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The effect of xanthan and sucrose on the physicochemical, rheological and morphological properties of wheat and corn starches

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ABSTRACT

The increase in the need for starch in the food processing industry has led to the recognition of the effect of other food compounds on the processing of starch-based foods. Xanthan and sugar are commonly used as hydrocolloids and sweeteners, respectively, in starch-based foods. These constituents can affect the structural, thermal, adhesive (dough) and rheological properties of these types of foods. The purpose of this study is to analyze the effect of sucrose and xanthan on the physicochemical, rheological and morphological characteristics of starch pastes. In addition, the comparison of the effect of the combination of xanthan and sucrose on corn and wheat starch pastes has been done in this study. In this research, the concentration of xanthan was 1% by weight and sucrose was 5% by weight, and the mixtures were prepared based on starch (corn or wheat starch). The results showed that in the presence and absence of xanthan 1% by weight and sucrose 5% by weight, the starch dough had a significant difference in terms of solubility, swelling power, water absorption, and dough transparency ($p < 0.05$). Rheological tests revealed that all pastes exhibited shear thinning behavior. By adding xanthan and sucrose, the apparent viscosity, storage modulus and loss modulus of starch pastes increased. Fourier transform infrared spectra showed the change in the intensity and wavelength of absorption peaks due to the addition of xanthan and sucrose. The measurements of scanning electron microscope and X-ray diffraction proved that as a result of adding xanthan and sucrose during gelatinization, changes were made in the network structure. The results of this study can improve processing and find optimal processing conditions to produce food based on Starch like baby food, bread, sweets, etc. help.

1. Introduction

Starch is a natural polysaccharide and is considered as a source of energy for humans and animals. Starch is an important ingredient for many food and non-food products due to its functionality and special properties. Starches with different botanical sources are widely used in food applications as gelling agents, thickeners, water retainers, stabilizers, bulking agents, and adhesives [1]. Starch grain or granule is a complex biopolymer consisting of amylose and amylopectin as linear and branched polymers of glucose. The properties of starch mainly depend on the ratio of amylose to amylopectin; But the less important components that are present in starch grains are: proteins, lipids and phosphorus, which affect the properties of starch. Amylopectin forms the semi-crystalline portion of starch granules, while amylose forms the amorphous or amorphous portion of starch. The amount of amylose, amylopectin and other constituents of natural starch grains depends on its botanical origin and isolation method [2]. The increasing demand for starch in the food industry has drawn more attention to determine the effect of other food constituents (such as sucrose and hydrocolloids) on the processability of starches; Therefore, hydrocolloids are commonly used in starch-based foods to modify texture, improve and control moisture retention, and acceptability of food products [3].

Xanthan gum is a hydrocolloid produced from the fermentation of carbon sources by bacteria*Xanthomonas campestris* It is produced and widely used as a thickener in starch-based food systems. This material is soluble in cold water and its aqueous solution exhibits strong pseudo-plastic behavior [4]. Investigating the effects of different gums (guar and xanthan) on the gel properties of high-amylose corn starches proved that the synergistic and positive effects of the gums on the starch properties depend on the amount of amylose in the starch. Evaluation of the effects of xanthan gum on the rheological properties of kudzu starch showed a strong interaction between xanthan gum and kudzu starch, which affects the properties of starch [5]. Also, sugars, as one of the essential components of starch-based foods, play a significant role in staleness. and gelatinization of starch paste. Studies have proven that sugars have diverse effects on the functional properties of starch systems, depending on the type of starch. Evaluating the effects of sucrose, isomalt and maltodextrin on the gelatin properties of wheat and cassava starch showed that in the presence of sugars, the gelatinization of starches was delayed [6]. However, there are many studies in the field of evaluating the separate effects of xanthan or sugars on the properties of different starches, few studies have addressed the combined effects of xanthan and sugars on starch properties [7, 8]. For example, determining the effects of sodium chloride, sucrose and xanthan gum on gel syneresis and pasting properties of canary seed starch showed the ability of sodium chloride, sucrose or xanthan gum at low concentrations to change the gel stability and pasting properties of canary seed starch [7]. . Most starch-based systems commonly manufactured as human food have experienced heating and cooling in the presence of moisture under shear. Due to heating, starch grains are gelatinized and lose their structural organization and crystallinity. During cooling, individual starch molecules form a gel and then slowly turn into semi-crystalline or stale masses [9]. The rheological properties of starches are one of the main properties that affect the functional properties of starch systems. Also, the structural and morphological changes caused by starch gelatinization indicate the effect on the performance of starch-based food systems [10]. The focus of the present study is on comparing the effects of single and combined addition of sucrose and xanthan on the physicochemical, rheological and morphological properties of starch-based pastes, including wheat and corn starches, as important sources of starch in the diet.

2- Materials and methods

2-1- Materials

Ultrapure corn and wheat starch were provided by Kian Chemical Company (Iran). Sucrose (Merck, Germany) and xanthan gum (Sigma-Aldrich, USA) with laboratory purity were used as received.

2-2- Chemical composition

The calorimetric method (colorimetry) was

used to determine the amount of amylose in wheat and corn starches [11]. The amount of fat and moisture was determined using AOAC 963.15 and 935.29 methods, respectively. Kjeldahl apparatus was used to determine the protein content of starches according to the AACC 12-46 method.

2-3- Preparing the mixture based on wheat and corn starch

To compare the effect of adding xanthan and sucrose on the physicochemical, rheological and morphological characteristics of starches, wheat starch, corn starch, xanthan gum 1% by weight and sucrose 5% by weight were used to prepare eight treatments according to Table 1. The selection of levels was done using screening.

Table 1 The treatments investigated in the research

Weight percentage of components				**Treatments**
Sucrose	Xanthan	wheat starch	Corn starch	
--	--	--	100	**1**
--	--	100	--	**2**
5%	--	--	95	**3**
5%	1%	--	94	**4**
--	1%	--	99	**5**
5%	--	95	--	**6**
--	1%	99	--	**7**
5%	1%	94	--	**8**

2-4- Solubility and swelling power

To determine the swelling power and solubility, 0.4 g of each treatment was poured into centrifuge tubes and 40 ml of distilled water was added to each of them. The resulting liquids were heated using a water bath for 30 minutes at a temperature of 80 degrees Celsius. As a result, after cooling the samples to room temperature, the obtained solutions were centrifuged at 3000 g for 15 minutes. Supernatants and sediments of each treatment were carefully separated. The supernatant water was evaporated overnight at 110 degrees Celsius. The solubility and swelling power of each treatment was calculated using equations (1) and (2) [12].

$$\text{Solubility}(\%) = \frac{\text{dry supernatant weight}(g)}{\text{dry sample weight}(g)} \times 100$$

$$\text{swelling power } (\boldsymbol{g}/\boldsymbol{g}) = \frac{\text{wet sediment weight}(\boldsymbol{g})}{dry\ sediment\ weight(\boldsymbol{g})}$$

5-2- Water absorption

In order to evaluate the water absorption capacity, one gram of each treatment was dissolved in 30 ml of distilled water in a centrifuge tube and heated using a water bath for 30 minutes at a temperature of 95 degrees Celsius while gently stirring. . As a result, the dough was cooled to room temperature using a cold water bath and centrifuged at 3000 g for 10 minutes. After separating the supernatant in the centrifuge tube, the rest of the starch paste was weighed and used to determine the water absorption capacity using equation 3 [13].

$$Water\ absorption\ capacity \left(\frac{g}{g}\right) = \frac{\text{starch remaining dough weight}(g)}{\text{starch initial powder weight}}$$

2-6- The transparency of the paste

In order to determine the transparency of the paste, 0.05 grams of each treatment was dissolved in 5 ml of distilled water in a sealed test tube and heated using a boiling water bath for 30 seconds, and during heating, gentle stirring was done every 5 seconds. became. After cooling to room temperature, the transmittance at 650 nm was measured using a spectrophotometer (UNICO, UV/Vis 2100, USA) compared to a water control [14].

2-7- Rheological measurement

An Anton Parr rheometer (MCR-302, Austria) with a parallel plate (mm=25d, nm1gap=) was used to study the seismology of starch-based dough of each treatment. Starch-based pastes were poured into 19 ml of distilled water by adding 1 gram of each treatment and heated for 5 minutes at a temperature of 95 degrees Celsius with a magnetic stirrer at a stirring speed of 200 rpm. The doughs were quickly cooled using a water bath and reached ambient temperature (approximately 25°C) and were gently stirred while cooling. Dynamic rheological measurements were performed by checking the storage (G') and loss (G") moduli, using frequency sweeps in the range of 0.10-10 Hz at a strain of 1%, after determining the linear viscoelastic region [15].

2-8- FTIR spectroscopy

Fourier transform infrared spectroscopy (Nexus 670, Nicolet, Madison, WI, USA) was

used to analyze possible chemical interactions during gelatinization. The samples related to FTIR analysis were prepared using powder of gelatinized pastes after freeze-drying (Pa 63, -30°C for 24 hours) and mixing with KBr and subjected to hydraulic pressure.

2-9- X-ray diffraction and scanning electron microscopy

X-ray diffraction measurements were performed with XRD (Philips, PW 1729 XRD, Netherlands) at 35 kV and 30 mA with Cu kα (λ) radiation at 0.15405 nm. The scanning area was set from θ2=4° to θ2=70° with a step distance of 1.04° and a scanning speed of 0.5°/min. Samples related to XRD analysis with

The use of powder gelatin pastes were prepared after freeze-drying (Pa 63, -30 degrees Celsius - for 24 hours) [16]. Also, the broken surface of the starch-based dough of each treatment was examined using a scanning electron microscope (JSM 6400, Jeol, Japan) with an accelerating potential of 20 kV and a magnification of x600 [17].

3- Statistical analysis

The properties of the starch-based mixtures were analyzed with at least three repetitions and reported as the mean value ± standard deviation. Statistical analyzes were performed through analysis of variance by SPSS software, version 18.0 (SPSS Inc. Chicago, IL, USA).

4- Results and discussion

4-1- Physicochemical characteristics

The results of the evaluation of the chemical composition of the used starches are presented in Table 2, which shows a significant difference between the chemical compositions of wheat and corn starches ($p < 0.05$). The results proved that native wheat starch contains a higher amount of amylose, fat and moisture compared to native corn starch, while the amount of protein used in corn starch is higher than wheat starch. The ratios of amylose/amylopectin of corn and wheat starch were equal to 23.1: 76.9 and 28.7: 71.3, respectively. Studies reported that the ratio of amylose/amylopectin in starch grains affects starch properties (such as gelatinization temperature, viscosity, solubility, viscosity, etc.) and the final properties of starch-based products [18]. Also, the main building materials (such as protein and fat) in starch grains affect the relative crystallinity, swelling power, syneresis, pasting and thermal properties of starches [19].

Table 2 **Chemical compositions of the native starches**

Chemical compositions (%)				starch
Protein	Moisture	Fat	Amylose	
0/04^{a}±0/43	0/21^{b}±8/7	0/01^{b}±0/42	0/27^{b}±23/1	corn
0/02^{b}±0/36	0/41^{a} ±28/7	0/01^{a}±0/79	0/41^{a}±28/7	wheat

* Different letters mean significant difference at P<0.05.

The results of evaluating the effects of adding xanthan and sucrose on the solubility, swelling power, water absorption and transparency of native corn and wheat starch paste in (**Error! Reference source not found.**3) is shown. The results showed that there is a significant difference in the physical properties of starch in the presence and absence of xanthan and sucrose ($p < 0.05$). Based on the results, the solubility of native wheat starch is higher than the solubility of native corn starch, and the water absorption capacity of corn starch is higher than that of wheat starch. This can be related to more interactions between amylose and amylopectin of wheat starch relative to corn starch, which is caused by the higher amount of amylopectin of corn starch [20]. The swelling power and solubility of starch gives results based on the existence of interactions between starch chains in amorphous and crystalline parts. These interactions are influenced by the ratio of amylose to amylopectin and the characteristics of amylose and amylopectin in terms of molecular weight, distribution, degree and length of branching and spatial arrangement[21].

In addition, the results showed that due to the addition of sucrose, the water absorption capacity, swelling power and solubility of starches decreased. The data indicate that the effect of sucrose on reducing the swelling power and water absorption capacity of wheat starch was higher than its effect on corn starch, while its effect on the solubility of corn starch is lower than its effect on wheat starch. This can be attributed to the higher amylose content of wheat starch compared to corn starch. By binding with free water, sucrose limited water absorption and reduced amylose leaching by

forming bridges with starch chains and consequently creating a rigid structure [22]. In the presence of sugar, swelling of starch grains occurs at higher temperatures. The decrease in solubility and swelling power of different starches with the increase of sucrose has been reported by many researchers [6, 23].

Table 3 Physical properties of starch-based mixtures

Paste clarity	Water absorption (g/g)	Swelling power (g/g)	Solubility (%)	Treatments
0/05[a] ± 0/798	0/22[lt is] ± 7/26	0/31[b] ± 14/02	0/56[a] ± 9/04	wheat starch (Wt% 100)
0/03[b] ± 0/685	0/49[c] ±8/51	0/12[a] ± 16/4	0/29[b] ± 7/8	Corn starch (Wt% 100)
0/08[b] ± 0/699	0/38[c] ± 8/97	0/23[c] ± 13/16	0/34[b] ± 7/84	wheat starch (Wt% 99)+ Xanthan (Wt% 1)
0/06[d] ± 0/617	0/51[a] ± 11/82	0/17[c] ± 13/28	0/16[d] ± 5/82	Corn starch (Wt% 99)+ Xanthan (Wt% 1)
0/05[c] ± 0/643	0/31[f] ± 6/50	0/52[lt is] ± 8/42	0/22[c] ± 6/59	wheat starch (Wt% 95)+ Sucrose (Wt% 5)
0/04[lt is] ± 0/589	0/43[d] ± 8/02	0/34[d] ± 10/26	0/29[d] ± 5/53	Corn starch (Wt% 95) + Sucrose (Wt% 5)
0/06[d] ± 0/614	0/42[c] ± 8/85	0/25[f] ± 6/33	0/13[lt is] ± 4/32	wheat starch (Wt% 94)+ Xanthan (Wt% 1)+ Sucrose (Wt% 5)
0/04[lt is] ± 0/558	0/6[b] ± 10/93	0/49[g] ± 7/81	0/41[lt is] ± 3/98	Corn starch (Wt% 94)+ Xanthan (Wt% 1)+ Sucrose (Wt% 5)

***** Wheat starch (WS), Corn starch (CS), Xanthan gum (XG), Sucrose (S), Transmittance (T)
** Different letters mean significant difference at P<0.05.

The results proved that the presence of xanthan increased the water absorption capacity of starches, while decreasing their solubility and swelling power. This can be related to the higher water absorption capacity of gums compared to starches, which is caused by the large number of hydroxyl groups in the structures, which reduced the water absorption by starch molecules [24]. The results showed that the effect of adding xanthan on the solubility, swelling power and water absorption capacity of corn starch is higher than that of wheat starch. This can be related to the higher formation of fat-amylose complex in wheat starch dough compared to corn starch, which is due to the higher amount of fat in wheat starch compared to corn starch. Researchers revealed that the formation of amylose-lipid complexes decreased the solubility and swelling power of hydrocolloids in water [25].

The results showed that the transparency of wheat starch dough is higher than that of corn starch. This can be related to the presence of more amorphous regions in wheat starch dough compared to corn starch dough, which is due to the higher amount of amylose in wheat starch compared to corn starch [26]. The evaluation of the effect of adding xanthan and sucrose on the transparency of starch paste showed that the addition of xanthan and sucrose in starch-based mixtures reduced the transparency of the resulting paste. The presence of gums in the starch-based mixture can affect the properties of the dough, which is caused by preventing the leaching of the starch grains [27], but the structural change of the starch grains in the presence of other raw materials can lead to a decrease in the clarity of the starch-based dough [28]. . The evaluation of the effect of the addition of xanthan and sucrose on the properties of the starch-based mixture showed a sharper decrease in terms of solubility, swelling power, clarity of the dough, and an obvious increase in water absorption capacity compared to pure starches. This can be due to the interaction between the ingredients of the mixture and the binding of sucrose molecules with starch molecules and the competitive

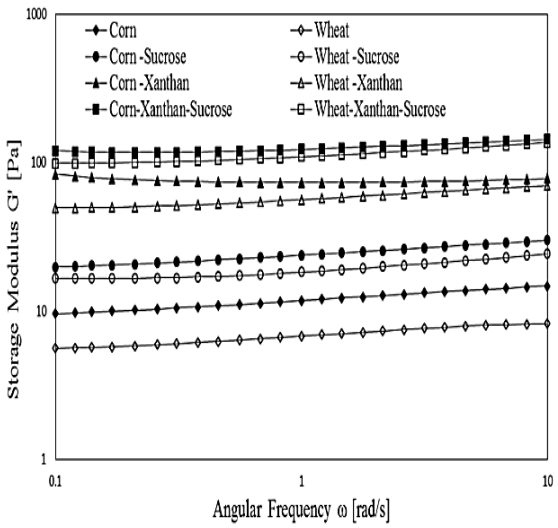
effect of xanthan with starch in absorbing water, which affects the characteristics of the starch-based mixture [8].

4-2- Rheological characteristics

DEPENDENCE OF APPARENT VISCOSITIES OF STARCH-BASED PASTES ON CUTTING SPEED, IN (FIGL a1) is shown. All starch-based doughs showed shear-thinning behavior, but doughs with xanthan or sucrose showed higher apparent viscosities compared to pure starch doughs. The results indicated that at low cutting speeds, the pure corn starch dough showed a higher apparent viscosity compared to the pure wheat starch dough, while this trend was reversed by adding xanthan and sucrose. This can be related to the different ratio of amylose to amylopectin and the different characteristics of amylose and amylopectin of wheat and corn starches in terms of molecular weight, distribution, degree, branching length and spatial arrangement [21]. Both xanthan and sucrose increased the apparent viscosity of starch-based pastes. The increasing effect of sucrose (concentration of sucrose greater than 20 wt%) on the viscosity of starch paste, which is caused by its increasing effect on the swelling of starch grains, has been reported in previous studies [29]. The results showed the shear thinning behavior of starch-based pastes in the presence of xanthan and sucrose. As shown in Figure a1, the effect of addition of xanthan and sucrose on the apparent viscosity of wheat starch pastes was greater than that of corn starch. However, the simultaneous addition of xanthan and sucrose had a synergistic effect on the growth of apparent viscosity.

The dynamic rheological behavior of the starch-based mixtures is plotted in (Figures b1 and c1). The storage (G') and dissipation (G") moduli as a function of angular frequency are presented in (Figures b1 and c1), respectively. As shown in Figure b1, under the same conditions, the storage modulus of corn starch pastes (starch paste with and without xanthan and sucrose) is higher than the storage modulus of wheat starch pastes.

Since the storage modulus shows quasi-solid behavior, the higher storage modulus of corn starch compared to wheat starch can be related to the higher crystalline part of corn starch grains (amylopectin content) compared to wheat starch grains [3]. The data presented in Figure 1c showed that the loss modulus of all corn starch-based doughs was lower than the loss modulus of wheat starch-based doughs. Loss modulus reflects the viscous nature of pastes; Therefore, the higher loss modulus of doughs based on wheat starch can be attributed to the higher amorphous part (amylose) of wheat starch grains compared to corn starch grains. The data revealed that with increasing angular frequency of all starch-based pastes, the magnitude of storage modulus and loss modulus increased. Also, the storage modulus is larger than the loss modulus and there is no intersection between the storage and loss modules throughout the studied frequency range [30].



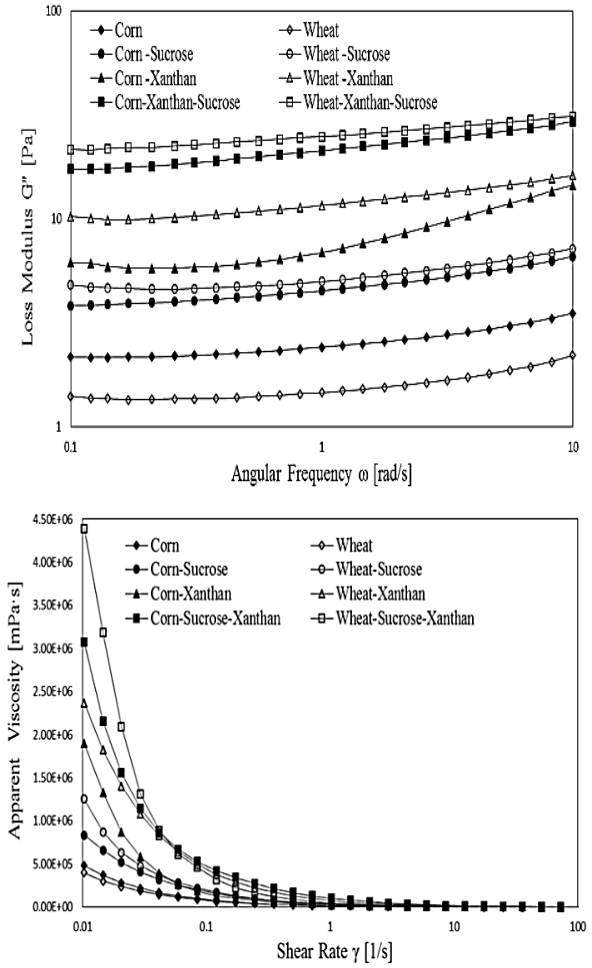


Fig 1 Effects of xanthan and sucrose on (a) the apparent viscosities; (b) storage modulus; (c) loss modulus of starch-based pastes

This issue can be attributed to the strong intermolecular interaction of xanthan and the data indicated that the addition of xanthan and sucrose increased the storage modulus and loss modulus of starch pastes. The increase in storage and loss moduli caused by the addition of xanthan gum was consistent with the findings of previous studies regarding the effect of gums on the dynamic properties of different starch pastes [3, 5]. But the thickening effect caused by the addition of hydrocolloid in starch pastes was previously reported [31]. An increase in the storage modulus of starch pastes as a result of adding sucrose was reported, which was due to the crosslinking between the amylose gel network and sucrose [32].

4-3- FTIR spectra

FTIR spectra of gelatinized corn and wheat starch pastes with and without xanthan and sucrose in (**Error! Reference source not found.**) Provided. Absorption peak in the range of cm^{-1} 3600-3200 indicates the presence of hydroxyl groups, which is a reflection of the presence of hydrogen bonds. Absorption peaks located in cm^{-1} 2930 and cm^{-1} 1650 is attributed to C-H stretching vibration and bonded water in starch, respectively [33]. As shown in (Figure 2), there is no significant difference in terms of the main absorption peaks of the FTIR spectra of gelatinized wheat and corn starch pastes. However, in gelatinized wheat and corn starch pastes, the absorption peaks of hydrogen-bonded OH groups at wavelengths of 3567 cm^{-1} can be seen Also, there is some difference in the intensity and location of the fingerprint peaks (peaks presented in the fingerprint region) which can be related to the different molecular structure of corn and wheat starch pastes. As a result of adding xanthan and sucrose to the pastes, the location and intensity of the main peaks of the pure starch paste changed. The decrease in the intensity of the O-H stretching peak and its wavelength can be the result of the strong hydrogen bond reaction between the hydroxyl groups of starch, xanthan and sucrose.

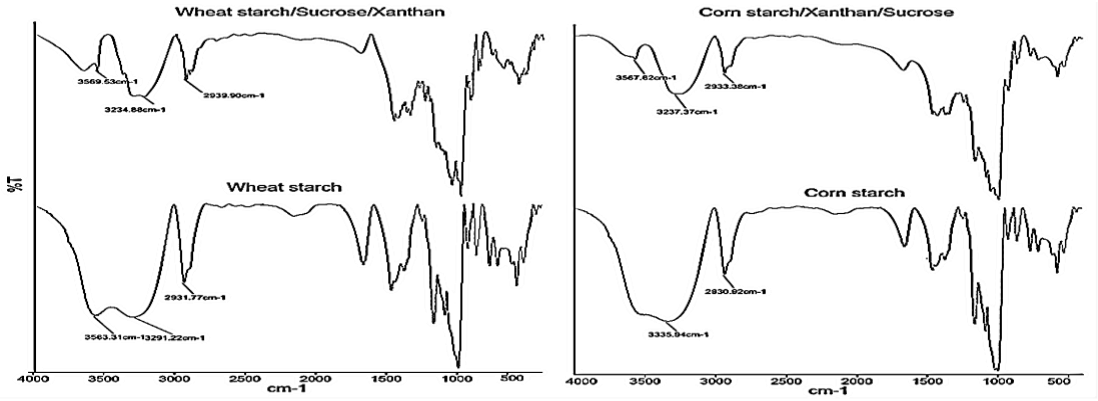


Fig 2 **The FTIR spectra of the gelatinized wheat and corn starch pastes with and with xanthan and sucrose.**

4-4- Evaluation of crystallinity using X-ray diffraction

XRD patterns of corn and wheat starch pastes in the absence and in the presence of xanthan and sucrose are drawn in figure a and b. According to diffractograms (parameters), corn starch paste showed peaks at θ2 equal to 11.79°, 16.41° and 23.63°, while wheat starch paste showed peaks at θ2 equal to 12.21°, 07°. It showed 24.16 and 24.71 °. Also, the intensity of the peaks of the XRD pattern of corn starch paste is higher than that of wheat starch paste. This issue can be related to the higher crystallinity of corn starch compared to wheat starch, which is due to the higher amount of amylopectin in corn starch compared to wheat starch. From the X-ray diffraction patterns, wheat and corn starch crystals can be identified with C-type structure [34]. After heating and cooling corn and wheat starches, some of the A-type crystals changed to B-type crystals. C type crystal pattern is a mixture of A type pattern and B pattern [35]. Other small peaks observed in X-ray diffraction patterns could be mainly related to crystalline compounds with smaller molecular size. The results show the intensity and position of the crystalline peaks of corn and wheat starch pastes as a result of the addition of xanthan and sucrose. X-ray diffraction patterns showed that the intensity of the crystal peaks of starch-based pastes including xanthan and sucrose is higher than that of pure starch pastes. Adding xanthan and sucrose increased the gelatinization temperature [8].

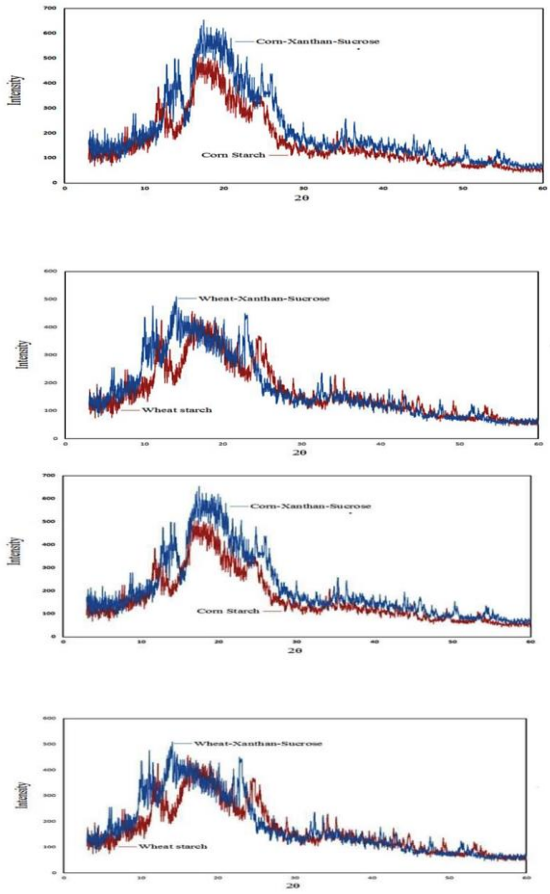


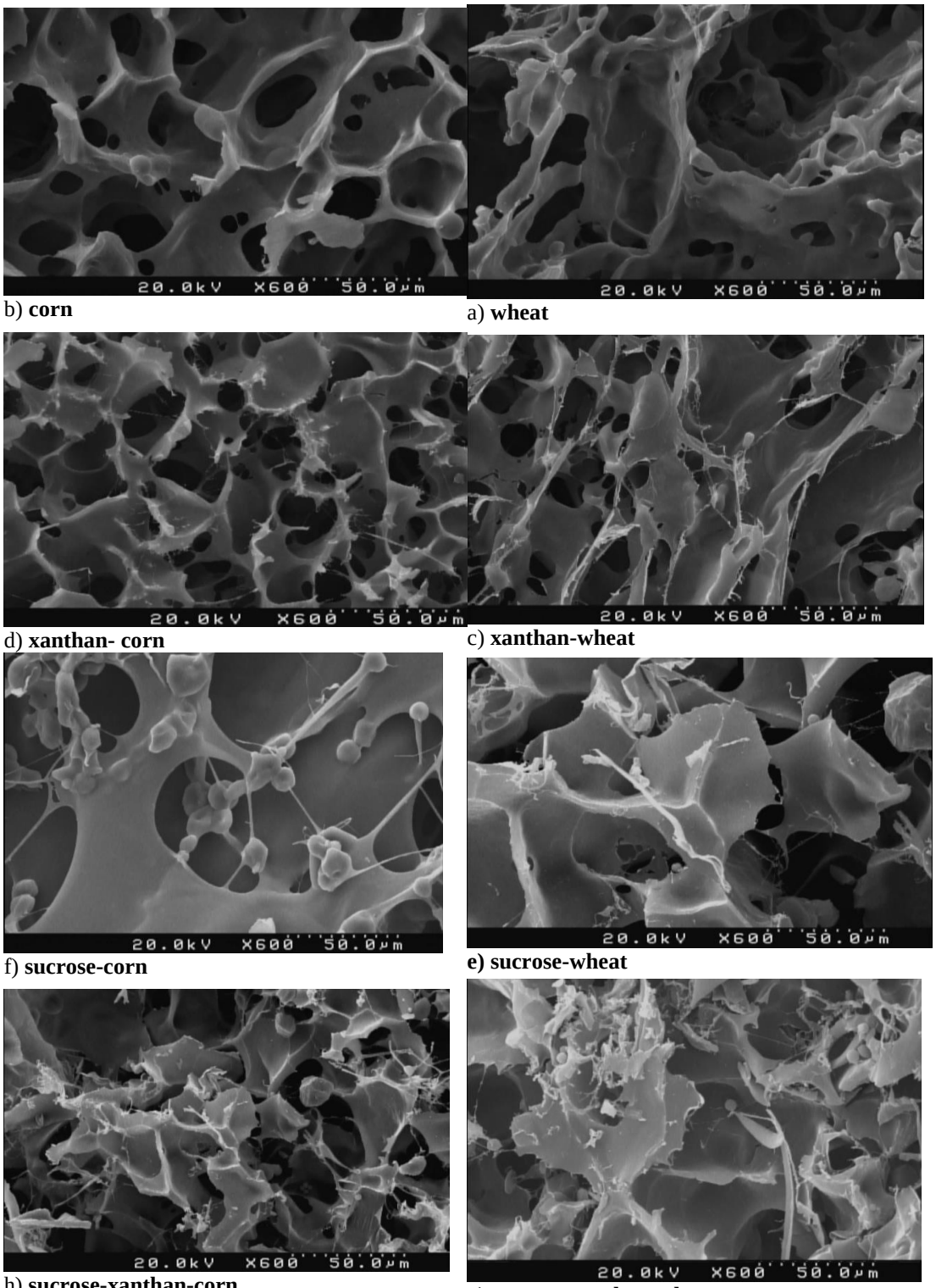
Fig 3 XRD patterns of corn (a) and wheat (b) starch pastes alone and with xanthan-sucrose

While gelatinization reduces the crystalline state of starches; Therefore, the presence of xanthan and sucrose reduced the gelatinization and increased the crystallization of starch pastes. In addition, the addition of xanthan and sucrose broadened the central peak and changed the crystalline peaks, which could be due to the amorphous structure of xanthan and the interaction between xanthan, sucrose and starches. As a result of adding xanthan and sucrose, crystal peaks were formed in the range of θ2 between 10° and -15°, which can be identified with the type V crystal pattern.

There are evidences regarding the formation of type V starch crystals after heat treatment. V-type crystal pattern is formed due to complex formation between individual amylose coils with different polar and non-polar components [36].

5-4- Evaluation of microstructure using scanning electron microscope

Scanning electron microscope images of starch pastes with and without xanthan and sucrose are presented in Figure 4.



b) **corn**

a) **wheat**

d) **xanthan- corn**

c) **xanthan-wheat**

f) **sucrose-corn**

e) sucrose-wheat

h) **sucrose-xanthan-corn**

g) **sucrose-xanthan-wheat**

Fig 4 **SEM images of the fractured surface of the starch-based paste a) wheat; b) corn; c) xanthan-wheat;**

d) xanthan-corn; e) sucrose-wheat; f) sucrose-corn; g) sucrose xanthan-wheat; h) sucrose-xanthan-corn

The images show the structure of the starch network as a result of the thermal gelatinization process. As shown in Figures a4 and b4, the differences in the network structure of wheat and corn starch pastes can be attributed to the difference between the ratio of amylose to amylopectin of wheat and corn starches. Figures c4 and d4 better depict the effect of xanthan addition on the network structure of wheat and corn starch pastes. Xanthan molecules have a flexible helical structure. The images show the interaction of xanthan polysaccharide chains with each other and the starch network to produce a complex network structure. The effect of sucrose addition on the network structure of wheat and corn starch pastes is shown in figures e4 and f4. As shown in these figures, in the corn starch paste, part of the sucrose granules retained their original crystalline structure after gelatinization, while the sucrose granules in the wheat starch paste completely lost their original crystalline structure. It should be noted that the presence of sucrose changed the network structure of corn starch, while xanthan did not significantly change the network structure of wheat starch. Figure g4 and h4 show the effect of simultaneous addition of xanthan and sucrose on the network structure of wheat and corn plates, respectively. These images revealed the significant effect of xanthan and sucrose on the network structure of starch pastes. The difference in SEM images as a result of separate and combined addition of xanthan and sucrose can be attributed to the interaction between starch, xanthan and sucrose. At a lower magnification scale, holes and microstructures and especially interactions were not shown well.

5- General conclusion

In the food industry, hydrocolloids are usually used in starch-based foods to modify the texture, improve and control the moisture retention and water acceptance of food products. In addition, sugars are the main components of starch-based foods, which play a significant role in the separation and gelation of starch dough; Therefore, the proper use of these building materials can improve the processability and final qualities of foods for consumers. The results of examining the physical properties of starch-based pastes in the presence and absence of xanthan and sucrose revealed that the chemical compounds of starch have a significant effect on the solubility, swelling power, water absorption and transparency of starch pastes. Rheological evaluation showed the shear thinning behavior of starch-based pastes. The combined addition of xanthan and sucrose had synergistic effects on increasing the apparent viscosity and dynamic rheological properties of starch paste. The existence of interaction effect between starch, xanthan and sucrose was confirmed by FTIR spectra, X-ray diffraction patterns and SEM images. The change in the intensity and position of the FTIR and XRD peaks and the change in the network structure due to the addition of xanthan and sucrose can be a confirmation for the presence of an interaction effect between starch, xanthan and sucrose.

6- Resources

[1] Fu, Z. Zhang, L. Ren, M. H. & BeMiller, J. N. (2019). Developments in Hydroxypropylation of Starch: a review. *starch strength*,71(1-2): 1800167.

[2] Xu, Y. Chen, X. Xu, X. Wang, B. Du, X. & Chen, P. (2020). Investigation on the Crystal Transition of Maize Starch from Semi-crystalline to Amorphous State. *Journal of Cereal Science*, 92: 102924.

[3] Shahzad, S. A. Hussain, S. Mohamed, A. A. Alamri, M. S. Qasem, A. A. A. & Osman, M. A. (2019). Pasting, thermal, textural and rheological properties of rice starch blended with 6 different hydrocolloid gums. *Pakistan Journal of Agricultural Sciences*, *56*(3).

[4] Habibi, H. & Khosravi-Darani, K. (2017). Effective variables on production and structure of xanthan gum and its food applications: A review. *Hournal of Agricultural Biotechnology*. 10: 130-140.

[5] Zheng, Y. Sun, W. Yang, W. Chen, S. Liu, D. Tian, J. & Ye, X. (2020). The influence of xanthan gum on rheological properties and in vitro digestibility of kudzu (Pueraria lobata) starch. *Starch strength*, *72*(3-4), 1900139.

[6] Pourmohammadi , K. Abedi , E. Hashemi , S. M. B. & Torri , L. (2018). Effects of sucrose, isomalt andmaltodextrin on microstructural, thermal, pasting and textural properties of wheat and cassava starch gel. International journal of biological macromolecules, 120, 1935-1943.

[7] Abdel-Aal, E. S. M. Rabalski, I. Hernandez, M. L'Hocine, L. Patterson, C. A. & Hucl, P. (2019). Effect of sodium chloride, sucrose, and xanthan gum on pasting properties and gel syneresis of hairless canary seed starch. Cereal Chemistry, 96(5), 908-919.

[8] Zolelmein, A. Movahhed, S. Azizi, M. H. & Ahmadi Chenarbon, H. (2019). Assessment of simultaneous addition of sucrose and xanthan effects on the thermal, pasting, and rheological behavior of corn starch. *Journal of texture studies*, *51*(3), 453-463.

[9] Pratiwi, M. Faridah, D. N. & Lioe, H. N. (2018). Structural changes to starch after acid hydrolysis, debranching, autoclaving-cooling cycles, and heat moisture treatment (HMT): A review. *Starch strength*, *70*(1-2), 1700028.

[10] De Souza Gomes, D. do Prado Cordoba, L. Rosa, L. S. Spier, M. R. Schnitzler, E. & Waszczynskyj, N. (2018). Thermal, pasting properties and morphological characterization of pea starch (Pisum sativum L.), rice starch (Oryza sativa) and arracacha starch (Arracacia xanthorrhiza) blends, established by simplex-centroid design. *Thermochimica Acta*, *662*, 90-99.

[11] McGrance, S. J. Cornell, H. J. & Rix, C. J. (1998). A simple and rapid colorimetric method for the determination of amylose in starch products. *Starch strength*, *50*(4), 158-163.

[12] Nadiha, M. N. Fazilah, A. Bhat, R. & Karim, A. A. (2010). Comparative susceptibilities of sago, potato and corn starches to alkali treatment. *Food Chemistry*, *121*(4), 1053-1059.

[13] Hedayati, S. & Niakousari, M. (2018). Microstructure, pasting and textural properties of wheat starch-corn starch citrate composites. *Food hydrocolloids*, *81*, 1-5.

[14] Waliszewski, K. N. Aparicio, M. A. Bello, L. A. & Monroy, J. A. (2003). Changes of banana starch by chemical and physical modification. *Carbohydrate polymers*, *52*(3), 237-242.

[15] Chang, Y. H. Lim, S. T. & Yoo, B. (2004). Dynamic rheology of corn starch–sugar composites. *Journal of Food Engineering*, *64*(4), 521-527.

[16] Sani, I. K., & Alizadeh, M. (2022). Isolated mung bean protein-pectin nanocomposite film containing true cardamom extract microencapsulation/CeO2 nanoparticles/graphite carbon quantum dots: Investigating fluorescence, photocatalytic and antimicrobial properties. Food Packaging and Shelf Life, 33, 100912.

[17] Rasul, N. H., Asdagh, A., Pirsa, S., Ghazanfarirad, N., & Sani, I. K. (2022). Development of antimicrobial/antioxidant nanocomposite film based on fish skin gelatin and chickpea protein isolated containing Microencapsulated Nigella sativa essential oil and copper sulfide nanoparticles for extending minced meat shelf life. Materials Research Express, 9(2), 025306.

[18] Kim, H. S. Patel, B. & BeMiller, J. N. (2013). Effects of the amylose–amylopectin ratio on starch–hydrocolloid interactions. *Carbohydrate polymers*, *98*(2), 1438-1448.

[19] Li, W. Wu, G. Luo, Q. Jiang, H. Zheng, J. Ouyang, S. & Zhang, G. (2016). Effects of removal of surface proteins on physicochemical and structural properties of A-and B-starch isolated from normal and waxy wheat. *Journal of food science and technology*, *53*(6), 2673-2685.

[20] Jayakody, L. Lan, H. Hoover, R. Chang, P. Liu, Q. & Donner, E. (2007). Composition, molecular structure, and physicochemical properties of starches from two grass pea (Lathyrus sativus L.) cultivars grown in Canada. *Food Chemistry*, *105*(1), 116-125.

[21] Hoover, R. (2001). Composition, molecular structure, and physicochemical properties of tuber and root starches: a review. *Carbohydrate polymers*, *45*(3), 253-267.

[22] Puri, R. Gill, B. S. & Khetra, Y. (2014). Effect of Acacia gum, NaCl, and sucrose on physical properties of lotus stem starch. *International journal of food science*, *2014*.

[23] Chen, H. H. Wang, Y. S. Leng, Y. Zhao, Y. & Zhao, X. (2014). Effect of NaCl and sugar on physicochemical properties of flaxseed polysaccharide-potato starch complexes. *Science Asia*, *40*(1), 60-68.

[24] Chaisawang, M. & Suphantharika, M. (2006). Pasting and rheological properties of native and anionic tapioca starches as modified by guar gum and xanthan gum. *Food Hydrocolloids*, *20*(5), 641-649.

[25] Chao, C. Yu, J. Wang, S. Copeland, L. & Wang, S. (2018). Mechanisms underlying the

formation of complexes between maize starch and lipids. *Journal of agricultural and food chemistry*, *66*(1), 272-278.

[26] Koo, S. H. Lee, K. Y. & Lee, H. G. (2010). Effect of cross-linking on the physicochemical and physiological properties of corn starch. *Food hydrocolloids*, *24*(6-7), 619-625.

[27] Nagano, T. Tamaki, E. & Funami, T. (2008). Influence of guar gum on granule morphologies and rheological properties of maize starch. *Carbohydrate Polymers*, *72*(1), 95-101.

[28] Morikawa, K. & Nishinari, K. (2000). Effects of concentration dependence of retrogradation behaviour of dispersions for native and chemically modified potato starch. *Food Hydrocolloids*, *14*(4), 395-401.

[29] Wang, B. Wang, L. J. Li, D. Özkan, N. Li, S. J. & Mao, Z. H. (2009). Rheological properties of waxy maize starch and xanthan gum mixtures in the presence of sucrose. *Carbohydrate Polymers*, *77*(3), 472-481.

[30] Kashyap, P. & Jindal, N. (2019). Effect of date syrup on physicochemical, pasting, textural, rheological and morphological properties of sweet potato starch. *Journal of Food Measurement and Characterization.* 13(3): 2398-2405.

[31] Von Borries-Medrano , E. Jaime-Fonseca , M. R. & Aguilar-Mendez , M. A. (2019). Tapioca starch-galactomannan systems: Comparative studies of rheological and textural properties.*International journal of biological macromolecules*, *122*, 1173-1183.

[32] Pongsawatmanit, R. Temsiripong, T. & Suwonsichon, T. (2007). Thermal and rheological properties of tapioca starch and xyloglucan mixtures in the presence of sucrose. *Food research international*, *40*(2), 239-248.

[33] Lopez-Silva, M. Bello-Perez, L. A. Agama-Acevedo, E. & Alvarez-Ramirez, J. (2019). Effect of amylose content in morphological, functional and emulsification properties of OSA modified corn starch. *Food Hydrocolloids*, *97*, 105212.

[34] Li, C. Gong, B. Hu, Y. Liu, X. Guan, X. & Zhang, B. (2020). Combined crystalline, lamellar and granular structural insights into in vitro digestion rate of native starches. Food Hydrocolloids, 105, 105823.

[35] Luckett, C. R. & Wang, Y. J. (2012). Effects of β-amylolysis on the resistant starch formation of debranched corn starches. *Journal of agricultural and food chemistry*, *60*(18), 4751-4757.

[36] Hasjim, J. & Jane, J. L. (2009). Production of resistant starch by extrusion cooking of acid-modified normal-maize starch. *Journal of food science*, *74*(7), C556-C562.

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تاثیر زانتان و ساکارز بر خصوصیات فیزیکوشیمیایی، رئولوژیکی و مورفولوژیکی نشاسته‌های گندم و ذرت

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چکیده

افزایش نیاز به نشاسته در صنایع فرآوری غذایی، سبب توجه به تشخیص تأثیر سایر ترکیبات غذایی بر فرآوری غذاهای مبتنی بر نشاسته شده است. زانتان و قند به ترتیب معمولاً به‌عنوان هیدروکلوئید و شیرین کننده در غذاهایی بر پایه نشاسته مورد استفاده قرار می‌گیرند. این مواد سازنده می‌توانند بر خصوصیات ساختاری، حرارتی، چسبندگی (خمیری) و رئولوژیکی این نوع غذاها تأثیر بگذارند. هدف از این مطالعه، تجزیه و تحلیل نحوه اثر گذاری ساکارز و زانتان بر خصوصیات فیزیکوشیمیایی، رئولوژیکی و مورفولوژیکی خمیرهای نشاسته می‌باشد. بعلاوه، مقایسه تأثیر ترکیب زانتان و ساکارز بر خمیرهای نشاسته ذرت و گندم در این مطالعه به انجام رسیده است . در این پژوهش از غلظت زانتان ۱درصد وزنی و ساکارز ۵درصد وزنی انتخاب شد و مخلوط ها بر پایه نشاسته (ذرت یا نشاسته گندم) تهیه گردید. نتایج نشان داد که در حضور و عدم حضور زانتان یک درصد وزنی و ساکارز ۵ درصد وزنی ، خمیر نشاسته‌ها تفاوت معنی‌داری ازنظر انحلال‌پذیری، قدرت تورم، جذب آب و شفافیت خمیر داشتند ($p < ۰/۰۵$). سنجش‌های رئولوژیکی آشکار کردند که تمام خمیرها رفتار رقیق شونده با برش را نشان دادند. با اضافه کردن زانتان و ساکارز، گرانروی (ویسکوزیته) ظاهری، مدول ذخیره و مدول اتلاف خمیرهای نشاسته افزایش پیدا کرد. طیف‌های مادون‌قرمز تبدیل فوریه، تغییر شدت و طول موج اوج (پیک)های جذب را در اثر افزودن زانتان و ساکارز نشان دادند. سنجش‌های میکروسکوپ الکترونی روبشی و پراش پرتوی ایکس اثبات کردند که در نتیجه افزودن زانتان و ساکارز در حین ژلاتینی شدن، تغییراتی در ساختار شبکه ایجاد گردید .. نتایج این مطالعه می‌تواند به بهبود فرآوری و پیدا کردن شرایط بهینه فرآوری جهت تولید غذاهای بر پایه نشاسته مانند غذای کودک، نان، شیرینی‌های و غیره کمک کند.