

EVALUATION OF THE PHYSICO-CHEMICAL PROPERTIES OF ETHIOPIAN MAIZE VARIETY (BH-660) FOR DEXTROSE PRODUCTION

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ABSTRACT

Dextrose was produced from locally available hybrid variety of maize (Bako Hybrid-660) in Ethiopia, using acid extraction. The variety was selected as an experimental input from Bako Agricultural Research Centre for the production of intermediate product starch using wet milling and end-product dextrose. The proximate composition values in the wet, milled, dried and cleaned white dent 2000 g BH-660 maize when steeped in 0.3% sulfur dioxide for 46 hrs at 50°C were determined. The mean values were 11.74%, 64.15%, 4.51%, 10.23%, 6.53% and 2.81%, for moisture content, total starch, germ, gluten, husk and fibre, respectively on dry weight basis. The total starch obtained from wet milling was 91.8% pure starch by mass. The proximate analysis values of moisture, crude protein, crude fat, crude fibre and total ash content of the sample were 7.65 %, 4.89%, 0.35%, 0.75 % 0.29 % , respectively on dry weight basis. Besides these, pH value was also determined to be 4.79. This obtained starch was hydrolyzed by an acid extraction method for the production of BH-660 maize dextrose. An average yield of 91.64% dextrose result was obtained and from this, 92.24% was pure dextrose by mass. Analysis result revealed that moisture, crude protein, crude fat, crude fibre and total ash content of the produced dextrose were 6.24%, 0.11%, 0.25%, 0.30% and 0.03%, respectively on dry weight basis. In addition, the pH value of 6.28 was determined. The control dextrose obtained from Ethiopian Pharmaceutical Manufacturing Share Company analysis values of moisture, crude fibre, crude fat and dextrose content were 5%, 0.24%, 0.23% and 93.73%, respectively on dry weight basis. From these data, it can be concluded that the BH-660 maize variety has a significant potential for the production of high quality starch and dextrose, which can be used as a raw material for starch and dextrose processing industries.

Key words: BH-660, Wet milling, Starch, Dextrose

INTRODUCTION

The use of maize (*Zea mays* L.) as a source of food product dates back to about 4000 B.C. when it was grown near what is now Oaxaca, Mexico [1]. The United States of America ranks as the world's largest grower of maize with 392.25 million tonnes annually. From this total annual production, around 40% of maize is processed in the USA at industry level to produce starch and different maize sweeteners. Maize is widely used in the production of animal feed, organic fertilizers, different household utensils, adhesives, textile manufacturing, cosmetics, pharmaceuticals and as a component of many food products [2].

Maize is not indigenous to Ethiopia and is believed to have been introduced Ethiopia in the 1600s and 1700s. However, it is widely grown in Ethiopia in various agro-ecological zones. Maize grows at altitudes ranging from 500 to 2400 m above sea level [3]. The country has a number of released varieties of maize including BH-660 (Bako Hybrid-660) that are registered at national level. This variety was released by the Bako Research Centre and has become one of the most successful hybrid varieties in Ethiopia. It is a three-way cross hybrid and the most prominent throughout Ethiopia due to its high productivity and coverage. It gives on average seven tonnes per hectare [3, 4]. Therefore, BH-660 variety was selected as an experimental material for the production of dextrose from maize starch.

The maize grain contains, on average, about 61.50 to 77.40% starch (dry basis). This high starch quantity provides a good raw material for the production of starch and different sweeteners [2, 5]. Starch is fairly versatile and has a wide variety of uses. In food industries, starch is used to impart functional properties to processed food because it affects the physical characteristics of many foods. It is mainly used as thickener, binder, and filler in canned soups, instant deserts, ice creams, processed meats, sauces and bakery products [1, 2, 5]. Starch is also converted into sugar and used as a taste enhancer like maize sweetener in form of dextrose and syrup. In non-food industries, starch is used to produce adhesive, agro-chemicals, cosmetics and toiletries, detergent, paper making additives, pharmaceuticals, paints, textiles, water purification agents, and biodegradable plastics [5, 6].

The most common method of producing starch from maize is wet milling. In wet milling, maize is first soaked in water (steeped) for several hours prior to undergoing a series of grinding and separation steps that result in one or more of several products such as maize oil, starch, maize gluten feed, maize gluten meal, fibre, and maize steep liquor. The purified starch is subjected to heat treatment and reaction with acid to convert it to dextrose. The dextrose solution is clarified and undergoes further purification steps to remove impurities such as colour and minerals. It is then evaporated, crystallized, and dried to produce dextrose powder. Dextrose from maize starch can be used in a variety of food and industrial products. It serves as the starting material for high fructose maize syrup, the substrate for almost all fermentation processes, and is used by many pharmaceuticals and confectionery producing industries [1, 2, 5, 6, 7].

Maize starch and dextrose are not produced in Ethiopia even though the raw materials for their production are widely available in the country. Import of starch and dextrose started with the emergence of modern industries that continuously demand their usage. For example, in 2003, the country imported a total of 457.40 tonnes of starch worth 1.96 million US Dollars. From this amount of starch, 437 tonnes was maize starch that was worth 1.86 million US Dollars. Similarly, in 2006, a total of 8,734.50 tonnes of dextrose and glucose syrup was imported at a cost of 3.40 million US Dollars [8].

The objective of this study was to evaluate production of dextrose from a locally available variety of maize (BH-660) using acid extraction method. The proximate and physicochemical analyses of starch and produced dextrose extracted from BH-660 maize variety were evaluated and compared with the imported one with respect to proximate composition and pH analysis.

MATERIALS AND METHODS

Sources of materials and preparation

Maize grain (BH-660) that was used for the production of maize starch and dextrose was obtained from Bako Agricultural Research Centre of Ethiopia at a moisture content of 11.74% on dry weight basis. It was stored at room temperature (25°C) during the experimental period. The analysis samples, starch and dextrose were prepared and packed in polyethylene packaging material [9]. All analyses were conducted by using distilled water and analytical grade chemicals and reagents. Commercial dextrose sample obtained from Pharmaceutical Manufacturing Share Company of Ethiopia was used as a control.

PRODUCTION OF STARCH PROCEDURE

Acidic wet milling procedure

The initial laboratory procedure was steeping the dried and cleaned white dent 2,000 g of BH-660 maize in distilled warm water (2,800 mL) at 45°C, in a weak sulfurous acid solution containing 0.3% sulfur dioxide. The steeped maize was kept in the solution for 46 hr at 50°C. The softened grain was milled by a disk mill (BECON, type: RS200, Germany) to break up and slightly grind the endosperm mass and liberate the oil-containing embryos. The clearance between the disks of the mill was adjusted to 4.375 mm. In the initial milling step, the steeped maize was fully passed through an attrition mill, along with 4000 mL distilled water at 42°C poured continuously for the purpose of liberating germ [10,11,12,13]. The suspension was passed through V-shaped germ separator (RETSCH, type: 16V40/45, Germany) with gentle agitation. The starch pulp mass settled down while the hulls and the germs floated, so that they could be easily skimmed out. The germ was washed four times to remove any remaining starch.

The wet de-germed maize mass consisting of starch, gluten and fibre was thoroughly ground by a roller mill (ERWEKA, type: AR400, West-Germany). As a result, the starch and gluten were rubbed from the hulls and fibre. After the endosperm was

finely milled, the starch and gluten particles were separated from the pericarp and other large kernel fragments by sieving the slurry through 0.63 mm sieve size. The remaining starch and gluten particles in the slurry were separated by using a centrifugal separator (HERAEUS CHRIST GMBH, type: UJ3, Germany) at a speed of 3000 rpm for 3 min [14, 15]. The lighter gluten particles with a light brown colour floated at the top, while the heavier starch granules with a bright white colour settled down. Further purification was accomplished by washing the gluten three times and passing it through the centrifugal separator at the same revolution and time. Finally, the starch was dried in an oven (HERAEW, type: RS232, Germany) at 40°C for 48 hr and milled (Henan, type: GL-500, China) to prepare for further processing. The sieve size of the final milled starch was 125 µm [14, 15,16].

Acidic Production of Dextrose

The dried and milled starch passed through a 125 µm sieve was suspended in distilled water at 42°C in the ratio of 1:10 (starch to water) to produce crystalline dextrose. This was mixed with hydrochloric acid (38%), which was 4 % of the weight of the starch in the suspension at pH of 3.0. The solution was heated by high-pressure hydrolyser (DEUTSCH and NEUMANN, type: RGS4, Germany) at 160°C with pressure of 300 kPa. Finally, the starch split into smaller molecular fragments within 30 minutes by the action of the heated acid and the steam pressure difference.

The hydrolyzed liquid of starch (350 mL) was neutralized by adding 4 g of sodium hydroxide to remove the free acid and obtained a pH of 6.21 for 10 minute [12, 13]. This clear brown solution was decolourized by passing it through activated carbon filters using 600 kPa compression pumps (JOHNSON service company, USA) for 0.5 hrs. This was to get a clearer colour and remove some other impurities from the solution by surface adsorption. In addition to these, the remaining solid impurities were removed by centrifugal separation at 4000 rpm for 5 min [17]. This purified and decolourized solution was concentrated in vacuum evaporator (JULABO and PFEIFFER, Germany) to increase dextrose equivalent (DE) and remove the remaining moisture at a temperature of 65°C for 30 min. Then it was immediately cooled at 40°C to prevent the oxidation of the sugar. This crystal slurry was centrifuged at 4000 rpm for 5 min, to separate the crystal from the slurry [15, 16].

The final crystal formation was controlled largely by the quantity of dextrin left in the glucose syrup. Dextrose crystallization was obtained by removing water from the slurry in the drier (HERAEW, type: RS232, Germany) at 48°C for 8 hours. Then a fine needle-like crystal was formed and this was milled and sieved through 125 µm. [15, 17].

Chemical analysis

Proximate composition of the moisture content, total ash, crude fat, crude fibre and crude protein of the whole grain BH-660 maize, starch and dextrose were determined by AOAC official methods of 44.7.02, 44.7.06, 4.5.06, 32.1.15, and 32.2.03, respectively [16].

Physicochemical Characterization

Experimentally obtained starch and dextrose from BH-660 maize varieties were analyzed to determine the pH values, total starch and dextrose content in percent by mass.

pH value

The pH value was determined for each sample of starch and dextrose using AOAC official method 14.022 [16]. About 10 g of each sample was suspended in 100 mL deionized water at 22°C of pH 7.0 and it was determined by using a pH meter (Denver Instrument, model 250, USA).

Total Starch and Dextrose Percent by Mass

A starch solution was prepared by extracting about 4 g weighed starch, with 10 mL ether on a filter paper. Then after, the ether was evaporated from the residue and the remaining residue was washed with 150 mL of 10% ethanol, and 200 mL of cold water. The insoluble residue was transferred from the filter paper to the 250 mL flask with 220 mL of 2.5% hydrochloric acid and boiled for 2.5 hr. The pH of the solution was adjusted to 6.5 by adding 2.5N sodium hydroxide solution with a continuous string.

Reducing sugar was determined to obtain the total starch content by the method of AOAC at 32.2.05 [16]. The precipitate was dried in the oven at 112°C for 30 min, then cooled to room temperature in a desiccator and weighed. By using the standard Munson and Walker Table [16], the weight of released dextrose (mg) from the starch was determined corresponding to the weight of Cu₂O consumed. Finally, the amount of total starch percent by mass was calculated using the formula:

$$\text{Total starch, \%} = \% \frac{W_1 * 50}{W_2 * Z} * 90 \text{-----[16]}$$

Where, W₁ = weight of reduced sugar (mg) against Cu₂O, from Munson and Walker Table [16]

W₂ = weight of sample (g); Z = prepared solution (mL)

The total dextrose percent by mass was determined by the AOAC official methods, 44.7.10 [16].

Data Analysis

The results were analyzed using the General Linear Model of Statistical Analysis (GLM) system software (SAS version 6.12) at 5% significant level.

RESULTS

Proximate Composition

a) Maize BH-660

The moisture content of the maize grain during wet milling is an important functional characteristic in the process of steeping to take less amount of water with a recommended range of 10 to 15% [12]. The moisture content BH-660 was 11.74%. The constituents of the maize obtained show that the maize had higher amount of gluten, germ and fibre

content, all within the range of values shown in Table 1 [12, 18]. This showed that the maize has good yields of both starch and protein [19]. The starch obtained in the maize, which was 64.15%, was lower than the value of 68.53% obtained by other researchers [20]. The possible reason may be the small grain size and the nature of the variety itself [21].

b) Starch

The proximate composition of starch obtained in the wet milling process (Table 2) agrees with results reported in the study of maize starch production, which has crude protein content of 4.45%, crude fibre 0.2%, fat 0.08% and ash 0.24%, respectively [22]. The values obtained in the analysis of maize starch fell within the range admitted by Codex Alimentarius standard, which reported that crude protein content should be less than 3.0%, crude fat not more than 1.5%, and crude fibre and ash not more than 1% on a dry basis [23]. The starch result was comparable with the accepted standard of Codex except for crude protein. The difference in crude protein content may be due to the intrusion of some gluten in the isolation of starch and gluten layers made in the centrifugal separation process. The moisture content of starch obtained in the study was lower than 13% obtained by other researchers [24]. This is because of the extended drying of the produced starch. This lower moisture content may have an advantage to prevent spoilage resulting from high moisture content.

c) Dextrose

Proximate composition values of produced dextrose from maize starch are shown in Table 3. Commercial maize dextrose powder obtained from the Pharmaceutical Manufacturing Share Company of Ethiopia was basically used for comparative purposes with the produced dextrose. It was significantly different from the produced dextrose mainly with respect to moisture content, crude fibre, crude fat and dextrose content. From the result of the analysis, the moisture content of the produced dextrose (DP) was found to be 6.24%, while the control dextrose (DC) and the Standard (theoretically recommended) dextrose (DS) were found to be 5% and 8%, respectively. Standard dextrose has the lowest crude protein, crude fibre, crude fat and ash contents of 0.0001%, 0.0001%, 0.0001% and 0.0014%, respectively. However, it has 99.5% dextrose by mass, which is the highest content. Statistical analysis revealed that there were significant differences in proximate analysis of produced and control dextrose except in their crude protein and ash content values. Sample of produced dextrose generally had the lower content of dextrose due to its acidic production method, compared to the control and standard dextrose (Table 3). This result suggests that acidic method is not the best option to get higher yield of dextrose.

Proximate composition values of maize dextrose were relatively higher than the recommended values obtained by others [25, 26]. It revealed that the produced dextrose had lower dextrose quality. This might come from the production unit used during laboratory product development and the method itself as compared to the result reported using enzymatic hydrolysis [27]. However, it is significantly comparable to the control dextrose except for the crude protein and ash contents. This could be the impact of high content of total starch as an input of the production. Even though the crude protein was not significant compared to the control dextrose, it had 3% content

of protein in the final product. This variation may be due to the use of different units of production materials and varieties of maize. The non-significant difference observed in ash content was due to the wide diversity of maize grain varieties and sieving efficiency during starch production [28, 29].

pH Values of Maize Starch and Dextrose

The pH value of maize starch shown in Table 2 was 4.79 as expected. The pH value of starch was comparable with standard for starch as reported in other studies [11, 22]. The produced dextrose and control dextrose pH values were 6.28 and 6.59, respectively, and were not significantly different at 5% probability level.

Total Starch and Dextrose Percent by Mass

From the total BH-660 kernel composition, 64.15% starch was obtained. Again from this amount of starch, 93.80% mean value of pure starch was obtained. The total amount of starch content in the BH-660 maize obtained was closer, nearer to those of maize varieties which have high quantity of starch. This result was generally comparable to the result obtained on the starch content of dent maize [13, 18, 29]. When compared to 93.8% of total amount of pure starch obtained from BH-660 dent maize, this value was relatively better than the 93 to 96% range of values reported by different researchers [1, 11]. This result suggests that the maize BH-660 variety has a great potential for production of better quality starch.

The total amount of dextrose obtained in study was 91.64% dextrose and from this 92.24% by mass. This value obtained in the produced dextrose was significantly lower from the control dextrose [26].

CONCLUSION

The results indicated that the maize variety BH-660 has comparable amount of starch to other varieties. It gives sufficiently high yield and percent of starch. In addition to this, the maize also has a better yield of germ which can be used to produce edible oil. The proximate compositions and pH value that resulted from the wet milling have shown significant effects on the product of starch. The proximate composition and pH value of starch are in the acceptable range to produce better quality of starch.

The results showed that the amount of dextrose produced comparable yield and physicochemical characteristics to the control dextrose. Generally, to get better yield of dextrose the quality of input starch as a starting material is a determining factor in addition to the proximate value of dextrose.

The results from this study can be used by agricultural researchers, agro-processors and investors as input for their works. More specifically, the results can contribute to those who are interested in the production of both starch and dextrose as well as the post harvest management of BH-660 maize variety.

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Table 1: Proximate compositions of BH-660 maize

Proximate composition (g/100g) dry basis	
Parameter	Content base
Moisture	11.74 ± 0.06
Starch	64.15 ± 0.09
Germ	4.51 ± 0.02
Gluten	10.23 ± 0.03
Husk	6.53 ± 0.01
Fibre	2.81 ± 0.21

All values Data expressed as means ± SD

Table 2: Proximate composition and pH values of BH-660 starch

Proximate composition (g/100g) dry basis and pH	
Parameters	Content in starch (%) ^a
Crude protein	4.89± 0.10
Moisture	7.65 ± 0.50
Crude fat	0.35 ± 0.01
Ash	0.75 ± 0.01
Crude fibre	0.29 ± 0.01
pH	4.79 ± 0.11

^a Data expressed as means ± SD

Table 3: Proximate composition and pH values of maize dextrose

Proximate composition (g/100g) dry basis and pH			
Parameter	DP	DC	DS
Moisture	6.24 ± 0.02 ^a	5 ± 0.01 ^b	8
Crude protein	0.11 ± 0.01 ^a	0.01 ± 0.00 ^a	0.0001
Crude fibre	0.30 ± 0.01 ^a	0.24 ± 0.01 ^b	0.0001
Crude fat	0.25 ± 0.01 ^a	0.23 ± 0.02 ^b	0.0001
Ash	0.03 ± 0.00 ^a	0.02 ± 0.00 ^a	0.0014
Dextrose ^c	91.64 ± 0.01 ^b	93.73 ± 0.03 ^a	99.5
pH	6.28 ± 0.04 ^a	6.59 ± 0.02 ^a	6.85-7.00

^{a, b} Means with the same superscript letters within a row are not significantly different (P > 0.05).

Data expressed as means ± SD

^c - Percentage of dextrose by mass

DP- Dextrose Produced

DC- Dextrose Control

DS- Theoretically Recommended Dextrose Standard

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