amylase are involved; the alpha-amylase liquefies the starch while the beta-amylase acts to increase sugar formation; a process known as saccharification. Malted barley is a generally accepted grain and primary raw material in the brewing industry because of its outstanding malting qualities.

However, barley is not locally produced in Nigeria and can only be imported at high cost. Therefore, there is the need to look inward for a local substitute. Rice is produced locally in almost all parts of Nigeria and is available all year round and can be used as alternative to barley in brewing and several other purposes.

Sweet potato has been recognized as having an important role to play in improving house hold and national food security, health and livelihoods of poor families in sub-Saharan Africa.

Corn is the major crop used in the production of glucose syrup because it is easy to store, readily available and easy to transport and its starch content is great. Potato and cassava starches have such qualities although, there is little information on the use of tuber starches for glucose syrup production and hence the objectives of this study;

1. To determine the functional properties of starches from cassava and potato varieties.
2. To produce glucose syrup from other carbohydrate based crops such as cassava and potato.
3. To determine the physico-chemical and rheological properties of glucose syrup from cassava and potato varieties.

MATERIALS AND METHODS

MATERIALS

Fresh cassava roots were obtained from Mile III market while potato (sweet potato and Irish potato) tubers were obtained from fruit garden market all within Port Harcourt metropolis. Local whole grain Abakaliki Rice was obtained from the National Cereal Research Institute (NCRI), Amakama Umuahia, Abia State.

Chemicals

Chemicals used for analysis were of analytical grade and were obtained from the Biochemistry Laboratory, Department of Food Science and Technology, Rivers State University of Science and Technology.

METHODS

Production Of Starch

The method described by Osunsami *et al.*, (1989) was used for the production of various starches. The cassava and potato roots (sweet and Irish) were washed to remove soils and dirt from their skin and peeled using kitchen knife. The peeled roots and tubers were washed, chopped into smaller pieces, milled with an electric grater and sieved by washing off in a basin of water. The mixture was filtered through a fine mesh sieve (muslin cloth) and the filtrate allowed to settle. The supernatant (effluent) was decanted and sediment obtained.

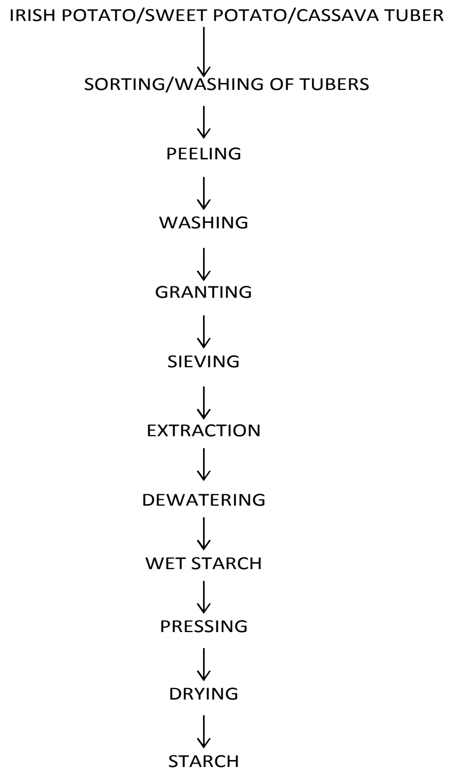


Figure 1 Flow diagram for starch production
Source: Osunsami et al., 1989) modified

The resultant wet starch was thinly spread on a tray and subjected to an oven drying method for 18 hours at 55°C. The starch obtained was packaged and stored for further use.

Production Of Glucose Syrup

The method of Osuji and Anih (2011) with slight modification was used for the production of glucose syrup. 100g each of starch from cassava, sweet potato and Irish potato tubers was transferred into 420ml of water in a beaker and 30% (30g) starch weight of rice malt was added. The content of the beaker was stirred continuously and allowed to gelatinize at 55°C for 1 hour (60minutes). The sugar content of the mixture was checked to ascertain starch conversion to glucose. After hydrolysis, the liquor was boiled for about 20 minutes and filtered over a double-layered muslin cloth. The filtrate obtained was concentrated to half the original volume in a shaker bath. The temperature of the bath was maintained at 80°C throughout the concentration process.

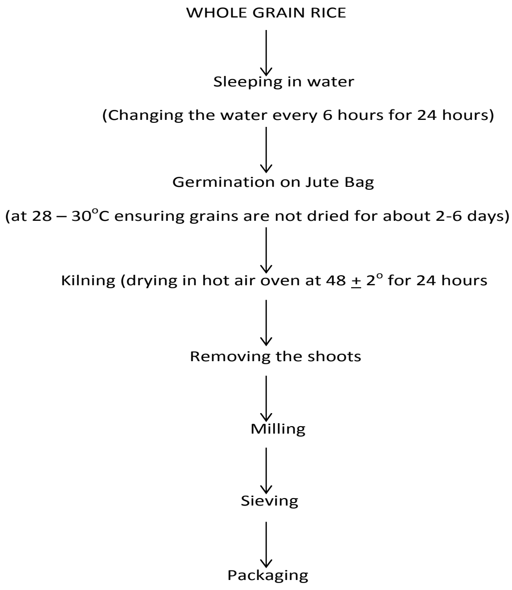


Figure 2 Flow Diagram for malting process

Source: Aniche1989

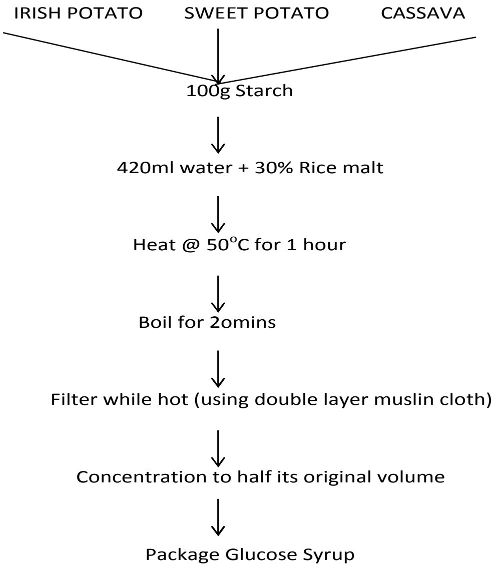


Figure 3 Flow diagram for the production of Glucose Syrup

Source: Osuji and Anih (2011) modified

Functional Properties Of Starches Used For The Production Of Glucose Syrup

Relative bulk density was determined by the method of Narayana and Narasinya 1984. Swelling power and solubility was by the method of Takashi and Sieb 1988. Starch dispersibility was determined by the method described by Kulkani *et al* 1991. Least Gelation Concentration LGC , while Water Absorption Capacity was by the method of Sosulski 1962

Physico-Chemical Analysis Of Glucose Syrup

Moisture content, mineral ash and Total Titratable Acidity(TTA) were determined by the AOAC 1990 method. Total Available Carbohydrate (TAC) was determined by the Manual Clagg Anthrone 1956 . Dextrose equivalent (DE) was determined by the method of Dziedzic and Kearsley (1995).

The sugar content expressed as glucose of the glucose syrup was determined using sugar refractometer, Sper Scientific 300001 model. The sugar content in °Brix was read directly from the refractometer by dropping the syrup using a stir rod on the prism of the refractometer.

The total hydrogen ion concentration from all sources which is experimentally measurable is expressed as the pH of solution. The pH meter was used to check the pH value of the various glucose syrup samples (model PHS – 2F, Harris England).

Rheological Properties: Viscosity

Viscosity is a measure of thickness of a fluid and the way which they flow. The viscosity of glucose syrup was determined with the aid of a rotary digital viscometer (NDj – 85 model) using spindle number 4 at 6rpm, 12rpm, 30rpm and 60rpm. The glucose syrup was transferred into sample bottles and the content in the sample bottle introduced directly into the rotating spindle and values of the viscosity displayed on the LCD screen in pas^{-1} as the viscosity of the various glucose syrup samples.

RESULTS AND DISCUSSION

Functional Properties Of Cassava, Irish Potato And Sweet Potato Starches

Table1 Shows the functional properties of starches extracted from Cassava, Irish potato and Sweet potato respectively.

Relative bulk density (g/ml) and water absorption capacity (WAC) of the starches ranged from 28.45% - 45.66% and 20.20% - 31.00% with cassava starch as the least and Irish potato starch as the highest respectively. The higher the relative bulk density of the starches, the higher the water absorption capacity as observed in this study. The water absorption capacity of Irish potato however, (31g water/g starch) is in agreement with the findings of Joseph *et al.,* (2012) who recorded a value, (31g water/g starch) for Irish potato starch.

Solubility of the starches recorded lowest for cassava and highest for Irish potato starch (12.00-14.00) while swelling power was highest in cassava starch and lowest in Irish potato starch (6.00-8.05). The result showed that the higher the solubility, the lower the swelling power. The higher swelling power of cassava starch may be due to the weak internal structure (Pomeranze, *et al.*, 1991) which is also a reason for its poor water absorption capacity.

Dispersibility (%) showed no significant difference (P>0.05) for all three starches with values raging from 82.50 - 84.00. Result of dispersibility ranging from 82% – 84% falls within the findings of Williams (2012) who reported 80-86% in cassava and sweet potato. Dispersibility in water shows the ease of breakup of agglomerates which allow particles to sink below the surface and disperse rapidly in a liquid (Tizazu and Emire, 2010).

The least gelation concentration (LGC) (%) of cassava, sweet and Irish potato starches ranged from 6.00-10.00, with cassava and sweet potato starches as the highest and Irish potato starch the least. The least gelation concentration can be described as a measure of the minimum amount of starch or blends of starch that is needed to form a gel in a given volume of water (Eke, 2006). The lower the least gelation concentration, the higher the amount of starch needed to form a gel (Adebowale, 2002). Gelling ability is a function of the ability of the starch/flour to absorb water and swell (Tizazu and Emire, 2010). This means that the higher the LGC, the higher the swelling power.

Physico-Chemical Properties

Table 2 shows the physico-chemical properties of glucose syrup made from cassava, Irish potato and sweet potato starches. Moisture content, ash, total titratable acidity (%TTA), sugar (°Brix), dextrose equivalent (DE), total available carbohydrate (TAC) and pH were determined. Moisture content of the samples ranged from 39.87% - 67.85% with Irish potato syrup as the least and sweet potato as the highest. The lower moisture content of the Irish potato syrup is indicative of better shelf life as compared to the moisture content of the sweet potato and cassava glucose syrups. Shelf life is the time during which a product will remain safe; maintaining desired sensory, chemical, physical and microbiological properties and complies with nutritional labeling. Factors that influence shelf life among others include moisture content and pH (http://www.aqualab.com/education/ the-effect-of-water-activity-on-shelf-life.

Cassava, lrish and sweet potato syrups had ash contents of 0.230%, 0.230% and 0.235% respectively. However, it is less than the ash content of High Fructose corn Syrup recording 0.5 (http://www.google.com/patents/u53784409. There was no significant difference (P>0.05) in ash content.

Total available carbohydrate (TAC) of syrups ranged from 23.1-29.6% with sweet potato as the least and Irish potato as the highest, while sugar (°Brix) content of the glucose syrups made from cassava, Irish potato and sweet potato ranged from 24.0 – 28.0 The higher the total available carbohydrate, the lower the sugar content in °Brix. Irish potato syrup had the highest total available carbohydrate (TAC) value and the least sugar content (°Brix) recording (29.60% and 24.00 °Brix) while sweet potato had the lowest TAC value and highest sugar content (23.10% and 28.00 °Brix)) respectively.

Dextrose equivalent (DE) ranged from 94.50% – 96.25% with cassava as the least and Irish potato as the highest. Dextrose equivalent (DE) represents the percentage hydrolyses of the glycosidic linkages present. Pure glucose has a DE of 100 and it indicates the extent to which starch has been cleaved (Dziedzic and Kearsley, 1995).

Total titratable acidity ranged from 0.13%-0.20% with cassava and sweet potato syrups as the least and Irish potato syrups as the highest. Titratable acidity 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).

pH of the samples ranged from 4.4 – 4.9 with cassava syrup as lowest and potato samples as highest all indicating acidity. pH is the negative log of hydrogen ion concentration (George, 2002). Williams and Dennis (2008) explained that foods at pH 4.4 - 5.0 are medium acid foods and they last better than foods above this range which favors microbial activity. However, the variance in acidity level in this study could possibly be as a result of the difference in starch origin and varietal difference.
Moisture content, total available carbohydrate, total titratable acidity sugar (°Brix) showed significant difference (p<0.05) amongst the samples.

Rheological Properties Of Glucose Syrup

Figure 1 shows the Viscosity (pas^{-1}) of the glucose syrup made from cassava, Irish and sweet potato starches determined at different shear rates specifically 6rpm, 12rpm, 30rpm and 60rpm respectively.

Table 1 Functional Properties Of Cassava, Irish And Sweet Potato Starches

Samples	Bulk Density (g/ml)	Solubility (%)	Swelling Power (g/g)	Dispersibility (%)	LGC (%)	WAC (%)
A	28.45^c	12.00^a	8.05^a	82.50^a	10.00^a	20.20^c
B	45.66^a	14.00^a	6.00^b	83.25^a	6.00^b	31.00^a
C	40.91^b	13.00^a	6.37^b	84.00^a	10.00^a	27.50^b
LSD	3.94	1.31	1.05	1.50	0.00	1.64

Means with same superscript in the same column are not significantly different P>0.05

Keys

A	=	cassava starch
B	=	irish potato starch
C	=	sweet potato starch
lsd	=	least significant difference
Lgc	=	least gelation concentration
Wac	=	water absorption capacity

Table 2 Physico-Chemical Properties Of Glucose Syrups From Starches

Samples	Moisture content (%)	Ash content (%)	TAC(% glucose)	DE (%)	TTA (%TTA)	Sugar content (°Brix)	pH
A	40.91[b]	0.230[a]	26.40[b]	94.50[a]	0.13[b]	27.40[a]	4.4[a]
B	39.87[b]	0.230[a]	29.60[a]	96.25[a]	0.20[a]	24.00[b]	4.9[a]
C	67.95[a]	0.235[a]	23.10[b]	94.59[a]	0.13[b]	28.00[a]	4.9[a]
LSD	2.31	0.17	3.81	3.07	0.14	1.9	

Means with same superscript in the same column are not significantly different P>0.05

Keys

A = cassava glucose syrup
B = irish potato glucose syrup
C = sweet potato glucose syrup
Lsd = least significant difference
Tac = total available carbohydrate
De = dextrose equivalent
Tta = total titratable acidity

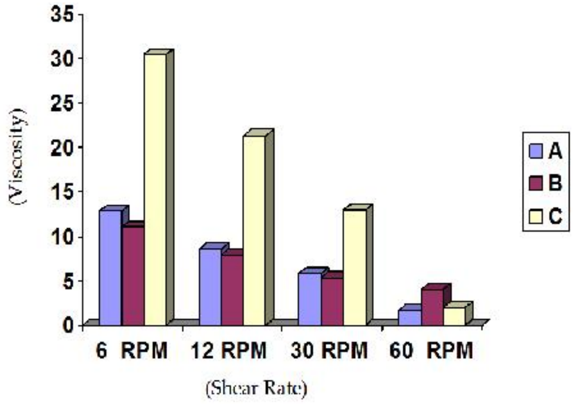
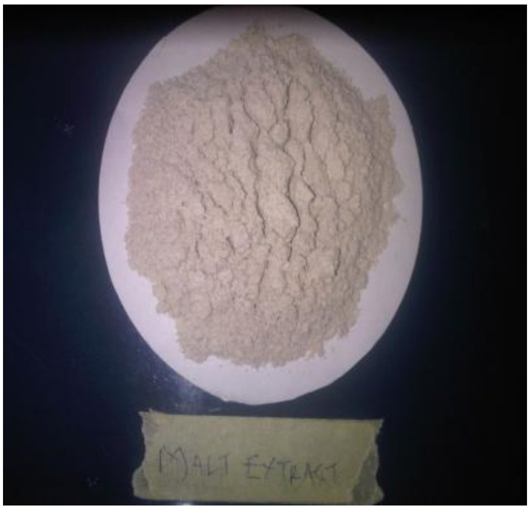


Figure 1 Viscosity of cassava, sweet potato and Irish potato glucose syrups (in pa/s)

KEYS
A = cassava glucose syrup
B = irish potato glucose syrup
C = sweet potato glucose syrup

Germination of Whole Grain Rice

Germinated Rice Grains



Malt Extract

GLUCOSE SYRUP

Keys
A = cassava glucose syrup
B = irish potato glucose syrup
C = sweet potato glucose syrup

At these speeds (6rpm, 12rpm and 30rpm,) the viscosity of the syrups ranged from 11.05-30.46, 7.92 -21.34 and 5.83-12.96 with Irish as the least and sweet potato as the highest respectively. At 60rpm Irish potato was more viscous recording 4.040 pas^{-1} and cassava the least viscous recording 1.68 pas^{-1}.

There is a great interaction in their behavior as all samples exhibited a pseudo plastic behavior (Non-Newtonian behavior) as their viscosity decreased with increased shear rate exhibiting thinning properties (Morris, 1989).

Rheology therefore can be defined as the study of the flow of matter, primarily in the liquid state, but also as "soft solid" or solids under conditions in which they can respond to plastic flow rather than deforming elastically in response to an applied force (Schowaller, 1978).

CONCLUSION

In conclusion, glucose syrup can be made from tuber starches such as cassava, Irish potato and sweet potato as they are available, cheap and has better starch yield and properties than the conventional cereal starch from maize, as they may find wide application in the food and pharmaceutical industries.

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