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Physicochemical properties of starch isolated from genetically modified corn (Ajeeb YG)

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Abstract

The objective of this study was to investigate the physicochemical properties of starch isolated from transgenic corn (Ajeeb YG) and its near isogenic (Ajeeb). The amylose content was significantly differed, also there are some significant differences in the physicochemical properties between the investigated samples. These include water absorption capacity, solubility index and viscosity. Scanning electron microscopy revealed that both corn starch samples had intact granular and multi-angular shapes with an average diameter of about 12.8 µm. The samples showed native X-Ray diffraction pattern of the A-type starch. Relative crystallinity for isogenic and transgenic corn starch samples was 16.75 and 19.5%, respectively. The result of DSC analysis showed that there are some differences in the transition temperatures, the gelatinization temperature, enthalpies of gelatinization and peak height indices. Also, the data revealed some differences between the isogenic and transgenic corn starch samples in their pasting properties.

Keywords: Transgenic corn, starch, physicochemical properties, viscosity, DSC, X-Ray diffraction

1. Introduction

Corn starch, an important product of the grain processing industry, is used in a wide range of applications in the food and non-food industries. To better suit these uses, the starch may be modified through chemical, physical, or biological (genetic) means [1,2]. Corn starch is a valuable ingredient to the food industry, being widely used as a thickener, gelling agent, bulking agent and water retention agent [3]. Starch molecule is composed of an amorphous region (amylose) and crystalline region (amylopectin), ratio and proportion of amylose and amylopectin are from 20% to 25% for amylose and from 75% to 80% for amylopectin [4]. The inherent chemical and physical properties of native starch granules govern the functionality of starch in most processed foods. The structure of the starch granule in foods is considered an important contributing factor in its digestibility and availability as a nutritional carbohydrate. Starch granules are biological structures and are not likely to be physically or chemically homogeneous [5].

With the growing interest in healthful and natural foods over the past decade, chemically modified starches are losing their attractiveness for food applications, and maize starches modified by genetic means (which can be labeled as natural or native) are the focus of increased attention [6]. A number of patents for genetically modified maize carrying different starch-modifying genes have been granted through the years [7, 8]. Much work has been done on the starch structure and physicochemical properties of starch-modifying mutants. Variation in

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the function of mutant starches related to structural differences were noted when the mutant was placed in corn with different background. For example, Inouchi et al. [9] and Boyer and Liu [10] found that common starch mutants waxy (dull) *du* and sugary-2 (*su2*) genes are associated with increased amylose content to different extents. On the basis of differential scanning calorimetry (DSC) analysis, the onset (T_o), peak (T_p), and conclusion (T_c) temperatures and enthalpy (ΔH) of *su2*/*su2* starch were significantly lower than in starches from other mutant genotypes [11,12]. The value of ΔH for *du*/*du* starch was smaller than for normal starch [13].

The effects of genetic background on some starch properties of several maize mutant genes have been noted. Sanders et al. [2] reported that genetic background influenced the variation in thermal properties and amylopectin fine structures among waxy (*wx*) containing genotypes. Significant differences for thermal properties were observed among the *su2* populations from crosses of exotic germplasm with Oh43*su2* [14]. However, there is little information about the effects of genetic background on other physicochemical properties. Moreover, Ji et al. [15] used a texture analyzer for studying the gel properties of starches from some corn lines and found significant differences among them. Furthermore, Sandhu et al. [16] studied the effect of corn types on the physicochemical, thermal, morphological and rheological properties of corn starches. The author found that textural properties of starch gels are very important criteria, used to evaluate the performance of starch in a food system. The functional characteristics that are imparted by the starches to aqueous systems and their application in various foods vary with their biological origin. Recently, Milašinović-Šeremešić et al. [17] investigated molecular and functional properties of starches isolated from ZP maize genotypes of different genetic background. The amylose content in the isolated starches of 10 ZP maize genotypes was characteristic for both types of maize starches, normal and waxy. The waxy type had the highest average molecular weight of amylopectin (4.84 x 108 Da). The onset temperature of gelatinisation values of starches of 10 ZP maize genotypes ranged from 62.1ºC to 65.0ºC. The waxy maize starch displayed a significantly higher enthalpy change for gelatinized starch (ΔH=18.1 J/g) than normal maize starches (ΔH=13.6-15.6 J/g). Rapid Visco Analyser (RVA) profiles of starches of ZP maize genotypes were typical for both types of maize starches, normal and waxy [17].

Egypt imports huge amounts from corn every year to be used in the production of flour, starch and oil as well as in animal feeds. Therefore, studying safety, quality and nutritional properties of GM corn is very important to the Egyptian food industries as well as health authorities. So, the purpose of this study is to evaluate the effects of genetic modification on the physicochemical properties of starch isolated from genetically modified corn (Ajeeb YG).

2. Material and methods

2.1. Materials.

Transgenic corn sample (Ajeeb YG) and its near-isogenic line (Ajeeb) were obtained from the Agricultural Administration, Hehia, Sharkia Governorate, Egypt. The Cairo based company Fine Seed International is partnering with Monsanto to distribute the variety in Egypt. Ajeeb YG (YieldGard corn, event MON-00810-6) is a genetically modified insect resistant corn produced by incorporated the MON 810 borer resistance trait in the best corn germplasm "Ajeeb".

2.2. Methods

2.2.1. Starch Isolation. Corn starch was isolated using the method of Sandhu *et al*. [18]. About 500 g of clean, sound and whole corn (10–20% moisture content) were added to 1.25 liter of distilled water containing sodium hydrogen sulfite (0.1% SO_2). The mixture was maintained at 50º ± 2 ºC for about 18–20 h with intermittent circulation of the liquid. After 20 h, the steep water was drained off and corn was ground in laboratory grinder. About 250 g of steeped corn were ground with 250 ml of distilled water. The ground slurry was screened through nylon cloth (0.150 mm), and the residue was washed with distilled water until it was free of starch. The filtrate was passed successively over 0.075 and 0.037 mm screens. The starch-protein slurry was then allowed to stand for 4–5 h. The supernatant was removed by suction and the settled starch layer was re-suspended in distilled water and centrifuged in wide mouthed cups at 2800 rpm for 5 min.

The upper non-white layer was scraped off. The white layer was re-suspended in distilled water and re-centrifuged 3– 4 times. The starch was then collected and dried in an oven at 40ºC for 12 h.

2.2.2. Scanning Electron Microscopy. Scanning electron micrograph (SEM) of the starch granules were taken at 500 and 1000x magnification with a JSM-5800 LV microscope (JXA-840A ELECTRON PROBE MICROANALIZER, JEOL, TOKYO, JAPAN). Starch samples were sprinkled on adhesive tape, attached to specimen studs and coated with gold (S150A SPUTTER COATER).

2.2.3. Amylose/Amylopectin Content (%). Amylose content of the isolated starch was analyzed using the method of Sandhu and Singh [19]. A 20 mg of starch sample were taken and 10 ml of 0.5 N KOH were added into it. The suspension was thoroughly mixed. The dispersed sample was transferred to a 100 ml volumetric flask and diluted to the mark with distilled water. An aliquot of test starch solution (10 ml) was pipetted into the 50 ml volumetric flask and 5 ml of 0.1 N HCl were added, followed by 0.5 ml of iodine reagent. The volume was diluted to 50 ml and the absorbance was measured at 625 nm.

2.2.4. Swelling Power (g/g) and Solubility (%). Swelling power and solubility were determined using the method of Zakpaa *et al.* [20]. One gram of corn starch from each sample was transferred into a weighed graduated centrifuge tube (50 ml). Distilled water was added to give a total volume of 40 ml. The suspension was stirred sufficiently and uniformly, avoiding excess speed to prevent fragmentation of the starch granules. The sample in the centrifuge tube was heated at 20 and 70°C in a thermostatically controlled water bath for 5 and 15 min with constant stirring. The tube was then removed, wiped dry on the outside and cooled to room temperature. It was then centrifuged for 15 min at 2200 rpm. The solubility was determined by evaporating the supernatant and weighing the residue. The sediment paste was weighed and the percentage solubility and swelling power was then calculated.

2.2.5. Turbidity . Turbidity of starch pastes from the studied samples was measured as described by Perera and Hoover [21]**.** A 1% aqueous suspension of starch from each corn sample was heated in a water bath at 90ºC for 1 h with constant stirring. The samples were stored for 5 days at 4º C and turbidity was determined every 24 h by measuring absorbance at 640 nm against a water blank with a spectrophotometer (model 6505 UV/Vis, JENWAY, UK.).

2.2.6. Water-Binding Capacity (%). Water-binding capacity (WBC) of the starches from the corn samples was determined using the method of Abbey and Ibeh [22]. A suspension of 5 g starch (dry weight) in 75 ml distilled water was agitated for 1 h and centrifuged (3000g) for 10 min. The free water was removed from the wet starch, which was then drained for 10 min. The wet starch was then weighed.

2.2.7. Syneresis (%). Syneresis was determined using the procedure of Sandhu *et al.* [18]. Starch suspension (2%, w/v) was heated at 85ºC for 30 min in a temperature controlled water bath, followed by rapid cooling in an ice water bath to room temperature. The starch samples were stored for 24, 72 and 120 h at 4ºC. Syneresis was measured as % of water released after centrifugation at 3200 g for 15 min.

2.2.8. Determination of Viscosity. The viscosity of starch samples was determined by the method of Nwosu [23] with minor modification. Ten grams of the starch sample were blending with 90 ml distilled water using a mixer. The viscosity was measured at room temperature (30 ±1^{o}C) with a Brookfied Viscometer (model LV, USA), at 250 rpm for 1 min using spindle No 21. The viscosity readings were recorded in centipoises (cP).

2.2.9. Determination of pasting properties. Pasting properties of corn starch suspensions were determined according to the procedure of Hagenimana and Ding [24] with some modification. Brabender peak viscosity, setback, temperature of initial viscosity increase, and temperature of peak viscosity were determined on 10% starch-water suspensions using a Brabender temperature programmed viscometer (Brabender Visco Amylo-Graph, Duisburg, Germany). Samples were heated at 1.5°C min^{-1} to 95°C, held at this temperature for 10 min, and then cooled to 65°C.

2.2.10. X-ray Diffraction Pattern. X-ray diffraction was carried out using an X-ray diffractometer (JOEL, JOX-8030, Japan) according to the procedure of

Siriwong *et al*. [25]. The X-ray source was operated at 45 kV and 35 mA with a Cu target. Data collected by step-scanned method between 5º to 60º in 2θ with a step size of 0.04º 2θ and a counting time of 1.5 s/step.

2.2.11. Differential Scanning Calorimeter (DSC). Thermal characteristics of the isolated starches were studied using a differential scanning calorimeter (DSC) according to Herceg *et al*. [26]. An empty pan was used as a reference. Corn starch was weighed into standard aluminum pan (40 µL). The pans were sealed and equilibrated for 24 h at room temperature before heat treatment in the DSC. The starch slurry was gelatinized in the DSC using a heat rate of 10ºC min^{-1} from 25 to 95ºC. After the heat treatment, the samples were cooled to 25ºC and removed from DSC. The changes in enthalpy (ΔH in kJ kg^{-1} of dry starch), onset temperature (To), peak temperature (Tp), and conclusion temperature (Tc) for gelatinization were obtained from the exothermal DSC curves.

2.3. Statistical Analysis

The statistical analysis was performed using a SPSS 16 program. Data were expressed as mean ±standard deviation (SD) and statistical significance was assigned at $P \leq 0.05$ level. An independent sample t-test was conducted to compare the means between the isogenic and transgenic corn samples.

3.Results and Discussion

3.1. Amylose Content

Amylose contents of starch from the two investigated corn samples differed significantly (***Table 1***), as the isogenic corn starch sample showed lower value (21.5%) than the transgenic corn starch sample (23.4%). These results fall in the range reported by Seetharaman *et al*. [27], they found that amylose content for 35 corn landraces ranged between 16.1–23.3%. Also, Sandhu and Singh [19] reported that amylase content of various corn starches ranged from 16.9% to 21.3%.

3.2. Water Absorption Capacity

As seen in ***Table*** (1) water absorption capacity of the isogenic corn starch sample was significantly lower ($P<0.05$) than the transgenic corn starch sample. The values for isogenic and transgenic corn samples were 0.784 and 0.854%, respectively.

Sandhu and Singh [19] found that the differences in the degree of availability of water binding sites among the starches may have contributed to the variation in water holding capacity among different starches.

3.3. Solubility Index

The solubility index of the starch gel prepared from the isogenic corn starch sample was somewhat significantly higher ($P<0.05$) than that prepared from transgenic corn starch sample (***Table 1***). In addition the solubility index for both corn starch samples increased with the increasing of temperature and time of treatment. Herceg et al. [26] reported that the major impact on starch granule disintegration is caused by the strong mechanical forces. These causes shear forces that are capable of pitting the starch granule and breaking the chains of polymers by disrupting covalent bonds. Singh et al. [28] reported that the crystalline molecular structure of corn starch is broken and the water molecules are bonded to the free hydroxyl groups of amylose and amylopectin by hydrogen bonds, which could cause an increase in solubility and swelling power.

3.4. Swelling Index

Swelling power and solubility can be used to assess the extent of interaction between starch chains, within the amorphous and crystalline domains of the starch granule [29]. In our study, swelling index of isogenic corn starch sample was observed to be higher than that of transgenic corn starch sample; however these differences were almost not significant (***Table 1***). Singh *et al*. [30] reported that starch swelling occurs concomitantly with loss of birefringence and precedes solubilization.

3.5. Synersis

The syneresis of gels prepared from isogenic and transgenic corn starch samples was measured as amount of water released from gels during storage (up to 120 h) at 4°C (***Table 1***). No significant differences ($P<0.05$) were observed in the average values of syneresis of starch from isogenic and transgenic corn starch samples. The increase in percentage syneresis during storage has been attributed to the interaction between leached amylose

and amylopectin chains, which leads to the development of junction zones, which reflect or scatter a significant amount of light [21].

Amylose aggregation and crystallization have been reported to be completed within the first few hours of storage while amylopectin aggregation and crystallization occurs during later stages [31,32].

Table 1. Physicochemical properties of isogenic and transgenic corn starch samples

Constitutents	Corn starch samples	
	Isogenic (Ajeeb)	Transgenic (Ajeeb YG)
Amylose (%)	21.5 ±0.321[b]	23.4 ±0.120[a]
Water absorption capacity (%)	0.784 ±0.139[b]	0.854 ±0.005[a]
Solubility index (%):		
At 20º after 5 min	0.0073 ±0.0003[a]	0.0055 ±0.0005[b]
At 20º after 15 min	0.0160 ±0.001[a]	0.0117 ±0.002[b]
At 70º after 5 min	0.049 ±0.001[a]	0.047 ±0.001[a]
At 70º after 15 min	0.088 ± 0.001[a]	0.082 ± 0.002[a]
Swelling index (g of hydrated molecules / g starch dry matter):		
At 20º after 5 min	1.026 ± 0.001[a]	1.022 ± 0.0004[a]
At 20º after 15 min	1.170 ± 0.126[a]	1.065 ± 0.004[b]
At 70º after 5 min	4.223 ± 0.009[a]	4.096 ± 0.114[a]
At 70º after 15 min	4.712 ± 0.035[a]	4.338 ± 0.101[a]
Synersis (% of released water)	69.01 ± 0.276[a]	62.90 ± 0.677[a]
Viscosity (centipoise, cP)	1.80 ± 0.000[b]	2.60 ± 0.000[a]

*The same letter in the same row is not significant different (P<0.05).
*Results are mean ±SD (n=3).

3.6. Viscosity

As seen in ***Table*** (1), the isogenic corn starch paste showed significantly lower viscosity value (1.8 cP) than transgenic corn starch paste (2.6 cP). The decrease in gels viscosity is reflected in a decrease of the overall resistance of the sample to flow [33]. The differences in viscosity values may be due to different power swelling presenting each of the starches, owing to their different chemical composition, amylose/amylopectin ratio, average degree of polymerization of its constitutes, as well as its lipid and phosphorus content [34].

3.7. Turbidity

The turbidity values of starch suspensions from isogenic and transgenic corn starch samples are

depicted in ***Fig***. (1). Turbidity values of both starch suspensions increased progressively during storage of starch gels at 4°C and at all storage time the values of the transgenic corn starch sample were higher than that of the isogenic corn starch sample. Turbidity development in starches during storage has been attributed to the interaction of several factors, such as granule swelling, granule remnants, leached amylose and amylopectin, amylose and amylopectin chain length, intra or interbonding, lipid and cross-linking substitution [35].

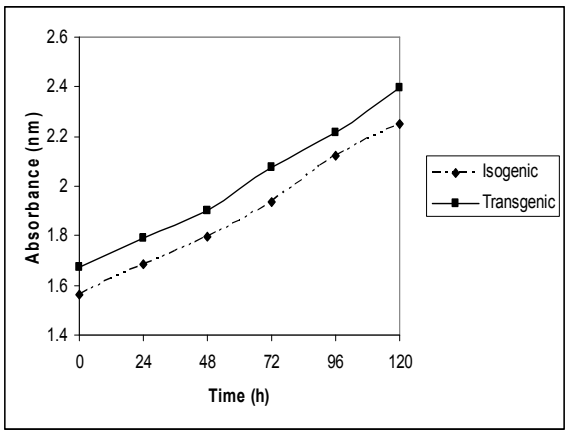

Figure 1. Effect of storage duration on the turbidity of the isogenic and transgenic corn starch pastes.

3.8. Scanning Electron Micrograph

The size and distribution of starch granules can be very important for specific applications and even this very basic physical characteristic can be value-added. For example, the small granule size of rice starch makes it very suitable for applications laundry sizing of fine fabrics and for skin cosmetics. Carbonless paper requires the use of starch as a stilt material to protect ink capsule from premature rupturing [36].

The scanning electron micrographs of isogenic and transgenic corn starch samples are shown in ***Fig***. (2) at 1000x magnifications, respectively. Both corn starch samples had intact granular and multi-angular shapes with an average diameter of about 12.8 µm. These results are in agreement with those of Pilla [36] who reported that corn starch granules size ranged between 5 to 25 µm.

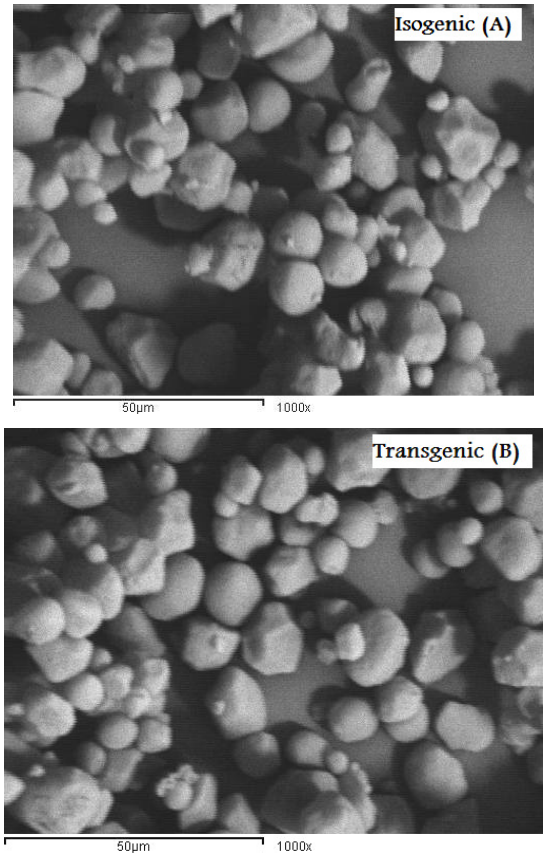

Figure 2. Scanning electron micrograph (SEM) of corn starch (1000x) from isogenic and transgenic corn starch samples.

3.9. X-Ray Diffraction Pattern

Degree of crystallinity as measured by X-ray diffraction, is a semi-qualitative assessment of long-range order within a sample determined using the ratio of diffraction intensities contributed by ordered (crystalline) components relative for the total diffraction pattern.

The X-ray diffraction patterns of isogenic and transgenic corn starch samples are shown in ***Fig.*** (3). The isogenic corn starch sample appeared native pattern typical of the A-type starch crystal with maximum d-spacing = 5.83, 5.08 and 3.86 (Å) as described by Zobel [37].

Also, the transgenic corn starch sample showed native pattern typical of the A-type starch crystal with maximum d-spacing = 5.90, 5.24 and 4.46 (Å).

A-type of starch crystals is a common to most cereal starches [38]. As reported by Zobel [37] and Miyoshi [39] the X-ray d-spacing of 5.8, 5.02, 4.4, 3.8, 2.6, 2.3, 2.1 and 1.9 were characteristics of A-type starch crystals. As seen in ***Fig.*** (3) some peak positions at >27 [°2 Theta] in the isogenic corn starch sample were under the limit of detection, while in the transgenic corn sample many peaks were detected at >27 [°2 Theta]. Percent relative crystallinity was calculated by dividing the area of the diffraction curve above the smooth curve by the area of the diffraction curve above the baseline (***Fig.*** **3**). Relative crystallinity for isogenic and transgenic corn starch samples was 16.75 and 19.5%, respectively. These results are in the range of 12.4 - 30.3% which reported for several corn varieties by Cheetham and Tao [40] and Johnson *et al*. [41]. Also, Zobel [37] found that starches of different origin have a different degree of crystallinity (range about 15–45%).

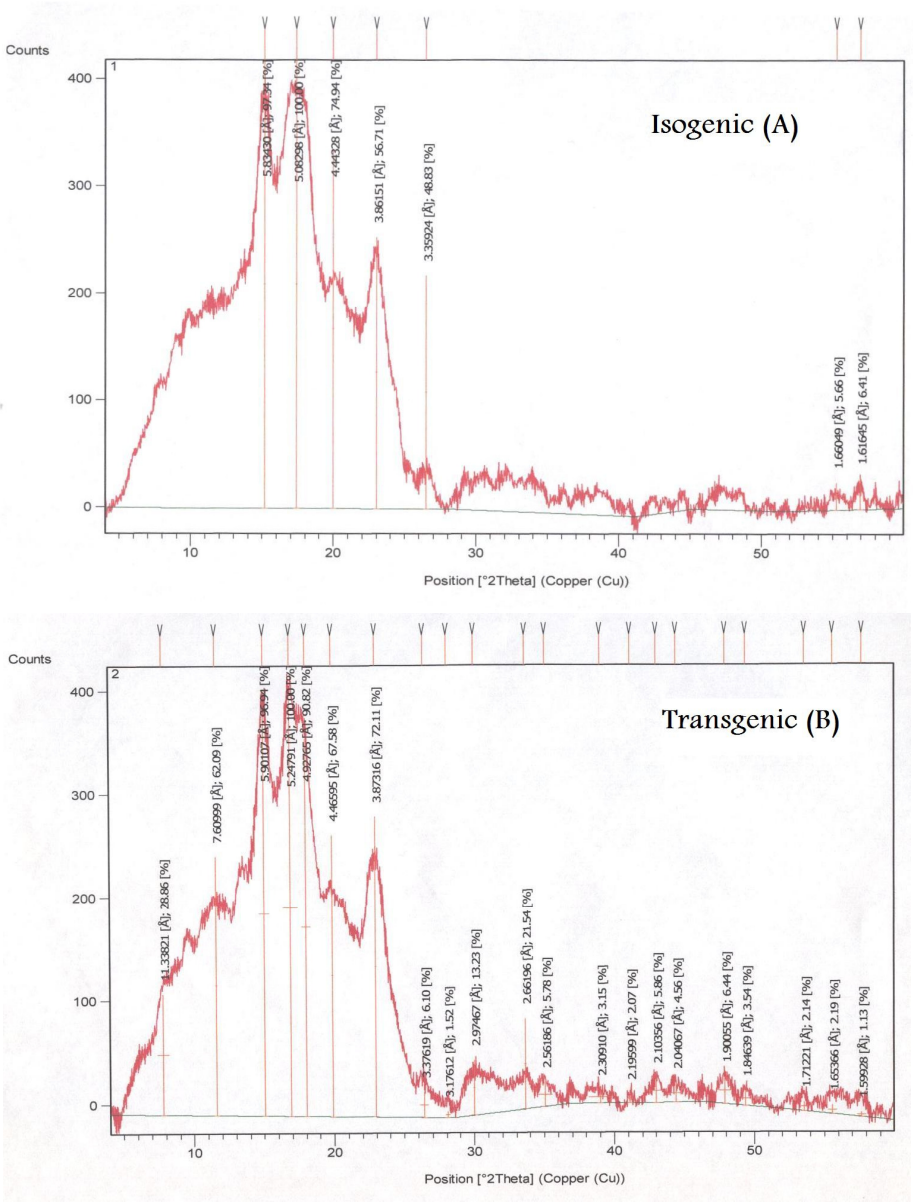

Figure 3. X-ray diffractogram of the isogenic and transgenic corn starch samples

Hayakawa *et al*. [42] and Fujita *et al*. [43] mentioned that the higher degree of crystallinity is usually associated with higher amylopectin content. Ao and Jane [44] reported that amylase in starch granules is amorphous, thus normal starch displays less percentage of crystallinity than waxy starch.

3.10. Differential Scanning Calorimeter (DSC)

Thermal analysis is recognized as an instrumental method of food analysis able to give unique information regarding the nature of the sample or modifications introduced by industrial processing. Thermal analysis comprises a series of analytical techniques evaluating changes in samples as function of temperature, or if done at a constant temperature, evaluating changes as a function of energy over time. These techniques include DSC [45].

DSC thermograph of the endothermic gelatinization profiles of the two tested corn starch samples are shown in ***Fig***. (4, A and B). The result of DSC analysis of tested corn starch samples are summarized in ***Table*** (2).

The transition temperatures (T_o, T_p and T_c), (R) the gelatinization temperature range (T_c - T_o), enthalpies of gelatinization (ΔH) and (PHI) peak height indices ((ΔH/ T_p - T_o), PHI provides numerical value that is descriptive of the relative shape of the endotherm, e,g., a tall narrow endotherm has higher PHI than does a short broad one, even if the enthalpy of transition involved in the process is the same; were varied among the examined corn starch samples. The T_o values for isogenic and transgenic corn starch samples were 34.46 and 30.00 ^oC, respectively (***Table, 2***). While, peak gelatinization temperature (T_p) was higher (91.34 ^oC) in the transgenic sample than the isogenic sample (71.46 ^oC).

The differences in the transition temperature among tested corn starch sample were due to the differences in the degree of crystallinity. Barichello *et al.* [46] reported that high transition temperatures (T_o and T_p) of could be attributed to a high degree of crystallinity, which provides structural stability and makes resistant to gelatinization. On the other hand, Shujun *et al.* [47] found that the starch separated from Song Beimu with lowest degree of crystallinity had the highest transition temperature. This could be due to the compact association of amylase and amylopectin molecules in the starch.

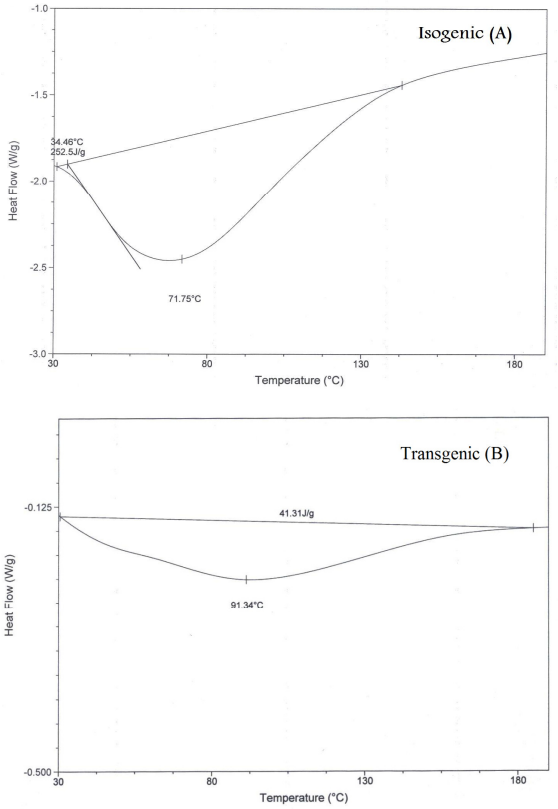

Figure 4. DSC thermograph of thermal properties for the isogenic and transgenic corn starch samples.

The conclusion temperatures (T_c) of isogenic and transgenic corn starch samples were 136.25 and 167.5^oC, respectively. Furthermore, the gelatinization temperature ranges (R) were higher in transgenic corn starch sample (137.5 ^oC) than the isogenic sample (101.79 ^oC). The enthalpy of gelatinization (ΔH) value was higher in the isogenic corn starch sample (251.5 J/g) than the transgenic sample (41.31 J/g). These differences may be due to the amylase content which depressing the enthalpy energy or just a result of differences in starch content in the corn starch samples. Iouchi *et al*. [9] mentioned that the increasing enthalpy change indicates the decreasing amylase content of the starch sample. Moreover, peak height indices (PHI = ΔH/(T_p - T_o) were ranged from 6.77 and 0.673 for isogenic and transgenic corn starch samples, respectively.

Table 2. Thermal characteristics of the isogenic and transgenic corn starch samples

Property	Corn starch samples	
	Isogenic (Ajeeb)	Transgenic (Ajeeb YG)
T_o (^oC)	34.46	30.00
Transition temp.		
T_p (^oC)	71.46	91.34
T_c (^oC)	136.25	167.5
ΔH (J/g)	251.5	41.31
PHI	6.77	0.673
R	101.79	137.5

T_o = onest temperature, T_p = peak temperature, T_c = conclusion temperature, R = gelatinization range (T_c - T_o), ΔH = enthalpy of gelatinization (dwd, based on dry weight basis of starch), PHI = peak height index ΔH/(T_p - T_o).

Variations in DSC measurements have been demonstrated for a variety of maize mutants including *amylose-extender* (*ae*), *dull* (*du*), *sugary-1* (*su1*), *sugary-2* (*su2*), and *waxy* (*wx*) [2,9,11,13,48-51]. These particular mutants cause changes from normal corn starch in amylose percentage and phytoglycogen accumulation [52]. For example, the *ae* mutation results in starch with 50–70% apparent amylase content [52-54], which may dilute the crystalline regions, thus causing a loss of cooperative melting [48]. The *ae* mutation also was reported to increase the chain length of amylopectin [53], which would then require a higher temperature to gelatinize [48]. Therefore, the *ae* starch typically has a broad gelatinization peak that is not complete until up to 120°C, and a high Δ*H* [11,13]. The *du* and *su1* genotypes also are reported to increase apparent amylose percentage [53,54], but do not have broad gelatinization peaks typical of *ae* starch [9,13,48]. They both, however, typically possess a lower Δ*H* value and a *T*° a few degrees below that of normal starch, which may be a result of slightly lower and less perfect crystallinity in the starch [9]. Starch from the *su2* genotype also has a higher apparent amylose content than normal starch but gelatinizes at a much lower temperature and Δ*H*, which may be a result of the very low percentage of crystallinity and higher amount of short branch-chains of amylopectin in *su2* starches than in normal starches [9,50]. The *wx* genotype causes an elimination of amylose content, unlike the other mutants presented in [9]. This mutant results in starch with ≈100% amylopectin, the crystalline component of starch, which requires more energy to gelatinize [9]. Furthermore, the differences in the thermal properties may be attributed to differences in granule structure, amylase content, the gelatinization temperature and the presence of degree and crystalline regions of different strength in the granules of starch samples [3]. Starches with large sized or irregular granules had higher ΔH, PHI and R values, while the reverse was true for starches with small oval or round granules [47].

3.11. Pasting Properties

Rheological and mechanical properties of starch-water dispersions and gels wherein essentially pure starch has been swollen and or solubilized to various extents by heating have been extensively investigated over the years. These studies have contributed to an understanding of the gelatinization mechanism and are important because of the utilization of starch in a wide range of food and industrial applications. Understanding these properties offers considerable promise in improving starch containing foods", this knowledge can be applied to alter end use properties by reformulation or changes in processing conditions [55]. Pasting is the phenomenon following gelatinization in the dissolution of starches. It involves granular swelling, exudation of the granular molecular components, and eventually, total disruption of the granules [56]. Viscosity changes of starch dispersions during gelatinization are the most

frequently measured with the Brabender Visco-amylograph which is used in the food industry as a quality control instrument [57].

Brabender amylograph curve of the rheological properties for the two investigated corn starch samples are showing in ***Fig.*** (5, A and B).

It can be observed that in the isogenic and transgenic corn starch samples, the onset temperatures and the peak viscosities increase when heating temperature increase. According to Barichelo *et al*. [46] high gelatinization transition temperatures are indicative of a high degree of crystallinity, which provides structural stability and makes starch gelatinization difficult. Quantitative values of peak viscosities, temperature of initial viscosity, and temperature of peak viscosity and setback of viscosity were calculated and presented in the ***Table*** (3).

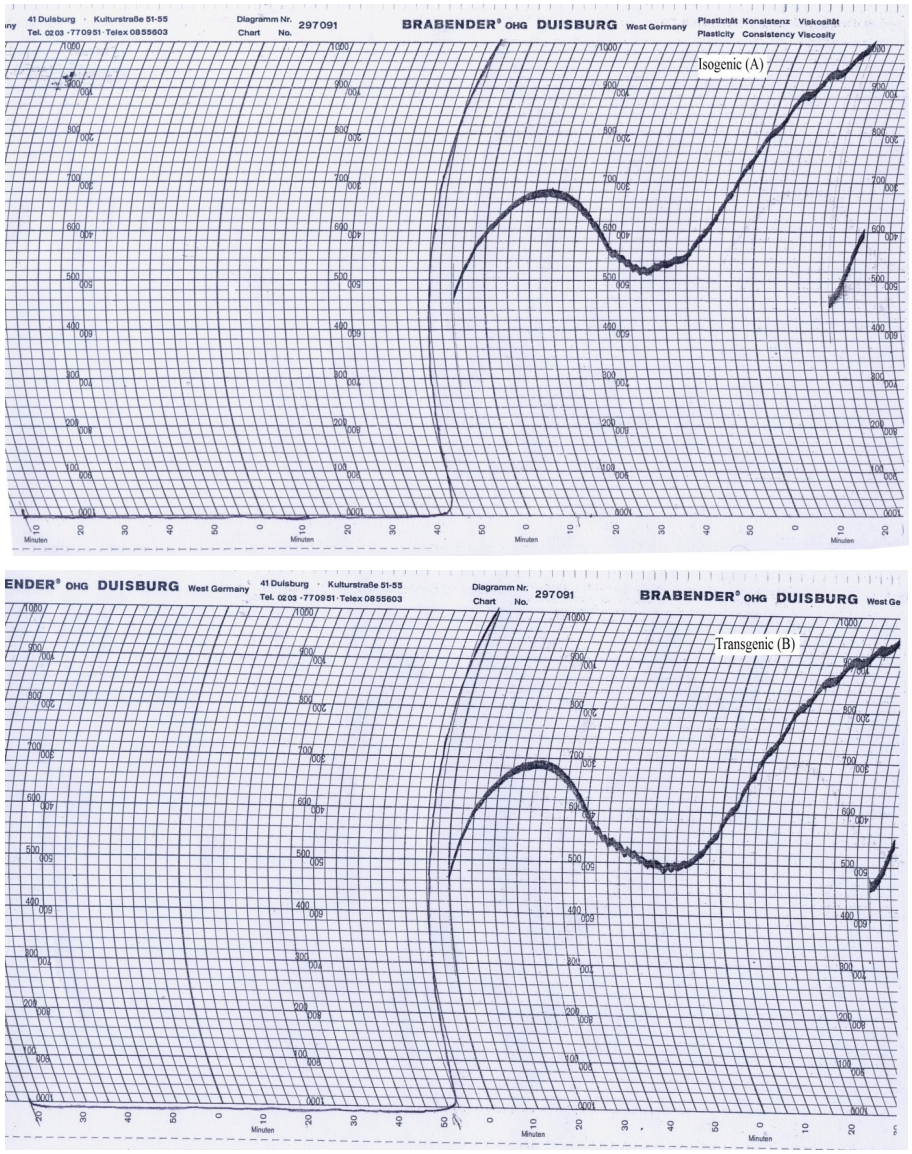

Figure 5. Amylograph response of the isogenic and transgenic corn starch samples.

Peak viscosity values were 1215 and 1225 BU for isogenic and transgenic corn starch samples, respectively (***Table 3***). Kuo *et al*. [58] stated that peak viscosity usually occurs when the temperature of the suspension has reached to 92-95°C. Amylograph peak viscosity is a measurement of the ability of the known starch granules to swell markedly before rupturing. Thus, amylographic peak viscosity is an important index for evaluating the grains quality. Furthermore, as seen in ***Table*** (3) the temperatures of initial viscosity were the same for isogenic and transgenic corn starch samples, while temperature of peak viscosity of isogenic corn starch sample was higher (96.5°C) than the transgenic corn starch sample (92.8°C).

Table 3. Pasting properties of isogenic and transgenic corn starch samples measured by brabender amylograph

Property	Corn samples	
	Isogenic (Ajeeb YG)	Transgenic (Ajeeb YG)
- Peak viscosity (BU)	1215	1225
- Temperature of initial viscosity (°C)	76.3	76.3
- Temperature of peak viscosity (°C)	96.5	92.8
- Setback (BU)	65	145

Shimelis *et al*. [59] reported that final viscosity is used to indicate the ability of starch to form various paste or get after cooling and that less stability of starch paste is commonly accompanied with high value of breakdown. The variation in the final viscosity might be due to the simple kinetic effect of cooling on viscosity and the re-association of starch molecules in the samples [60]. Regarding to the Setback of viscosity for the two analyzed corn starch samples (***Table 3***), it was observed that the value of isogenic corn starch sample was lower (65 BU) than the transgenic corn starch sample (145 BU). Sanni *et al*. [61] reported that lower set back viscosity during the cooling indicate higher resistance to retrogradation. This means that the isogenic corn starch sample without changing the water will exhibit higher resistance to retrogradation than the transgenic corn starch sample.

4. Conclusion

Variation in physicochemical properties of starch isolated from transgenic corn (Ajeeb YG) and its near isogenic (Ajeeb) was observed. These include amylose content, absorption capacity, solubility index and viscosity. Also, there are some differences in the result of DSC analysis and pasting properties. Based on the obtained result, genetic modification affected the physicochemical properties of starch isolated from transgenic corn and we recommend further investigations on the effect of genetic modification on food composition.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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