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Physicochemical Properties of Starch Extracted from Different Sources and Their Application in Pudding and White Sauce

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Abstract: This study was carried to investigate the physicochemical properties of starches extracted from (tiger nuts, sweet potato and taro) and to study their effect on the sensory properties of pudding and white sauce as compared to corn starch. The moisture content was within the range of 9.179-5.372 % for different tested starches. Taro starch recorded the highest ash content (0.851%), protein content (5.605%) and phosphorus content (0.407%). Meanwhile, taro starch showed the lowest lipid content (0.223%). Starch from tiger nuts showed the lowest value of pH. The 2% gel of corn (control sample), tiger nuts, sweet potato and taro starches were recorded 0.442, 0.33, 0.332 and 0.472 OD for clarity, respectively. The maximum viscosity of tiger nuts starch reached 2900 BU with breakdown, set back and pasting temperature being 660 BU, 400 BU and 67.5°C, respectively. The extracted starches showed turbidity in the range of 1.013- 1.4910 at zero time of storage which was gradually increased during 5 days of cold storage. Both solubility and swelling power were increased as gelatinization temperature increased from 55°C to 95°C for all tested starch samples. The highest value of swelling power was appeared in sweet potato starch at 95°C, followed by tiger nuts starch at both 85°C and 95°C of gelatinization. Both of corn and tiger nuts starches granules were round and irregular morphology and large in size, meanwhile, the lower diameter was found in taro starch. Low gelling temperature and the stability during refrigeration and at room temperature could be adequate for foods requiring moderate temperature process but not for frozen food. Generally, white sauce contained 4% of different starch samples attained the significant highest sensory scores than 5% and 6%. Among pudding, the most suitable concentration was 5% for sweet potato, tiger nuts and corn starches but for taro was 4%.

Key words: Starch · Tiger nuts · Sweet potato · Taro · Corn, Physicochemical · Pudding · White sauce

INTRODUCTION

Starch is the most abundant storage reserve carbohydrate in plants. It is found in many different plant organs, including seeds, fruits, tubers and roots, where it is used as a source of energy during periods of dormancy and re- growth. Many of these starch-storing for example, the grains of maize and rice or the tubers of cassava and potatoes are staple foodstuffs in the human diet. Starch is a versatile and useful polymer not only because it is a cheap, natural material but also because of the ease with which its physicochemical properties can be altered through chemical or enzyme modification and/or physical treatment [1]. Starch is the major caloric source in a variety of diets of people worldwide. Thus, starches from various plant species, especially cereals, have received very extensive attention in food research. Corn, potato and cassava are the most common sources of starch for such industries [2]. Starch is an important ingredient in various food systems as thickening, gelling and binding agents. It imparts texture to a great diversity of foodstuffs such as soups, potages, sauces, processed foods, etc. [3].

Maize or corn starch makes up more 80% of the world market for starch and most of this is produced in USA. Europe is the major producer of wheat and potato starches, where cassava or tapioca starch is produced mainly in Asia. Other starches, such as those from rice and sweet potato, make up only a minor portion of the total [1]. Sweet potato *(Ipomoea batatas)* is a dicotyledonous plant that belongs to the family Convolvulaceae. Its large, starchy, sweet testing tuberous roots are an important root vegetable [4]. Root and tuber

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crops are grown worldwide and usually have low commercial value for direct consumption. Even though the information available on such underutilized crops is spare, it has been proved that the starch of such crops would be a good source for different food industries as mentioned by Amani *et al.* [5].

Most tropical plants produce underground storage organs classified as roots or modified stems or tubers, examples of plants that produce tubers as storage organs are *Xanthosoma sagittifolium* (tannia, yautia, ocumo criollo) and *Colocasia esculenta* (taro, ocumo chino). The tubers of this tropical plants belonging to the family Araceae, store a high starch concentration that range between 22 and 40% [6- 8]. Taro (*Colocassia esculenta)* is a tropical tuber crop largely produced for its underground corms and consumed in tropical areas of the world. Taro has been reported to have 70-80 % starch with small granules [9]. Because of the small sizes of its starch granules, taro is highly digestible and as such has been reported to be used for the preparation of infant foods in some countries [10].

Taro has a poor position on the food security profile of countries. In fact, it has been estimated that there is an average of 30 % loss during storage of these tubers and that this portion could resolve starvation problems in non- developed countries. In order to minimize tuber losses, they must be converted from perishable to non-perishable through food processing operations. Since the transformation into starch or flour will decrease losses after the tubers have been harvested, value added processes such as drying and milling may be useful in order to obtain flours and starches from these tubers. Before consideration is given to taro as potential sources of starch to produce foods, it is necessary to characterize their chemical composition, physical, physicochemical and functional properties [11]. It is therefore clear that a significant amount of work remains to be done on the functional characteristics of native taro starch if it is ever to become competitive with commercial starches such as corn, wheat and potato [12].

Cyperus esculentus (tiger nuts or hab El-azez) is a tuber and the oldest cultivated plants in Ancient Egypt. The tubers are edible, with a slightly sweet, nutty flavor. They are quite hard and are generally soaked in water before they can eaten thus making them much softer and giving them a better texture and Ancient Egyptian were used it to make cakes[13]. The isolation of the starch from *Cyperus esculentus* tubers was easy and settling was not hampered by the presence of non-starch materials which remained suspended and floating and was easily decanted off. There has been no report on the properties of the starch of *Cyperus esculentus* [14].The starches major physical-chemical and functional properties for feeding ends and other industrial applications are gelatinization, retrogradation, solubility, water absorption power, syneresis and their rheological behavior in pastes and gels. These physicochemical and functional properties are influenced by the shape, molecular structure and botanical source of native starches in the different vegetable sources [15, 16].

The objective of this work was to investigate some physicochemical properties of the starches extracted from different sources (sweet potato, taro and dried tiger nuts) and their application in pudding and white sauce.

MATERIALS AND METHODS

Materials

Sources of Starch: Sweet potato (*(Ipomoea batatas*) and taro (*Colocassia esculenta*) were purchased from local market at Cairo. Dried tiger nuts (*Cyperus esculentus)* were obtained from local market at Rasheed-EL-Behaira, Egypt. Corn (*Zea mays* L.*)* starch was obtained from Gomhoria Company for Chemicals, Egypt.

Pudding and White Sauce Ingredients: Powdered whole milk, sunflower oil, salt, fine sucrose and vanilla were purchased from local market Cairo, Egypt. Skimmed milk was obtained from Dena farm, Egypt.

Methods

Extraction of Starch

Extraction of Starch From Tiger Nuts: Starch was extracted from tiger nuts by the modified methods of Umerie *et al.* [14]. The sorted (530g) were washed and steeped in potassium metabisulphite solution (0.8133g $K_2S_2O_5$ /L) at 30°C for 48h. The steep water was changed after 24h, then, the tubers were milled to slurry which was suspended in 2 L of $K_2S_2O_5$ solution, stirred and allowed to stand for 2 min. Afterwards, the starch milk was stirred again, passed through a 100 mesh sieve cloth and the suspension was allowed to stand for 24h.The supernatant was decanted and the starch sediment was collected and resuspended in pure water. The starch milk was then passed through a fine sieving and the suspension was allowed to settle for 8h. The wet starch cake was crushed manually, dried at room temperature for 24h and then oven dried at 50°C for 3h.

Extraction of Starch from Sweet Potato and Taro: Sweet potato and taro were washed, peeled manually, cut into small pieces and homogenized with distilled water for 1-2 min. The slurry of each one was then passed through close sieving and the filtrate was allowed to settle for a minimum of 3h at 4°C. The precipitated starch was washed three times with distilled water, dried at room temperature for 2 days and then in oven at 50°C for 3 h [2].

Determination of Chemical Composition of Tested Starch: Moisture content, ash, crude protein and total lipids were determined according to the methods of AOAC [17], where the total carbohydrate was calculated by difference. Phosphorus concentration in acid digested of samples was determined by colorimetric method using ammonium molybdate and spectrophotometer [18].

Yield: The yield of the tested starches extracted from tiger nuts, sweet potato and taro was given in duplicate and calculated in percentage.

Physicochemical Properties of Starch

pH: The pH was measured according to the method of Camargo *et al.* [19], with an ORION model SA520.

Clarity: Clarity was obtained from a 2% solution of the tested starches using the absorbance at 500nm [20].

Starch Paste Properties: Rheological properties of the different sources of starch paste were determined according to AACC [21] using Viscoamylograph at Egyptian Baking Technology Center (EBTC). The results obtained from the amylogram were used to calculate the maximum viscosity, breakdown and setback in Brabender units and pasting temperature.

Turbidity: The different sources of starch gels turbidity was measured as described by Perera and Hoover [22], by means of a 1% aqueous suspension placed in water bath at constant temperature (90°C) and constantly shaken for 1h. The paste was cooled at ambient temperature and stored at 4°C for 5 days and turbidity was measured at 640 nm every 24h using spectrophotometer (Shimadzu UTV-1201c Shimadzu Co., Ltd., Kyoto, Japan)

Swelling Power and Solubility: Swelling power and solubility were determined according to the method of Li and Yeh [23], with some modification. Starch (100mg, dry weight basis) was weighed directly into a screw-cap test tube and 10 ml distilled water was added. The capped tubes were then placed on a vortex mixer for 10s and incubated at 55°C, 65°C, 75°C, 85°C and 95°C in water bath for 30 min with frequent mixing by vortex at 2 min intervals. The tubes were then cooled to room temperature in an iced water bath and centrifuged at 2000 g for 30 min and the supernatant was removed. The cloudy solid layer was considered as supernatant, only the material adhered to the wall of the tube was thought as sediment weight (ws).The supernatant was dried to constant weight (w_1) in air oven at 100°C. The solubility (S) and swelling power (Sp) were calculated as follows:

$$(s) = (w1 / 0.1) \times 100$$

$$(Sp) = [ws / 0.1 \times (100 - s)] \times 100$$

Stability to Refrigeration and Freezing: Stability of different sources of starches to refrigeration and freezing were determined according to Eliasson and Ryang [24]. A starch suspension (6%) was heated up to 95°C for 15 min; then cooled to 50°C and kept at this temperature for 15 min. Aliquots of 50ml were placed in centrifuge tubes and these were conditioned at three temperatures; ambient, 4°C and -10°C for 5 days. After every 24h the samples were centrifuged at 8000g for 10 min and the amounts of water expelled during storage were measured.

Scanning Electron Micrographs: The size and shape of starch granules were observed by means of a backscattering electron microscope model T.330A in the Central Laboratory of the Faculty of Agriculture, Ain Shams University. Starch samples were coated with gold by the LADD, Burling Tonvermont Coater. The granules measurement was reported as the averages of the diameter [25].

Technological Methods

Pudding Preparation: Pudding was prepared by mixing the following solid ingredients with water and the dispersion was heated at 90°C for 6 min under strong agitation. The pudding samples were placed in closed glass containers, cooled to room temperature (25°C) and then stored in a refrigerator (4-5°C) for 24h, [26].

Formula of Pudding

Powdered whole milk	Starch	Liquid vanilla	Sugar	Water
9 g	4.2 g	2.5 g	8 g	Up to 100 g

White Sauce Preparation: All ingredients of the following formula were placed into a cooking device and heated up to 90°C for 6 min with agitation. The obtained sauces were placed in crystal containers covered and cooled down to 20°C in an ice-water bath [27].

Formula of white sauce

Skimmed milk	Sunflower oil	Starch	Salt	Water
9.3g	2.55g	6g	0.23g	Up to 100g

Sensory Evaluation: Ten panelists from the staff members of Food Science Department, Faculty of Agriculture, Ain Shams University were asked to evaluate texture, flavor, color and overall acceptability of the processed pudding and white sauce according to Ares *et al.* [26].

Statistical Analysis: The experimental data were analyzed using analysis of variance and Duncan's multiple range test at ($p < 0.05$). Data were analyzed according to User's Guide of Statistical Analysis System at Computing Center of Faculty of Agriculture, Ain Shams University [28].

RESULTS AND DISCUSSION

Proximate Composition: Proximate composition and pH of tested starches are given in Table 1. The moisture content of tested starches was within the range of 5.372 to 9.179 %; sweet potato starch recorded the lowest value while the highest value was observed in tiger nuts followed by corn (as a control sample) and taro starches. The ash content of taro starch (0.851%) was higher than other tested starches; due to its higher phosphorus content (0.407%) than others. Lipid content of different tested starches was in the range of 0.223 to 0.273%. Taro starch showed the highest protein content (5.605%) followed by sweet potato starch (4.335%), however, tiger nuts and corn starches showed the least and same protein values being 2.898 and 2.895%, respectively. Carbohydrate content varied from 93.321 to 96.598%. These results are accordance with those of Rondan-Sanabria and Finardi-Filho [25] and Carmona-Garcia *et al.* [29]. It was clearly noticed that tiger nuts starch was the more close one to corn starch as a control in its moisture, ash, lipid, protein and carbohydrate content followed by sweet potato then taro starches, except the moisture content of taro starch which was in the second order followed by that of sweet potato.

Phosphorus content is important parameter which used to define the functional properties of starches. From the same Table 1, taro starch showed the highest value (0.407%) followed by tiger nuts (0.291%) then sweet potato starch (0.191%)being the most close one to that of corn starch (0.175%) which showed the lowest phosphorous content. These results agree with Aboubakar *et al.* [12], who reported that the level of phosphorus in tuber starches is typically less than 500mg / 100g and is usually referred to ash. The pH values of tested starches are also presented in the same Table 1. The obtained values were within the acceptable range for food starches being 4.50, 6.25, 6.15and 6.15 for corn, tiger nuts, sweet potato and taro starches, respectively.

Yield: The yield values of tested starches are shown in Fig.1. Tiger nuts, sweet potato and taro starches yielded 15.3 %, 20 % and 10 %, respectively. The highest yield value was observed from sweet potato followed by tiger nuts and finally taro starch

Clarity: Clarity values of the tested starch samples are shown in Fig. 2. It could be noticed that, all the tested starch samples were considered to have high clarity, it was around 0.4. Taro starches clarity (0.472) being the more close one to that of corn starch followed by those of tiger nut (0.330) and sweet potato(0.332) starches which had the lowest values. The clarity of a starch gel directly influences the shine and color of product that contained it as a thickener. The highest clarity of these starches may

Table 1: Proximate composition** of tested starches

	Starch of			
Proximate composition (%)	Corn	Tiger nuts	Sweet potato	Taro
Moisture	8.357±0.029	9.179± 0.072	5.372± 0.010	7.128±0.021
Ash	0.241± 0.002	0.244± 0.003	0.275± 0.004	0.851±0.003
Lipid	0.273± 0.004	0.260± 0.002	0.242± 0.001	0.223±0.003
Protein	2.895± 0.014	2.898± 0.010	4.335± 0.035	5.605±0.039
Carbohydrate*	96.591±0.153	96.598±0.144	95.148±0.162	93.321±0.162
Phosphorus	0.175	0.291	0.191	0.407
pH	4.50	6.25	6.15	6.15

*Carbohydrate was calculated by different **calculated on dry weight

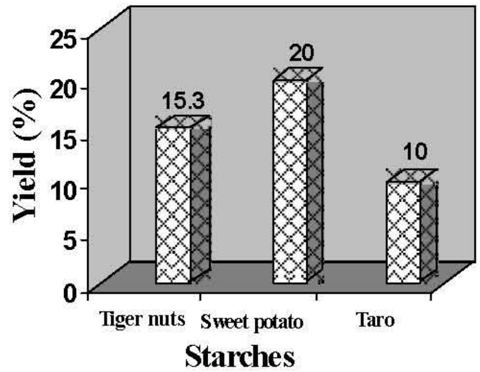

Fig. 1: Yield of tested starches

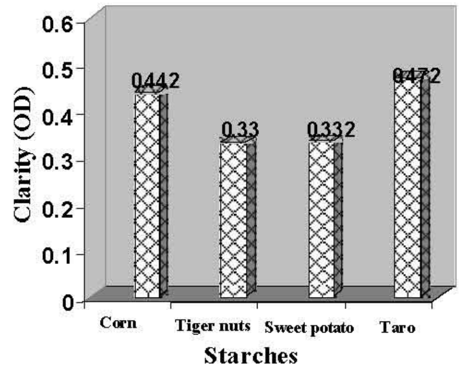

Fig. 2: Clarity of tested starches

Table 2: Paste properties of tested starches

	Starch of			
Parameters	Corn	Tiger nuts	Sweet potato	Taro
Maximum viscosity (BU)	120	2900	1340	1600
Peak viscosity temperature (°C)	90	90	75	76.5
Set back (BU)	260	400	320	560
Breakdown (BU)	40	660	440	660
Pasting temperature (°C)	81	67.5	69	56

serve as a model ingredient for food and other industrial applications that require processing at low temperature and dispense freezing. From these results, it could be recommended that the using of these starches could useful as thickening agents in soups or mayonnaise.

Paste Properties: The paste properties are influenced by several factors such granule size, amylase/amylopectin ratio, molecular characteristics of the starch and the condition of the thermal process employed to induce gelatinization [30]. The pasting characteristics play an important role in the selection of starches for use in the industry as thickener and binder [2]. Table 2 show the rheological behavior of corn, tiger nuts, sweet potato and taro starches measured in Barbender Viscoamylograph. The maximum viscosity of tiger nuts starch was the highest value being 2900 Brabender Unit (BU), when compared to that of taro (1600BU), sweet potato (1340BU), meanwhile, the least viscosity value was appeared in corn starch being only (120BU). The viscosity is related to the swelling power of the starch as mentioned by the break down of tiger nuts and taro starches showed the same values being (660BU) followed by that of sweet potato (440BU), whereas, corn starch had the lowest value (40BU). These results are agree with those obtained by Rondan-Sanabria and Finardi-Filho, [25].The set back value of taro starch was (560BU), which is considered high of followed by tiger nuts starch (400BU) and then sweet potato starch (320BU), the lowest value appeared in corn starch it was (260BU). On the other hand the beak viscosity temperature of tiger nuts starch was equal to that of corn starch (90°C) being higher than those of two others. However, corn starch characterized by the highest pasting temperature (81°C) compared to all studied starches.

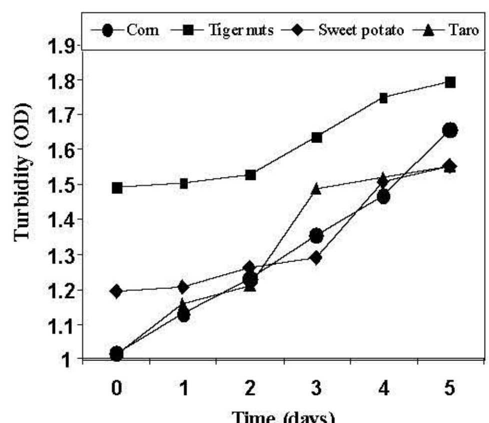

Fig. 3: Turbidity of tested starches stored at 4°C for 5 day

Turbidity: The turbidity of gelatinized tested starches suspensions during storage at 4°C for 5 day is shown in Fig. 3. Turbidity gradually increased during cold storage,

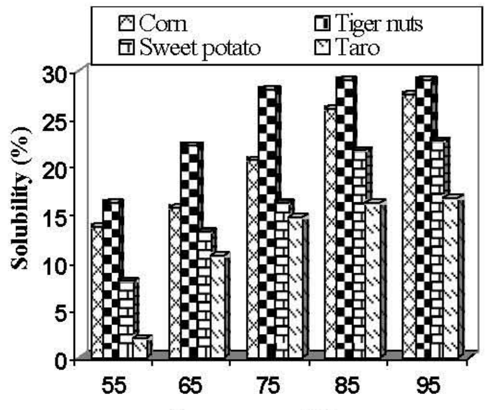

Fig. 4: Effect of temperature on solubility of tested starches

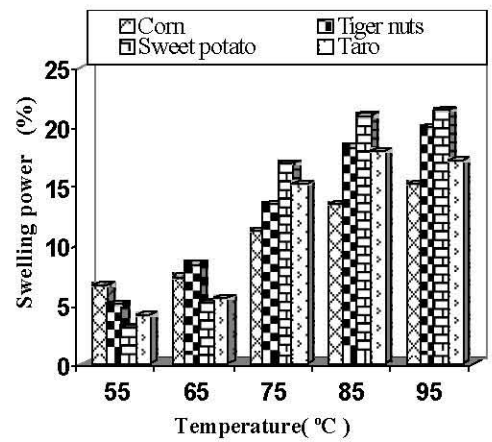

Fig. 5: Effect of temperature on swelling power of tested starches

the highest value was appeared in tiger nuts starch from the beginning and during subsequent cold storage (5days) at any time of storage, it was 1.4910 and reached 1.7963 at the end of storage followed by those of other starches, these results are in agreement with those obtained by Sandhu and Singh [31]. From Fig. 3 it could be observed that sweet potato starch was more stable than the other samples and its value was around 1.3 as OD at 640 nm through the 3days of cold storage.

Solubility(S) and Swelling Power (SP): The solubility(S) and swelling power (SP) of different tested starches at different temperature are shown in Figs.(4 and 5). Starches from taro when heated at 55, 65, 75, 85 and 95°C showed the lowest solubility it reached 2.00, 10.50, 14.50, 16.00 and 13.50, respectively. The other trend was appeared in tiger nut starch it had the highest solubility values being 16.00, 22.00, 28.00, 29.00 and 29.00

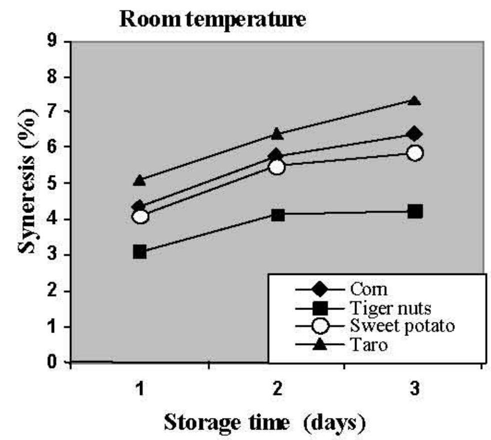

Fig. 6: Effect of storage time at room temperature on syneresis of tested starches

respectively at the same temperatures. As shown in Fig. 4 sweet potato showed the highest swelling power followed by tiger nuts starch, Meanwhile, the lowest value of this character were found in corn starch. As general, the solubility and swelling power are directly correlated to temperature. These results are in agreement with those obtained by Kong *et al.* [32].The highest swelling power and solubility would be explained by granule size and amylase content usually, starch with large granules swells rapidly when heated in water and amylase is crystalline, molecular structure of 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 increment in the absorption and solubility [33].

Stability to Refrigeration and Freezing (Synersis): Synersis characterize was expressed as the volume of water separated from the formed gel under storage at room temperature, refrigeration (4°C) and freezing -10°C. Synersis characterizes the starch stability to these temperatures as shown in Figs. 6-8. Overall, the gels had higher values of synersis under freezing condition than those stored under refrigeration and at room temperature, it means that gels were unstable under freezing condition of starch especially Taro and corn starchs. Chel-Guerrero and Betancur [34] reported that Synersis of legume starches is related to their amylose content which precipitates when gelatinization begins causing rigidity when the gels are cooled and stored.

Starches with high amylose content such as potato (20.1-31.0%) and taro (28.7-29.9%) present high synersis due to the large amount of water expelled during the retrograding process [35, 36]. Meanwhile, low values of

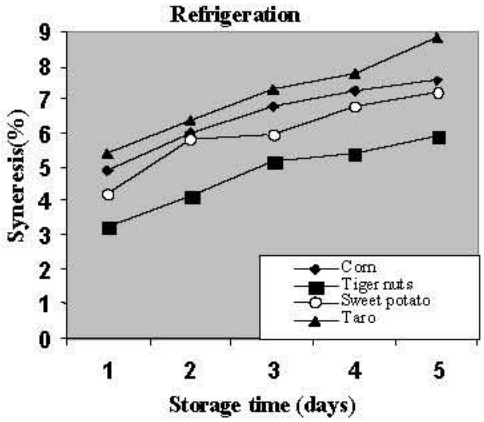

Fig. 7: Effect of storage time at refrigeration on syneresis of tested starches

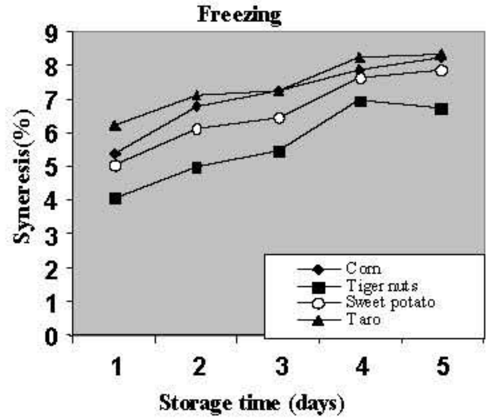

Fig. 8: Effect of storage time at freezing on syneresis of tested starches

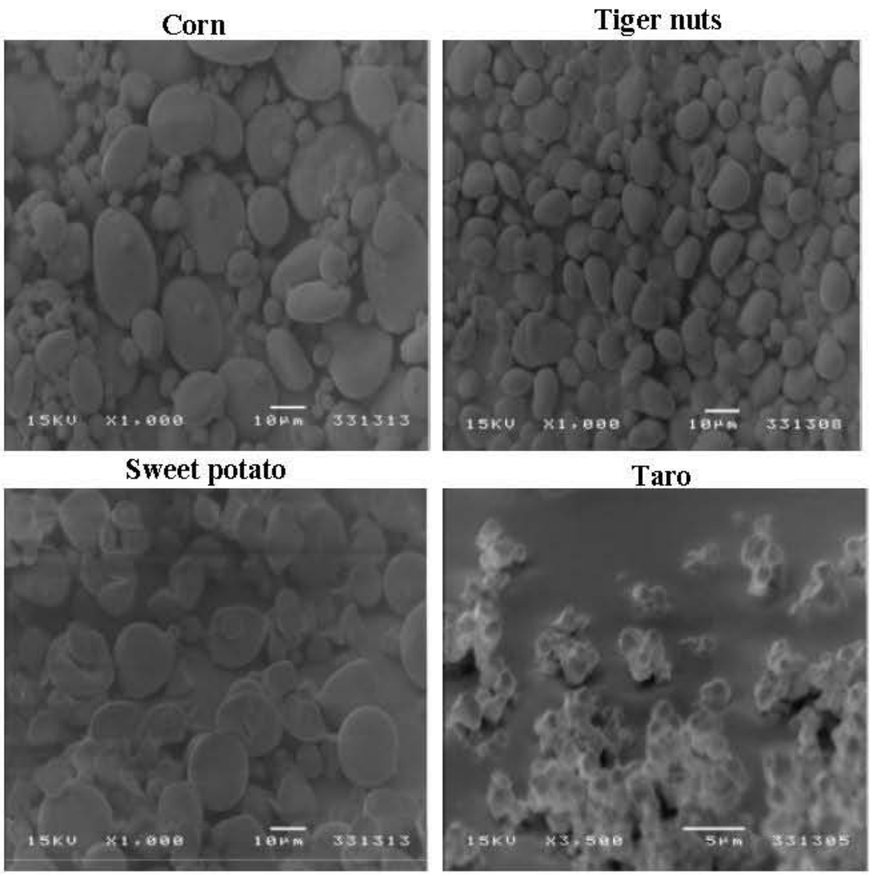

Fig. 9: Scanning electron microscopy (SEM) of tested starch granules

syneresis were appeared at the beginning of different storage conditions, while during subsequent storage either at room or at cooling temp., there was a continuous increase in syneresis values of gels in different starch gels. The starch of tiger nuts showed the most stable gel under different storage conditions. The lowest syneresis may be attributed to low amylase content also to the possible aggregation and to the amylase crystallization occurring during the first storing hours at different storage conditions, whilst in amylopectin it would occur at later stages as mentioned by Singh *et al.* [36]. The gel retrogradation is indirectly influenced by the structural

Table 3: Means value of sensory properties of pudding containing different concentration of starches extracted from different sources

Starch of	Concentration (%) 4	5	6
Texture			
Corn	7.4^{Bab}	8.5^{Aa}	7.3^{Bb}
Tiger nuts	6.8^{Bbc}	8.7^{Aa}	6.8^{Bb}
Sweet potato	7.6^{Ba}	8.8^{Aa}	8.0^{Ba}
Taro	6.4^{Ac}	6.2^{Ab}	4.5^{Bc}
Flavor			
Corn	8.5^{Aa}	8.3^{Ab}	8.1^{Ab}
Tiger nuts	7.3^{Cc}	8.5^{Ab}	8.0^{Ab}
Sweet potato	7.8^{Bb}	8.9^{Aa}	8.8^{Aa}
Taro	6.0^{Ad}	6.0^{Ac}	4.7^{Bc}
Color			
Corn	8.5^{Aa}	8.3^{Aa}	8.2^{Aab}
Tiger nuts	7.2^{Cc}	8.5^{Aa}	8.0^{Bb}
Sweet potato	7.7^{Bb}	8.8^{Aa}	8.7^{Aa}
Taro	6.0^{Ad}	4.4^{Cb}	5.4^{Bc}
Overall acceptability			
Corn	7.5^{Aa}	8.1^{Ab}	7.9^{Ab}
Tiger nuts	6.8^{Cb}	8.8^{Aa}	7.7^{Bb}
Sweet potato	7.5^{Ba}	8.9^{Aa}	8.5^{Aa}
Taro	6.3^{Ac}	4.3^{Cc}	5.6^{Bc}

Mean with different superscript small letters in the same column are significantly different ($P \leq 0.05$).
Mean with different superscript capital letters in the same raw are significantly different ($P \leq 0.05$).

Table 4: Means value of sensory properties of white sauce containing different concentration of starches extracted from different sources

Starch of	Concentration (%) 4	5	6
Texture			
Corn	6.7^{Ac}	6.2^{Bb}	5.5^{Cb}
Tiger nuts	7.8^{Ab}	7.7^{Aa}	6.4^{Ba}
Sweet potato	8.7^{Aa}	7.7^{Ba}	6.6^{Ca}
Taro	3.4^{Bd}	3.7^{Bc}	4.9^{Ac}
Flavor			
Corn	7.0^{Ac}	6.0^{Bb}	5.5^{Cc}
Tiger nuts	8.3^{Ab}	7.7^{Ba}	6.1^{Cb}
Sweet potato	8.8^{Aa}	8.0^{Ba}	6.9^{Ca}
Taro	3.8^{Bd}	4.0^{Bc}	4.8^{Ad}
Color			
Corn	7.0^{Ac}	6.0^{Bb}	5.2^{Cb}
Tiger nuts	8.4^{Ab}	7.6^{Ba}	6.3^{Ca}
Sweet potato	8.8^{Aa}	8.0^{Ba}	6.7^{Ca}
Taro	2.9^{Cd}	4.1^{Bc}	4.7^{Ac}
Overall acceptability			
Corn	6.9^{Ac}	6.2^{Bb}	5.3^{Cb}
Tiger nuts	8.4^{Ab}	7.6^{Ba}	6.5^{Ca}
Sweet potato	9.0^{Aa}	7.8^{Ba}	6.7^{Ca}
Taro	3.2^{Bd}	3.5^{Bc}	4.9^{Ab}

Mean with different superscript small letters in the same column are significantly different ($P \leq 0.05$).
Mean with different superscript capital letters in the same raw are significantly different ($P \leq 0.05$).

arrangement of the starch chains within the amorphous and crystalline regions of the non- gelatinized granule acting in the granule breakdown during gelatinization and also in the interactions occurring within the starch chains during the gel storage [22].

Starch Granules Shapes and Diameters: The tested starch granules shapes and diameters measured by scanning electron microscopy are shown in Fig. 9. Scanning electron micrograph showed that taro starch granules had polygonal and irregular shapes and the diameter was less than other tested starches with a granular diameter ranges from 0.868 to 2.20 Mm. On the other hand, corn and tiger nuts starch granules were round and irregular morphology, small, rounded medium and large in size with diameters ranged from 6.76 to 25.00 Mm and from4.27 to12.53 Mm, respectively. Sweet potato starch granules were oval, medium and regular in size, its diameters ranged from 6.32 to 20.70 Mm. In conclusion, the corn and sweet potato starches granules were bigger in size and diameters than the other tested starches. Their granules were smooth and rapid swelling and solubility. These results are in agreement with the findings obtained by Aboubakar *et al.* [12], Rondan-Sanabria and Finardi-Filho [25], Kong *et al.* [32] and Perez *et al.* [37].

Applications: Starch in seeds and cereal grains mainly contributed to the texture properties of some foods and as a raw material in some industrial application as thickener, colloidal stabilizer and gelling agent [38] so, it could be added in some food products such as:

Pudding: The mean values of sensory properties of pudding containing different concentrations of tested starches are given in Table 3. Pudding samples containing sweet potato, tiger nuts and corn starches showed significantly ($p < 0.05$) superior in texture, flavor, color and overall acceptability than those of taro starch. Statistical analysis of panelist scores for sensory properties of pudding containing different concentrations of tested starches was done to choice the best concentrations of tested starches. From these results, it could be to notice that, the addition of corn starch to pudding recorded the highest scores in all sensory properties followed by sweet potato and tiger nuts starches then taro starch. Increasing of added concentration (from 4 to 5 %) of sweet potato, tiger nuts and corn starches, improved all sensory properties of pudding samples while more addition altered these properties. It could be observed that the best concentration of these starches was at 5%. Among taro starch, its best concentration was found at 4% in pudding, which received the highest panelist scores.

White Sauce: The statistical analyses of sensory properties of white sauce containing different concentrations of tested starches are given in Table 4. White sauce samples containing sweet potato starch showed significantly ($p < 0.05$) superior in texture, flavor, color and overall acceptability followed by tiger nuts and corn starches while, the received scores of taro starch were the least one. Increasing the concentration (from 4 to 6%) of each of tiger nuts, sweet potato and corn starches, the decreasing in all sensory properties, it means that the best added concentration of three starches was 4% while, taro starch showed an opposite trend, the raising of its added concentration, the improvement of quality attributes of sauce the best panelist scores were at 6 %.

CONCLUSION

It could be concluded that tiger nuts starch was the closer one to corn as a(control sample)in its moisture, ash, lipid, protein and carbohydrate contents followed by sweet potato then taro starches. The maximum viscosity of tiger nuts starch was the highest value when compared to others starches. Both of corn and tiger nuts starches granules were round and irregular morphology and large in size, meanwhile, the lower diameter was found in taro starch. Sweet potato showed the highest swelling power followed by tiger nuts. The starch of tiger nuts showed the most stable gel under different storage conditions. The low gelling temperature and the stability during refrigeration and at room temperature could be adequate for foods requiring moderate temperature process but not for frozen food. From these results, it could be recommended to use tiger nuts and sweet potato starches as thickening agents in soups, white sauce, pudding and mayonnaise.

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