

Characteristics of Isolated Starch Granules of Two Sorghum Varieties

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Abstract: Sorghum, like other cereals, is a good source of starch, that reached to about 60–80% of kernels which had an brilliant potential for global industrial claims. In this study, starch had been isolated from tow sorghum varieties (low tannin; Giza 15 and high tannin; Assiut 14) using different extraction procedures (boiling in water and in alkaline media and soaking in alkaline media). Starch yield, gel consistencies, degree of syneresis, gelatinization temperature range, shape and size of starch granules, and starch color had been assayed for the isolated starch. The results revealed that Giza 15 had higher starch yield for all extraction procedures, gels made from (Giza 15) was thinnest than that made from (Assiut 14), the degree of syneresis increased by way of starch gel decrease. Results also showed that neither significant difference of gelatinization temperature between white and pigmented sorghum starches nor between the extractions procedure for the pigmented starch was noted. Giza 15 starch had the highest L^* value (91.3) however Assiut 14 variety gave a little darker starch. The pigmented sorghum starch appearance was comparable to that of white variety. The starch granules were mostly spherical and polygonal, with indentations and pores on the surface radial, tube-like channels of granules penetrate from the external surface into a cavity at the hilum, starch granule size of Giza 15 exhibited not significantly difference for larger size compared to that of Assiut 14 extracted using different extraction procedures. The result concluded that the starch isolated from pigmented sorghum grains using the alkaline procedure was comparable to white starches; thereby it could be replace it in the food industry fields

Key words: Starch granules isolation, Sorghum varieties. Starch characteristics

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench), typically cultivated crosswise the world in the warm climatic regions, is quantitatively the world's fifth largest important cereal grain after wheat, maize, rice, and barley (Taylor et al., 2006).

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However, with decreasing water supplies, and increasing world population it is forecasted as an important future crop. Sorghum is classified as sorghum, tannin sorghum, white sorghum, and mixed sorghum (FGIS-GIPSA, 2006).

Sorghum can practically be characterized according to end use. Sorghum, like other cereals, is rich in starch, that reaching from 68-75% depending upon cultivar, region and climatic conditions (Subramanian et al., 1994; Singh et al., 2009). Sorghum starch has brilliant use for industrial applications (Zhang et al., 2010) and using

excess sorghum is by way of producing starch and starch based sweeteners.

Starch granules consist of amylose (20-30%) and amylopectin (70-80%). The physicochemical and functional properties of starch normally are a clear outcome of the interaction between starch molecules and other food components and physical prearrangement of amylose and amylopectin and as well which affect the quality of starch and the starch based products (Boudries et al., 2009).

Sorghum starch occurs in a extremely arranged form inside the granules. Starch granules in the hard corneous type endosperm are strongly bound in a firm protein matrix, while the starch granules are lightly spaced and lightly surrounded by protein bodies in the floury soft endosperm (Turner, 2004). Morphology of starch granules such as shape and size are features of their botanical origin (Kaur et al., 2007). Environmental temperature is seriously effect on the starch composition, amylopectin structure and gelatinization properties (Matsuki et al., 2003). Starch granule size, amylose/amylopectin ratio as well as gelatinization temperature has effect on the physiochemical properties of the starch that subsequently influence the quality of starch and starch based products. Furthermore, they are important to starch potential purposes.

Little interest was associated to sorghum starches and still less to the starch of sorghum growing in the hyper arid areas of Egypt. Sorghum starch had an excellent potential for global industrial applications. Therefore, further characterization is required to better understanding the difference of physiochemical and functional properties of starch from different sorghum varieties. This article

focuses on morphological, thermal properties and content of isolated starch from white and red sorghum grains cultivated under southern conditions of Egypt.

2. Martials and methods

2.1. Materials:-

Sorghum cultivars (*Sorghum bicolor* L. Moench); low tannin sorghum (Giza 15) and high tannin sorghum (Assiut 14) samples were obtained from Agriculture Research Center, Shandawel, Sohag, Egypt, and Season 2013.

2.2. Methods

2.2.1. Starch isolation

Starch was isolated from sorghum grain by steeping and wet milling steps according to Sira and Amaiz (2004).

2.2.1.1. Starch isolation from white sorghum samples (Giza 15):

100 g of white sorghum grains were suspended in 0.25% NaOH (Method A) solution (200 mL). After overnight, steeping the grain was washed until neutral pH. The steeped grains were ready for wet milling.

2.2.1.2. Starch isolation from pigmented sorghum samples (Assiut 14):

For pigmented sorghum (Assiut 14) two different extraction procedures were used for starch isolation from sorghum grains as follow:

2.2.1.2.1. **Brown sorghum samples** were treated with sodium hypochlorite in alkaline medium (steeping procedure) prior to wet milling. The media for the steeping phase were composed as follows (Table 1), 5.25% sodium hypochlorite and 10.7% potassium hydroxide (Method 1A), 5.25% sodium hypochlorite and 5.35% potassium hydroxide (Method 1B), and 5.25% of sodium hypochlorite without KOH (Method 1C).

Table (1) Alkaline medium of treatment sorghum grains.

Sorghum Cultivars	Alkaline medium	Methods
Assiut 14	Heating with water	Control 1
	Heating with KOH 10.7% + NaOCL 5.25%	1A
	Heating with KOH 5.35% + NaOCL 5.25%	1B
	Heating with NaOCL 5.25%	1C
	Soaking 2days in water	Control 2
	Soaking 2days in NaOH 0.25% + NaHSO ₃ 0.025%	2A
	Soaking 2days in NaOH 0.25% + NaHSO ₃ 0.05%	2B
	Soaking 2days in NaOH 0.25% + NaHSO ₃ 0.1%	2C
Giza 15	Soaking in water all night	Control A
	Soaking in NaOH 0.25 % all night	A

Table (2) Effect of different extraction alkaline medium on yield of sorghum starch.

Sorghum Cultivars	Starch isolation procedure	Starch yield(%)
Assiut 14	Boiling in water	22.39
	Boiling in KOH 10.7% + NaOCl 5.25%	26.81
	Boiling in KOH 5.35% + NaOCl 5.25%	20.56
	Boiling in NaOCl 5.25%	21.69
	Soaking in water for 2 days	33.47
	Soaking in NaOH 0.25% + NaHSO ₃ 0.025% for 2 days	28.91
	Soaking in NaOH 0.25% + NaHSO ₃ 0.05% for 2 days	20.34
	Soaking in NaOH 0.25% + NaHSO ₃ 0.1% for 2 days	19.88
Giza 15	Soaking in water overnight	39.24
	Soaking in NaOH 0.25% overnight	37.57

2.2.1.2.2. *Three batches* of 100g each were steeped in 200 mL of sodium bisulfite in alkaline medium at different concentrations. Steeping medium consisted of 0.25% w/v NaOH, for Methods 2A, 2B and 2C, NaHSO₃ was added to give final sulfur concentrations of 0.025, 0.05 and 0.1%, respectively. All samples were wet milled after steeping for 2 days.

2.1.1.1. *Wet milling procedures:*

Wet grains milling were done in a blender home mill (Moulinex blenders) for 5 min, the resulting was filter by cheese cloth, the starch isolated by gravity and excess water was get ride. The resulted starch was dried overnight at 45°C (Perez et al., 1993).

2.2.2. Sorghum starch yield determination:

Sorghum starch yield were calculated according to the following equation (Ratnayake *et al.*, 2007):

$$\text{Starch yield \%} = \frac{\text{Extracted starch (g)}}{\text{Dry weight of used sorghum (g)}} \times 100$$

2.1.2. Determination of gel consistence:

Gel consistence was measured according to Chandrashekar and Kirleis (1988).

2.1.3. Determination of the syneresis degree:

The syneresis degree of starch gels was determined as described by Yang *et al.* (1980).

2.1.4. Determination of gelatinization temperatures range:

Gelatinization temperature range of starch was determined using a light microscopes described by Hosney (1994).

2.1.5. Determination of color:

The color was determined using the Hunter L, a, b method using Lovibond glasses calibrated in accordance with Giese (2000). The surface color characteristics of sorghum starch were measured by Colored Differences Meter (CDM) (model color Tec-PCM, U.S.A) using different color parameters ("L", "a", "b") (Beta *et al.*, 2001).

2.1.6. Determination of shape and size of starch granules:

Size and shape of resulted starch granules were examined as described by Hosney *et al.* (1981) using light microscope.

3. Results

3.1. Properties of starch isolated by different alkaline medium:-

3.1.1. Starch yield:

Starch yield obtained from Assiut 14 and Giza 15 sorghum samples are shown in Table 2 and Fig. 1. Starch yield varied according to sorghum variety and to the isolation procedure. Generally, Giza 15 had higher starch yield for both extraction procedures (Table 1) used in this study that reached to 39.24% for water isolation method and 37.57% for alkalin isolation method. In concern Assiut 14, two different procedures used for starch isolation table 1. The results in the same table showed that, both methods gave considerable amount of starch. The highest starch yield was obtained using soaking in water for two days by 33.47% starch yield followed by soaking in (0.25% NaOH + 0.025% NaHSO₃) yielded 28.91% starch and (10.7 % KOH + 5.25% NaOCL) yielded 26.81%, (5.25% NaOCL) yielded 21.69%, (5.35% KOH+ 5.25% NaOCL) and (0.25% NaOH +0.05% Na_HSO₃), had nearly the same starch yield (20.5%), and (0.25% NaOH + 0.1% Na_HSO₃) yielded 19.88% starch. The obtained results are close with those showed by Sira and Amaiz (2004), who showed that yields of starch obtained from dark and white sorghum samples ranged between 27.73 to 30.0%.

Table (3) Effect of different alkaline extraction on gel length and degree of syneresis of starch extract from sorghum grains

Sorghum Cultivars	Methods	Gel consistency (length, cm)			Degree of syneresis (ml H ₂ O)		
		4%	5%	6%	4%	5%	6%
Assiut 14	Control 1	7.4	10.6	12.2	24	21	14
	1A	6.8	8.1	12.3	31	26	14
	1B	10.2	13.3	19.8	33	0	0
	1C	9.8	12.7	14.3	24	0	0
	Control 2	8.4	9.6	13.5	22	12	10
	2A	11.2	12	12	24	18	0
	2B	10.2	14.3	15.8	20	19	0
	2C	10.4	11.6	13.7	25	23	11
Giza 15	Control A	5.1	7.5	9.3	25	22	10
	A	5.4	8.1	10.1	29	22	0

Control 1= Boiling with water

1B = Boiling with KOH 5.35% + NaOCl 5.25%

Control 2 = Soaking in water for 2days

2B = Soaking 2days in NaOH 0.25% + NaHSO₃ 0.05%

Control A = Soaking in water over night

1A = Boiling with KOH 10.7% + NaOCl 5.25%

1C = Boiling with NaOCl 5.25%

2A = Soaking in NaOH 0.25% + NaHSO₃ 0.025% for 2days

2C = Soaking in NaOH 0.25% + NaHSO₃ 0.1% for 2days

A = Soaking in NaOH 0.25% over night

3.1.2. Gel consistency and syneresis degree of starch:

Gel consistency of isolated sorghum (Giza 15 and Assiut 14) starch were determined by measuring the length of starch gel at different concentrations (4, 5 and 6%) and the obtained data are shown in Table. 3 The data showed that gel made with low sorghum tannin (Giza 15) was thinnest (gels with the highest values) than that made from high tannin sorghum (Assiut 14). Giza 15 showed gel consistency values between 5.1 and 10.1 cm, whereas the value for the Assiut 14 sample ranged between 6.8 and 19.8 cm. These results are in the line with Chandrashekar and Kirleis (1988) they reported that the gel consistency of sorghum starch ranged from 4 to 11 cm. Similar to the obtained results by Ahmed et al. (2016) who showed that the gel consistency ranged from 8.9 to 12.9 cm in sorghum starch.

The syneresis degrees of sorghum starch gels at different concentrations (4, 5 and 6%) are revealed in Table (3). Results noted that there was a difference in the degrees of syneresis (mL H₂O) were separated from the gel of starch for sorghum starch extracted using different method at 4% , while for 5 and 6% starch concentration, the degrees of syneresis of boiling with KOH 5.35% + NaOCl 5.25% and boiling with NaOCl 5.25% treatments recorded zero by other meaning there wasn't water were separated from the gel of starch starting from 5% starch concentrations. At the same time soaking in NaOH 0.25% + NaHSO₃ 0.025% for 2 days, soaking in NaOH 0.25% + NaHSO₃ 0.05% for 2 days and boiling with KOH 10.7% + NaOCl 5.25% procedures recorded zero degree of syneresis at 6% starch concentration. However for other treatments the degree of syneresis ranged between 10 to 14 at 6% starch concentration. Singh et al.(2012)

found the degree of syneresis of sorghum starch ranged from 0.95 to 26.21mL H₂O. The syneresis degrees were 16.60, 11.20 and 0.00 mL H₂O in 2, 4 and 6% mung bean

starch gel concentrations (Abdel-Rahman et al., 2008).

Table (4) Effect of Alkaline medium extraction on gelatinization temperature of starch.

Sorghum Cultivars	Methods	Gelatinization Temperature °C . range		
		Initial	Mid	End
Assiut 14	Control 1	64	76	79
	1A	64	71	78
	1B	60	66	70
	1C	63	72	77
	Control 2	63	68	80
	2A	63	70	78
	2B	62	69	78
	2C	62	68	75
Giza 15	Control A	60	68	76
	A	63	70	79

Control 1= Boiling with water

1B = Boiling with KOH 5.35% + NaOCl 5.25%

Control 2 = Soaking in water for 2days

2B = Soaking 2days in NaOH 0.25% + NaHSO₃ 0.05%

Control A = Soaking in water over night

1A = Boiling with KOH 10.7 % + NaOCl 5.25%

1C = Boiling with NaOCl 5.25%

2A = Soaking in NaOH 0.25% + NaHSO₃ 0.025% for 2days

2C = Soaking in NaOH 0.25% + NaHSO₃ 0.1% for 2days

A = Soaking in NaOH 0.25% over night

in

3.1.3. Gelatinization temperature range:

The gelatinization transition temperature T₀(onset) T_p (peak) and T_c (conclusion) of white and red sorghum starches are presented in Table.4 and Fig. (2). No significant differences of gelatinization temperature between white and pigmented sorghum starches were obtained. Pigmented sorghum starch showed a gelatinization temperature comparable to white sorghum starch. Results also revealed there were no differences in the gelatinization temperatures range between of pigmented sorghum starch extracted using

Results in the same Table showed that sorghum starch isolated using soaking in water for two days (Control 2) had the highest gelatinization temperature range 63-80°C, while sorghum starch isolated with boiling in KOH 5.35% + NaOCL 5.25% (1B) had the lowest gelatinization temperatures rang of 60.0°C - 70.0°C, on the other hand the white sorghum starch had a gelatinization temperatures rang 63-79.0°C. These results agreement with Taylor (1992) who reported that the gelatinization temperature range, the least onset and peak gelatinization temperatures of 60 °C and 77 °C respectively,

in sorghum starch. Similar to the obtained results by Liu and Rosentrater (2016) showed that the gelatinization temperature ranged from 68.0°C to 78.0°C in sorghum starch.

Color of starch:

The color of isolated sorghum starch under different isolation procedures are presented in Table. 5. Hunter L^* (lightness), a^* (red to green) and b^* (blue to yellow) values of sorghum starches are shown, Giza 15 ranged between ($L^*= 85.2$ and 91.3), ($a^*= 1.68$ and 3.0) and ($b^*= 5.28$ and 8.4), while Assiut 14 ranged between ($L^*= 86.46$ and 89.2), ($a^*= 0.33$ and 3.3), ($b^*= 4.4$ and 8.32) under different extraction procedures. Not surprisingly, Giza 15 starch had the highest L^* value (91.3) however Assiut 14 variety with pigmented testa gave a little darker starch. The extracted starches have a great clearness for both varieties. These results are in the line with that found by Beta *et al.* (2001) who reported that the color of sorghum starch under extraction in alkaline solution ranged from ($L^* = 75.9$ to 90.5 , $a^* = 0.34$ to 5.81 and $b^* = 4.11$ to 5.47). These results are in the same trend with Sira and Amaiz (2004) they showed that the color of sorghum starch under extraction in alkaline solution were found (L^*) value = 91.3 after isolated using the soaking in NaOH 0.25% over night and (L^*) value = 78.4 after isolated by heating in distilled water at 60°C for 7 min. The form of starch isolated from pigmented variety (Assiut 14) was comparable to that from white variety (Giza 15). The values of color yellowness b^* are ranged from 4 to 8 for white and pigmented sorghum starches; they direct a leaning of color near yellow (Sira and Amaiz, 2004) found where that b^* value was 10.1 for white sorghum and 16.5 for the pigmented sorghum

From the same Table it clears that the a^* value for treatments, soaking in water for 2 days (control 2), soaking in NaOH 0.25% +

NaHSO₃ 0.025% for 2 days (2A), soaking 2 days in NaOH 0.25% + NaHSO₃ 0.05% (2B) and boiling with KOH 10.7% + NaOCl 5.25% (1A) were high comparing to other treatments.

2.1.1. Shape and size of starch granules:

Sorghum starch granules shape and size are shown in Fig. (3) The granule starches of the two examined sorghum varieties (Giza 15 and Assiut 14) examined using scanning light microscope showed heterogeneity of shape and size, the granules were seen to be polygonal in shape and some of them had oval shape. Scanning light microscope for starch granules from Giza 15 and Assiut 14 under different extraction procedures had no significant difference in shape. Some granules showed pin holes locally at the smooth surface (Fig. 3) and the same observation was reported by Benmoussa *et al.*, (2006),

Our results are in accordance with Sang *et al.* (2008); Ai *et al.* (2011) who reported that, the granules are mostly spherical and polygonal, with indentations and pores on the surface radial, tube-like channels of granules penetrate from the external surface into a cavity at the hilum (Huber and BeMiller, 1997). The isolated starches from two sorghum varieties (Assiut 14 and Giza 15) using different procedures are shown in Fig. (3). The granule size of white sorghum starch (Giza 15) varies between 3 μm to 15 μm, while the size in pigmented sorghum (Assiut 14) varies from 3.14 μm to 14.78 μm. These results are in accordance with those reported by Benmoussa *et al.* (2006) and Singh *et al.* (2010). In the current study, starch granule size of Giza 15 exhibited not significantly difference for larger size compared to that of Assiut 14 extracted using different extraction procedures.

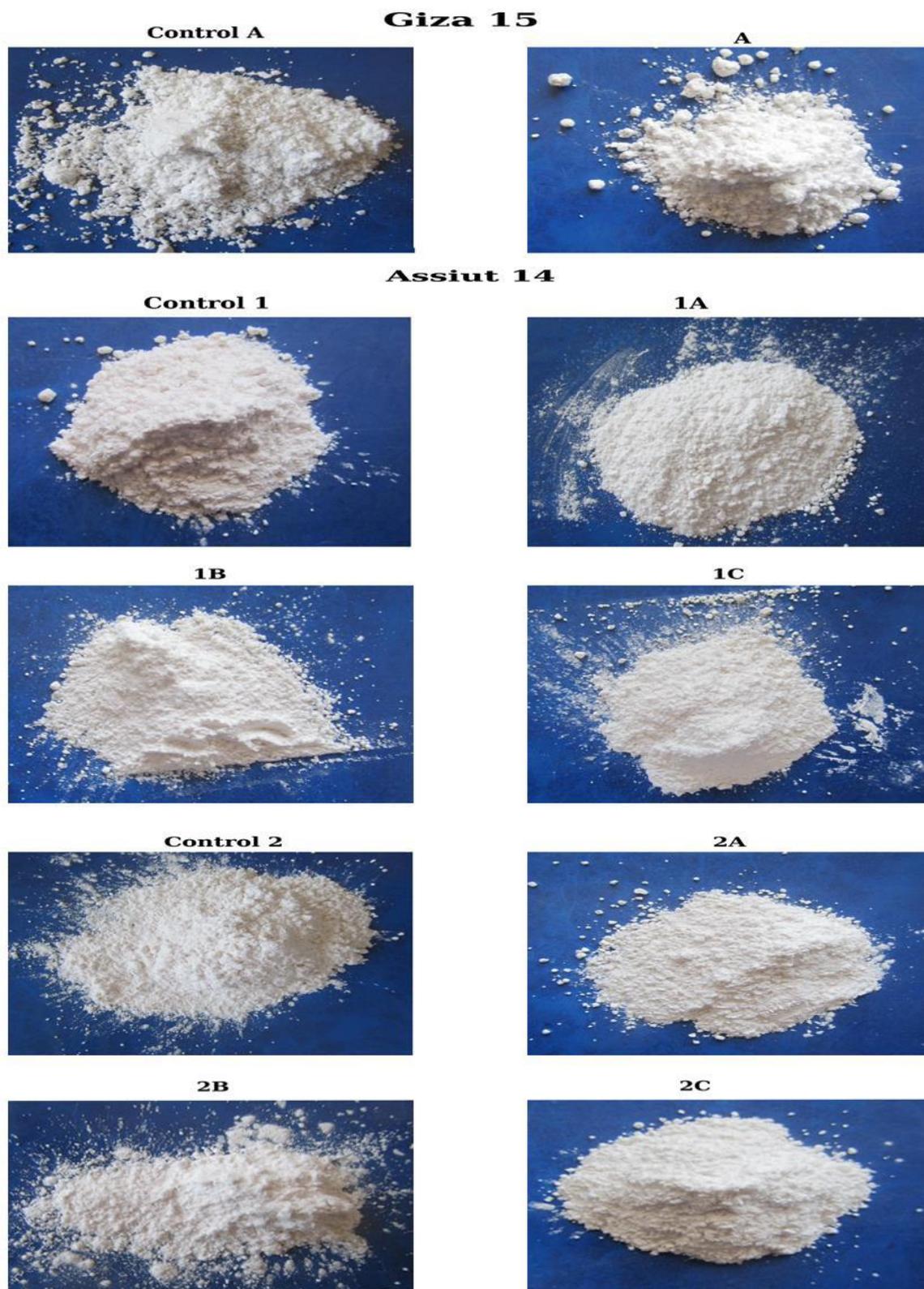


Fig (1) Effect of different extraction alkaline medium on sorghum starch isolation

Control A = Soaking in water overnight

Control 1 = Boiling with water

1B = Boiling with KOH 5.35% + NaOCl 5.25%

Control 2 = Soaking in water for 2 days

2B = Soaking in NaOH 0.25% + NaHSO₃ 0.05% for 2 days

A = Soaking in NaOH 0.25% overnight

1A = Boiling with KOH 10.7% + NaOCl 5.25%

1C = Boiling with NaOCl 5.25%

2A = Soaking in NaOH 0.25% + NaHSO₃ 0.025% for 2 days

2C = Soaking in NaOH 0.25% + NaHSO₃ 0.1% for 2 days

Table (5) Effect of different alkaline extraction on color of starch extract from sorghum grains.

Sorghum Cultivars	Methods	Color			LSD _{0.05}
		<i>L</i> *	<i>a</i> *	<i>b</i> *	
Assiut 14	Control 1	89.2±0.68	0.43±0.1	7.8±0.6	0.65*
	1A	87.1±0.5	0.33±0.04	4.4±0.52	
	1B	86.75±0.01	0.34±0.12	8.32±0.43	
	1C	87.2±0.02	0.67±0.12	7.3±0.18	0.65*
	Control 2	84.37±0.65	3.3±0.13	6.26±0.83	
	2A	87.46±0.22	2.7±0.23	5.6±0.28	
	2B	86.53±53	2±0.055	6.5±0.14	
2C	87.8±0.39	1.12±0.00	6.64±0.23		
Giza 15	Control A	85.2±0.9	3±0.86	8.4±0.47	1.2*
	A	91.3±0.6	1.68±0.015	5.28±0.33	

Control 1= Boiling with water

1B = Boiling with KOH 5.35% + NaOCl 5.25%

Control 2 = Soaking in water for 2days

2B = Soaking 2days in NaOH 0.25% + NaHSO₃ 0.05%

Control A = Soaking in water over night

*L** = lightness

*a** = red to green

*b** = blue to yellow

1A = Boiling with KOH 10.7% + NaOCl 5.25%

1C = Boiling with NaOCl 5.25%

2A = Soaking in NaOH 0.25% + NaHSO₃ 0.025% for 2days

2C = Soaking in NaOH 0.25% + NaHSO₃ 0.1% for 2days

A = Soaking in NaOH 0.25% over night

Gaffa et al. (2004) noticed that the higher amount of large molecules was shown from red sorghum comparing with the white sorghum starch. Boudries et al. (2014) found that the starch granule size varied between 6.33 and 39.91µm for whit sorghum and varied from 7.10 to 44.78µm for pigmented sorghum, size was nearly similar to those of corn and cassava.

3. Discussion

3.1. Properties of starch isolated by different alkaline medium:-

3.1.1. Starch yield:

The low yield of sorghum starch obtained in this study may be explained through extraction step, (filtering), that may cause the major mass loss in starch in all extraction procedures

3.1.2. Gel consistency and degree of syneresis of starch:

It is well known that gel consistency depends on some factors such as amylose content of sorghum, protein content, cell wall composition, and degradation enzymes. Ahmed et al. (2016) showed that the highest values for gel consistency of sweet sorghum varieties compared with grain ones attributed to amylose content, further more Beta et al. (2001) noticed that the gel hardness was mainly controlled by the amylose content of starch. The participation of protein in limiting starch gelatinization in germinated sorghums and thus producing thinner gels (Elkhalifa and Bernhardt, 2013). The grain modification during germination is mainly due to the action of cell wall degradation enzymes such as β-glucanase and proteases, which support the breakdown of protein matrix. The matrix protein in sorghum is

intimately bound to the endosperm cell walls and the phenolic compounds play a role in this attachment (Glennie, 1984; Parker et al., 1999). This study assumed that the content of phenolic compounds and the nature of these compounds for both sorghum varieties studied in addition to the differences in endosperm cell wall could be attributed to those differences of gel consistency made of Giza 15 and Assiut 14.

The degrees of syneresis of sorghum starch were decreased by increasing of starch concentration. The results suggested that the chemical treatment of sorghum grains could cause cell wall change and starch characteristics as associated. It may be of relevance to the findings of Glennie (1984) who indicated that the matrix protein in sorghum is intimately bound to the endosperm cell walls.

3.1.3. Gelatinization temperature range:

The starch gelatinization is measured by loss of granule birefringence in dilute granule suspensions exposed to an increased temperature. The temperature at which 95% of the starch granules lose birefringence is the birefringence endpoint temperature. The relative amount of gelatinized versus native starch granules determined by microscopic technique (Guiné and dos Reis Correia, 2013). Congo red dye test used to distinguish between native and gelatinized and damaged starch illustrated the gelatinization temperatures of sorghum starch granules examined under scanning light microscope. Gelatinization at high temperature can be an indication for the higher stability of starch crystallites in starch molecules.

3.1.4. Color of starch:

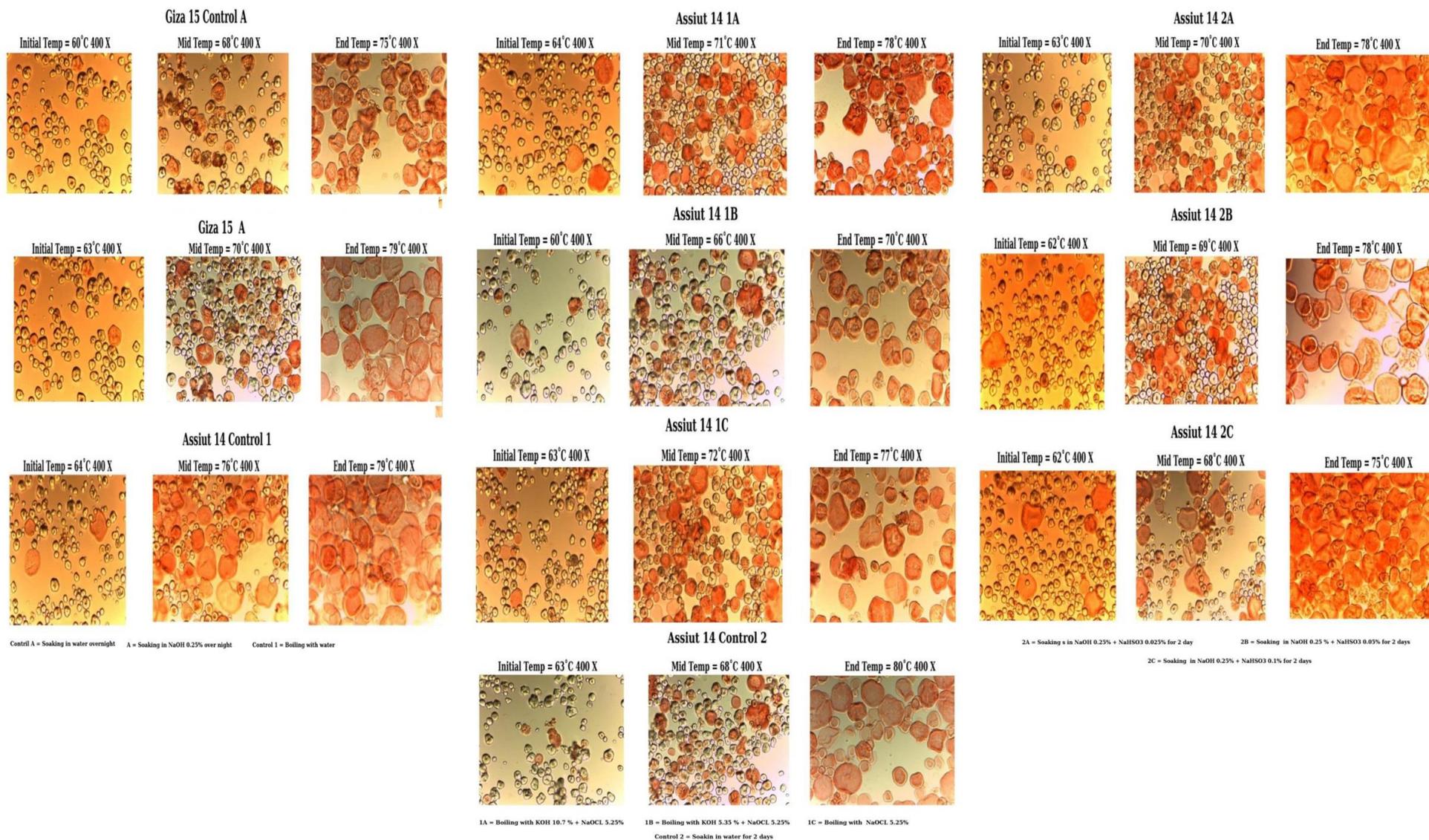
Color is an important measure for starch quality, and the starch paste should be clear and free from any off-color for better acceptability. The polyphenol content and the

kernel structure of sorghum were attributed to starch properties. A white pericarp, with no pigments, is vitally important to lower color in tannin-free sorghum used for white starch production. The polyphenolic compounds of Giza 15 could become adsorbed to the starch during wet milling. The starch of pigmented sorghum extracted by boiling had low a^* value, that could be as a result of the bleach effect of sodium hypochlorite.

The result in this study suggests that both sorghum varieties and the used isolation procedures had less yellow color and less remaining rate of protein and lipids too, by other meaning, grain pericarp, color, presence or absence of pigmented testa, and polyphenol content did not relate to the pink color of isolated sorghum starches. Therefore the isolated starch from pigmented sorghum could substitute that of white sorghum in food industry.

3.1.5. Shape and size of starch granules:

Sorghum starch existed in plant tissues in the form of granules whose characteristics of size, shape and form were distinctive to each botanical species starch heterogeneity could be caused by the difference in developing environment or in genetic characteristic. The floury endosperm has more rounded starch granules whereas in the horny endosperm the angular granules are the predominant Boudries et al. (2014). Therefore our results assumed that the endosperm in the examined sorghum varieties could be with horny endosperm and with high content of amylose. The pin holes appeared due to the action of amylases during the growth of sorghum grains or the starch isolation process (Takeda et al., 1989). The amylase content increase the irregularity of starch granule shape also increased (Wang et al., 1993).



Fg(2) Effect of Alkaline medium extraction on gelatinization Temperature. of starch

Conclusions

The examined sorghum varieties are good source of starch, pigment sorghum variety underwent to the alkaline extraction procedures produced starch with good quality that was comparable to those of white sorghum. Therefore, the isolated starch from both variety could use efficiently in food applications.

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Declarations

The authors declare that they have no conflicts of interests.

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