

Original Research Article

Effect of dry-heating with pectin on gelatinization properties of sweet potato starch

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Abstract

Purpose: To evaluate the effect of dry-heating with pectin at different dry heating temperatures, heating times and pH on the gelatinization properties of sweet potato starch.

Methods: The gelatinization properties of sweet potato starch - pectin blend were analyzed using a rapid viscosity analyzer (RVA), differential scanning calorimeter (DSC), and gel texture analyzer (TPA).

Results: The viscosity of the blends of sweet potato starches and pectin increased initially, and then decreased. Viscosity was highest at 120 °C, with a value of 744 cp. High viscosity values were also obtained after dry-heating for 2 and 7 h (540 cp and 639 cp, respectively). The enthalpy of the blend declined with increasing heat-treatment temperature from 3.973 J/g at 0 °C to 3.021 J/g at 150 °C. The initial (T_0), peak (T_p), and terminal (T_c) gelatinization temperatures of the blends were all lower than corresponding values at 0 °C. Gelatinization enthalpy values gradually increased with increase in dry-heating time and pH although they were still lower than for the control samples. In addition, as T_0 , T_p , and T_c values of the blend increased, the gelatinization temperature range became narrower. The hardness and viscosity of the blends increased initially, and then decreased after the dry-heat treatment. The hardness of treated samples was higher than that of control, and peaked at 130 °C, 4 h, and pH 11. The resilience of the blends attained a peak value after 2 h of dry-heat treatment at 120 °C and pH 9.

Conclusion: The results show that dry-heating with pectin is an effective way of improving the gelatinization and gel properties of sweet potato starch. This finding is considered significant for the developing of new modified starch from sweet potatoes.

Keywords: Sweet potato starch, Pectin, Dry heat, Gelatinization, Viscosity, Hardness, Enthalpy

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INTRODUCTION

China is the world's largest producer of sweet potatoes, with a total acreage of 42.72 % of total world acreage, and a total annual output of 79.09 million tons, accounting for 80 % of the world's total sweet potato production (FAO) [1]. Sweet potato starch contents can exceed 30%, and its unique properties are widely used in food, pharmaceutical and chemical industries.

Pectin is a natural plant colloid widely used in the food industry and can be used as a gelling agent, stabilizer, tissue-forming agent, emulsifier, and thickener. It is widely used in food. Pectin is nontoxic and is cheap to produce [2-4]. Starch and edible gum are often used together in the health and pharmaceutical industries to improve product quality or to increase product stability [5,6]. A new method used for physical modification of the properties of starches involves dry-heating them (at 120 – 200 °C) with

pectin at moisture contents below 10 %. Dry heat treatment is a promising method for production modified starch: it is simple, safe, and pollution-free, when compared with chemical methods. Dry heat-denatured starch can be used as a raw material for edible film, and may be used as a green packaging material [7–9]. Previous studies have shown that blending starches with edible gum and subjecting them to dry-heat conditions can effectively improve the physical properties of the starches and hence food quality and stability [10,11].

Lim *et al* [11] blended ceraceous corn and potato starches with ionic gums and then subjected the blend to dry-heat treatment (after adjusting the pH). Their results showed that there was a cross-linking reaction between the starches and gum (ascribed to an esterification reaction between carboxyl groups in the food gum and hydroxyl groups in the starches). In another study, Li *et al* [12] carried out *in vitro* simulations to investigate the slow release performance of a blend of pectin and cassava starches (which had been treated with dry heat) within the small intestines of humans. However, there are, at present, no relevant reports on the effect of dry-heating on the gelatinization properties of sweet potato starch blended with pectin.

The present study investigated the effects of factors such as temperature, treatment time, and pH on the viscosity, thermodynamics, and gel properties of the blends of sweet potato starch and pectin subjected to dry-heat treatment.

EXPERIMENTAL

Materials

Sweet potato starch was provided by the Saiwengfu Agriculture Development Limited Company, Shanghai. Pectin was provided by the Tang Ruisi Food Materials Company (Wichita, Kansas, USA). All the other chemicals used were of analytical grade.

Sample preparation

Pectin (1 g) and distilled water (84 mL) were put into a conical flask and stirred until the pectin was completely dissolved. Sweet potato starch (49 g) was then added to the uniformly mixed solution, and the mixture was stirred for 1 h at room temperature (25 °C). The pH was adjusted to 11 using 0.2 M HCl or 1 M NaOH. The solution was then dried at 40 °C in an oven until the moisture content was less than 10 %. The residue was then ground and filtered through a sieve with an aperture size of 0.154 mm so as to

obtain the raw blend of starch and pectin. This dried blend was then dry-heated for 4 h at 130 °C in an oven to obtain the Dry-heat treated sample which was used for further tests.

Evaluation of pasting properties

The determination of viscosity was mainly based on the method of Zeng *et al* [13].

A Rapid Visco-Analyzer (RVA) (RVA-Series 4, Newport Scientific Pty Ltd, Warriewood, Australia) was used. Each starch suspension (7%, w/w; 27 g total weight) was equilibrated at 50 °C for 1 min and then heated to 95 °C and the rate of 6 °C/min and maintained at that temperature for 5 min. The sample was then cooled to 50 °C at a rate of 6 °C/min. A paddle rotating speed of 160 rpm was used (the paddle speed was 960 rpm in the first 10 s).

Differential scanning calorimetry

The thermal properties of the potato starch-pectin blend were determined according to the method of Zeng *et al* [13], but with slight modification, using a differential scanning calorimeter (DSC, TA instruments Waters LLC, New Castle, DE, USA) equipped with a thermal analysis data station. Aluminum pans (Perkin-Elmer) were used for the analysis. Starch samples (1 mg, dried starch basis, dsb) were precisely weighed in the sample pans, mixed with distilled water (2 mg), and sealed. The heating rate was 10 °C per min over a temperature range of 20–100 °C. Indium and zinc were used as reference standards. Enthalpy change (ΔH), gelatinization onset temperature (T_o), peak temperature (T_p), and terminal temperature (T_c) were measured. The data were presented as means of three replicates for each starch sample.

Gel properties

Solutions (7 %) were prepared by adding the required amount of sample to water (2 g). A gel was formed after the solution was gelatinized and cooled for 24 h. The properties of the gel were then determined using a gel texture analyzer (in TPA mode). A P 50 probe was used for these tests (in downstream speed mode) at pre-test, test, and post-test speeds of 1.0, 1.0, and 3.0 mm/s, respectively. The compression ratio and induction force employed were 40 % and auto-5 g, respectively. Tests were conducted at room temperature and the changes in various parameters of the gel (hardness, springiness, gumminess, and chewiness) were assessed.

Statistical analysis

Statistical analysis was carried out using SAS 8.0. All measurements were repeated three times. Statistical analysis was carried out using Duncan and Multiple Range Test. Differences were considered significant at $p < 0.05$. Data were plotted using Origin 8.0 software (OriginLab, Northampton, MA, USA).

RESULTS

Viscoelastic properties

Effect of dry-heat temperature on viscoelastic properties

A series of experiments were made using different heat-treatment temperatures (110, 120, 130, 140, and 150 °C) while the other test conditions were fixed (the treatment time and pH of the blend were 4 h and 11, respectively). The viscosity of the starches was determined in each experiment so that the effect of using different heat-treatment temperatures could be investigated (Figure 1).

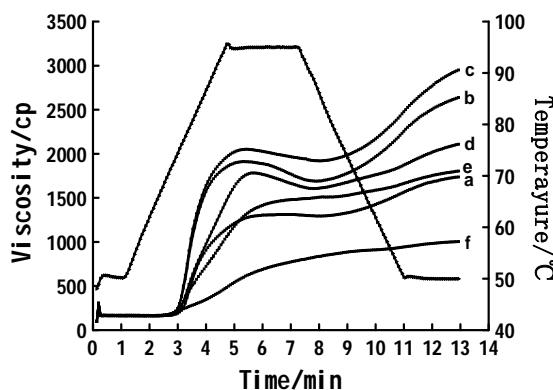


Figure 1: Effect of dry-heat treatment temperature on the RVA spectrum of sweet potato starch. (a = 0 °C; b = 110 °C; c = 120 °C; d = 130 °C; e = 140 °C; f = 150 °C)

The results on Figure 1 show that heat treatment had significant effect on pasting properties of the blends (sweet potato starch and pectin). The peak, trough, and final viscosities of the blend of sweet potato starch and pectin increased initially, and then fell as the dry-heat treatment temperature was increased. The highest viscosity of the blend was formed at 120 °C (744 cP), which was greater than viscosity at 0 °C. The higher viscosity value could be caused by higher degree of energetic collisions between the starch granules and pectin molecules at higher temperature, leading to higher dissolution of these molecules.

The peak, trough, and final viscosities of the blends formed at 150 °C were only half of those observed at 0 °C. This suggests that the water-induced swelling of the starch granules and pectin molecules was inhibited at this temperature, thereby making them difficult to break up. Moreover, the setback values were greater compared with those at 0 °C. This was probably caused by the fact that the forces between the starch and pectin molecules in the amorphous region declined due to the dry-heat treatment. This would result in a loose granular structure, so that the anti-retrogradation of the starches decreased [14]. The breakdown value was closely related to the stability of the starch granules (the greater the breakdown value, the worse the heat stability). The breakdown values after dry-heating at the different temperatures were all higher than that at 0 °C. The peak breakdown value occurred at 110 °C, which indicates that the blend of sweet potato starches and pectin exhibited the worst heat stability at this temperature.

Effect of dry-heat treatment time on the viscoelastic properties

Viscosity of the potato starch-pectin blend was determined at different heat-treatment times (1, 2, 3, 4, and 5 h) while the other test conditions were fixed (the treatment temperature and pH of the blend were 130 °C and 11, respectively). The viscosity of the starches was determined in each experiment so that the effect of using different heat-treatment times could be investigated (Figure 2).

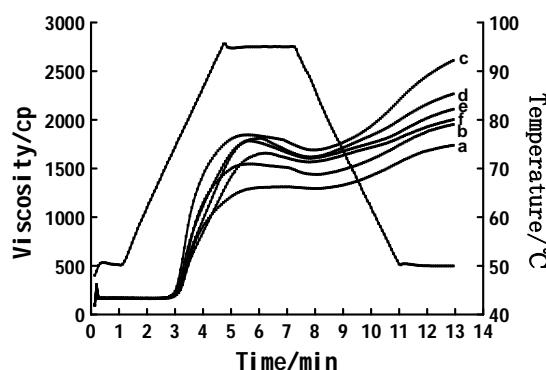


Figure 2: Effect of dry-heat treatment time on the RVA spectrum of sweet potato starch. (a = 0 h; b = 1 h; c = 2 h; d = 3 h; e = 4 h; f = 5 h)

The results shown on Figure 2 indicate that as the dry-heat treatment time increased, the peak, trough, and final viscosity of the blend increased at first, and then decreased. In addition, the viscosities of the blends were higher than that of control (blend that was not heat-treated).

Viscosity reached highest values at 2 h. These results suggest that the sweet potato starch underwent a slight cross-linking reaction with the pectin, and that the cross-linking chemical bonds thus formed promoted the stability of the starch. The water swelling and fracture of the starches were effectively inhibited after 5 h of dry-heat treatment. The breakdown and setback values attained their largest values after dry-heating for 2 h, i.e. the starches were most easily retrograded under these conditions. In addition, gelatinization temperatures increased with time.

Effect of pH on the viscoelastic properties of potato starch-pectin blend

The viscosity of potato starch-pectin blend was studied at different pH values (5, 7, 9, 11, and 13) while other test conditions remained fixed (the treatment temperature and time were 130 °C and 4 h, respectively).

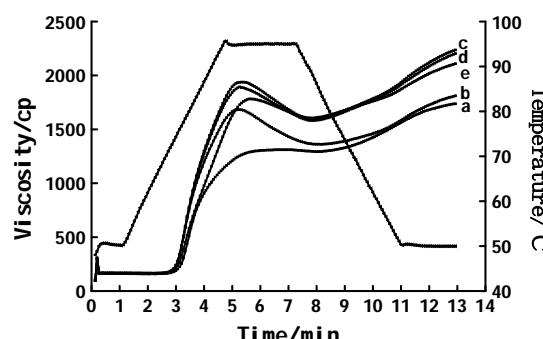


Figure 3: Effect of pH on the RVA spectrum of sweet potato starch. (a = control sample; b = pH 5; c = pH 7; d = pH 9; e = pH 11)

Dry-heat treatment had significant effects on pasting properties of the blends. The peak, trough, and final viscosities of the blends under dry-heating treatment were increased as a function of pH, when compared to corresponding values for control sample. The results indicate that sweet potato starch underwent cross-linking reaction with pectin under acidic and alkaline conditions. At pH 5, the peak viscosity was 1,678 cP, which was lower than that obtained at other pH values. This is due to the fact that partial

hydrolysis and degradation of the starch occur at acidic pH, a process which blocks the cross-linking reaction [15]. At pH 7, the viscosity of the blend was higher than that obtained at any other pH value, because hydrolysis and degradation of the starches do not readily occur at this pH. The hydroxyl groups of the starches are activated, allowing them to easily form cross-links chemical bonds with the pectin molecules. With increasing pH, the breakdown value gradually decreases, i.e. the gelatinization of the starches is effectively inhibited. However, in strongly alkaline conditions (pH 13) starch gelatinization occurs, so that it is difficult to determine viscosity of the starch.

Thermal characteristics

Effect of dry-heat treatment temperature on the thermal characteristics

The effect of dry heat treatment on the thermal characteristics of the blend was studied at different temperatures (110, 120, 130, 140 and 150 °C) while other test conditions remained unchanged (the treatment time and pH of the blend were 4 h and 11, respectively). The results obtained are shown on Table 1.

The gelatinization transition temperatures (T_o , T_p and T_c), gelatinization temperature range ($T_o - T_c$), and the gelatinization enthalpy (ΔH) of the starch-pectin blend are summarized in Table 1. The initial, peak and terminal gelatinization temperature (T_o , T_p and T_c respectively) of the blends decreased with the increases in temperature of dry-heat treatment. Moreover, the temperature range over which gelatinization occurred did not increase appreciably. The internal structure of the starch was reorganized due to the dry-heat treatment, while the double helices of the amylopectin became unwound, resulting in starches with loose granular structure. In addition, the binding forces within the crystals became weakened so that the starch chains shortened, while the gelatinization temperatures and gelatinization enthalpy decreased [16].

Table 1: Effect of dry-heat treatment temperature on the thermal properties of sweet potato starch

Variable	$\Delta H(J/g)$	$T_o/^\circ C$	$T_p/^\circ C$	$T_c/^\circ C$	$T_o - T_c/^\circ C$
0 °C	3.973±0.03 ^a	62.39±0.06 ^b	70.01±0.00 ^a	79.41±0.27 ^a	17.02
110 °C	3.372±0.12 ^b	62.93±0.15 ^a	69.76±0.00 ^b	79.26±0.16 ^b	16.36
120 °C	3.245±0.03 ^d	61.87±0.09 ^b	69.48±0.00 ^c	78.97±0.21 ^c	17.10
130 °C	3.176±0.14 ^e	61.75±0.14 ^b	69.07±0.00 ^d	78.83±0.11 ^d	17.08
140 °C	3.079±0.05 ^f	61.46±0.07 ^b	68.96±0.00 ^e	78.79±0.04 ^e	17.33
150 °C	3.283±0.11 ^c	61.25±0.11 ^b	68.75±0.00 ^f	78.65±0.17 ^f	17.4

Note: For data in the same column, the same letters represent insignificant differences ($p > 0.05$), while different letters indicate significant differences ($p < 0.05$)

Effect of dry-heat treatment time on thermal characteristics

The effect of different heat treatment times (1, 2, 3, 4 and 5 h) on some thermal characteristics of the potato starch-pectin blend was investigated while other test conditions were fixed (treatment temperature and pH of the blend were 130 °C and 11, respectively).

As shown in Table 2, T_0 , T_c , and T_p values all increased as the dry-heat treatment time was increased. In addition, T_0 exhibited the most significant change in value after 1 h of dry-heat treatment (T_0 fell by 1.41 °C, when compared with that of the control sample). The gelatinization temperature range becomes narrower with extended heating (from 17.41 °C for 1 h, to 17.08 °C for 4 h). The blends showed higher transition temperatures, lower gelation enthalpy and narrower gelatinization temperature range, when compared with corresponding values of these parameters at 0 °C. These results suggest that, with increase in dry heat treatment time, the crystal region of the sweet potato granules was broadened because of the dry-heat treatment, and the binding forces within the starch granules gradually increased.

Effect of pH on thermal characteristics

The effect of different pH (5, 7, 9, 11 and 13) on some thermal characteristics of the potato starch – pectin blend was investigated while other test

conditions were fixed (treatment temperature and treatment time were fixed at 130 °C and 4 h, respectively).

Results presented on Table 3 indicate that the gelatinization transition temperature (T_0 , and T_c) of the blends decreased with increase in pH of the blends. In addition, Also, T_0 underwent significant change (from 61.04 °C at pH 5, to 61.75 °C at pH 11). Gelatinization enthalpy gradually increased, while the gelatinization temperature range was gradually narrowed down. With progressive increase in pH, the dry-heat treatment lengthened the molecular chains and broadened the crystal region of the sweet potato starch granules. Thus, the binding forces inside the starch granules gradually increased. As a result, the gelatinization temperature and gelatinization enthalpy of the sweet potato starches increased.

Gel properties

Effect of dry-heat treatment temperature on gel properties

The effect of different heat-treatment temperatures (110, 120, 130, 140, and 150 °C) on the gel properties of the potato starch-pectin blend were determined; while the other test conditions remained unchanged (the treatment time and pH of the blend were 4 h and 11, respectively).

Table 2: Effect of dry-heat treatment time on the thermal properties of sweet potato starch

Variable	$\Delta H(J/g)$	$T_0/^\circ C$	$T_p/^\circ C$	$T_d/^\circ C$	$T_0 - T_d/^\circ C$
0 h	3.973±0.03 ^a	62.39±0.06 ^{ab}	70.01±0.00 ^f	79.41±0.27 ^a	17.02
1 h	2.675±0.02 ^e	60.98±0.29 ^{bc}	70.34±0.00 ^e	78.39±0.16 ^f	17.41
2 h	2.814±0.13 ^d	61.24±0.09 ^{ab}	70.68±0.00 ^d	78.59±0.21 ^e	17.35
3 h	3.047±0.11 ^c	61.56±0.14 ^{ab}	70.87±0.00 ^c	78.67±0.11 ^d	17.11
4 h	3.176±0.14 ^d	61.75±0.14 ^{ab}	71.34±0.00 ^b	78.83±0.11 ^c	17.08
5 h	2.820±0.06 ^d	61.83±0.11 ^a	71.45±0.00 ^a	79.01±0.06 ^b	17.18

Table 3: Effect of pH on paste properties of sweet potato starch

Variable	$\Delta H(J/g)$	$T_0/^\circ C$	$T_p/^\circ C$	$T_d/^\circ C$	$T_0 - T_d/^\circ C$
Control	3.973±0.03 ^a	62.39±0.06 ^{ab}	70.01±0.00 ^e	79.41±0.27 ^a	17.02
pH 5	2.548±0.04 ^e	61.04±0.29 ^{ab}	70.96±0.00 ^d	78.37±0.22 ^b	17.33
pH 7	2.691±0.11 ^d	61.28±0.09 ^a	71.04±0.00 ^c	78.48±0.40 ^c	17.20
pH 9	2.874±0.03 ^c	61.53±0.02 ^a	71.25±0.00 ^b	78.65±0.31 ^d	17.12
pH 11	3.176±0.14 ^b	61.75±0.14 ^a	71.34±0.00 ^a	78.83±0.11 ^e	17.08
pH 13*	.	.	.	.	.

*In strongly alkaline conditions gelatinization of the starches occurs, so that the thermal characteristics of the starches could not be determined

Table 4: Effect of dry-heat treatment temperature on the thermal properties of sweet potato starch

Variable	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
0 °C	210±2.81 ^e	0.92±0.02 ^a	0.90±0.01 ^{ab}	190±0.70 ^d	174±2.40 ^d	0.66±0.01 ^a
110 °C	363±2.50 ^c	0.92±0.02 ^a	0.93±0.01 ^a	339±4.84 ^c	308±5.82 ^c	0.67±0.01 ^a
120 °C	396±6.11 ^b	0.94±0.02 ^a	0.94±0.01 ^a	376±5.79 ^b	349±4.16 ^b	0.72±0.02 ^a
130 °C	503±4.14 ^a	0.92±0.03 ^a	0.84±0.01 ^b	420±4.26 ^a	392±5.50 ^a	0.69±0.01 ^a
140 °C	307±1.72 ^d	0.58±0.11 ^b	0.39±0.06 ^c	106±9.47 ^e	64±2.17 ^e	0.26±0.01 ^b
150 °C	106±0.19 ^f	0.42±0.04 ^c	0.27±0.03 ^d	27±0.73 ^f	11±0.82 ^f	0.09±0.02 ^c

Table 5: Effect of dry-heat treatment time on the thermal properties of sweet potato starch

Variable	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
0 h	210±2.81 ^f	0.92±0.02 ^a	0.90±0.01 ^a	190±0.70 ^f	174±2.40 ^e	0.66±0.01 ^a
1 h	312±2.92 ^e	0.92±0.01 ^a	0.90±0.04 ^a	272±5.41 ^d	251±5.36 ^c	0.68±0.02 ^a
2 h	455±4.10 ^c	0.95±0.03 ^a	0.90±0.01 ^a	407±3.34 ^c	393±5.67 ^b	0.72±0.03 ^a
3 h	567±4.55 ^a	0.93±0.02 ^a	0.91±0.03 ^a	525±5.84 ^a	498±2.68 ^a	0.72±0.03 ^a
4 h	503±4.14 ^b	0.92±0.03 ^a	0.84±0.01 ^b	420±4.26 ^b	392±5.50 ^b	0.69±0.01 ^a
5 h	371±3.51 ^d	0.83±0.02 ^b	0.71±0.02 ^c	253±4.51 ^e	206±4.18 ^d	0.59±0.04 ^b

Table 6: Effect of pH on the paste properties of sweet potato starch

Variable	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
A	210±2.81 ^d	0.92±0.02 ^a	0.90±0.01 ^a	190±0.70 ^d	174±2.40 ^d	0.66±0.01 ^a
pH 5	367±4.53 ^c	0.90±0.03 ^a	0.93±0.00 ^a	343±4.65 ^b	315±3.82 ^b	0.70±0.00 ^a
pH 7	363±5.95 ^c	0.91±0.05 ^a	0.92±0.05 ^a	325±2.73 ^c	302±5.79 ^c	0.69±0.07 ^a
pH 9	383±1.89 ^b	0.90±0.00 ^a	0.92±0.01 ^a	348±3.20 ^b	314±4.94 ^b	0.73±0.02 ^a
pH 11	503±4.14 ^a	0.92±0.03 ^a	0.84±0.01 ^b	420±4.26 ^a	392±5.50 ^a	0.69±0.01 ^a
pH 13*	.	.	.	.	.	.

*In strongly alkaline conditions gelatinization of the starches occurs, so that the gel properties of the starches could not be determined

Table 4 shows variations in gel properties of the potato starch-pectin blend with changes in dry-heat treatment temperature. It can be seen that as the dry-heat temperature was gradually increased, there were initial increases in hardness, gumminess, and chewiness of the blend which were followed by decreases in these parameters. The hardness, gumminess, and chewiness attained peak values at 130 °C. Optimal springiness and resilience appeared at 120 °C, but both indices gradually declined with increasing temperature.

Effect of dry-heat treatment time on the gel properties

The results obtained on the effect of dry heat treatment times (1, 2, 3, 4 and 5 h) on gel characteristics of potato starch – pectin blend are shown on Table 5.

The hardness, gumminess, and chewiness of the blends first increased and then decreased with increase in dry-heat treatment time. The highest values for hardness, gumminess, chewiness, and resilience were obtained at 3 h. These results suggest that the forces needed for sample modification are highest under such conditions (the binding forces in the samples are very strong, resilience is very high, so more energy is needed for modification and the resilience is the

best).

Effect of pH on gel properties

Table 6 shows the effect of pH on gel properties of the potato starch – pectin blend at fixed temperature (130 °C) and dry heat treatment period (4 h).

The hardness, gumminess, and chewiness of the blend of sweet potato starches and pectin increased as the pH was increased. The effect of pH on springiness of the blend was least at pH 9, while the best resilience was obtained at this pH.

DISCUSSION

Modified starches have a wide scope of applications. After modification, the starches have improved properties when compared to properties of the native starches. Modification may also confer new and desirable properties on starch. Some investigations have been carried out on the gelatinization properties, rheological behavior and film-forming characteristics of dry heat-modified starches. However, investigation on dry-heat modification of starches using gums have focused mainly on the effects of this treatment on gelatinization. Lim et al [11] blended corn and potato starches with ionic gums under

dry-heat conditions at 130 °C and at different periods of treatment times. They found that the gelatinization viscosity of the blends increased after dry-heat treatment while the transparency of the blends declined. Like cross-linking agents, ionic gums promote esterification between starches and gums. Therefore, this method can be utilized for the preparation of modified starches with specific functions. Chung *et al* [5] studied the effect of xanthan gum on the cross-linking reaction between rice starches and phosphates under dry-heat conditions. Their results showed that xanthan gum was advantageous to the cross-linking reaction. In addition, it was proposed that the viscosity of the starches changed due to breakage of hydrogen bonds between starch molecules during dry-heat treatment, while further heating could result in the breakdown of glucosidic bonds. It has been reported that when rice starches of different amylose contents were significant changes in the gelatinization properties of the starches [16]. Their results also showed that the tensile strength of the basilemma of the modified starches increased, while their oxygen and gas permeabilities declined. In the present study, the effects of dry heat treatment conditions such as temperature, time and pH on the gelatinization, thermodynamics, and gel properties of the dry-heated potato starch-pectin blend were systematically investigated. The results showed the viscosity of the blends increased after dry-heat treatment under different pH values, and at different temperatures and different treatment times. This implies there was extensive cross-linking between the potato starch and pectin. These results are consistent with the findings of Lim *et al* [11] who reported that the viscosity of blends of corn and potato starch with ionic gums increased under dry-heat treatment, while lactide was produced due to the reaction between the starch and pectin. However, the results of the present study are not in agreement with those of Yuan *et al* who found that (that the peak the peak values of viscosity and retrogradation of a blend of edible gums and corn starches decreased after dry-heat treatment while the gelatinization temperature of the starches increased.

CONCLUSION

The results obtained in this study demonstrate that the gelatinization properties of a blend of potato starch and pectin are influenced by dry-heat treatment. In particular, decreases in breakdown and setback values indicate that dry-heat modification with pectin enhances the stability of the starch. The results suggest that the internal structure of the starch is reorganized by the treatment, resulting in broadening of the

crystal region of the starch granules, and increase in the enthalpy and intermolecular binding forces as a function of increases in time and pH. Dry-heat modification with pectin enhances the hardness, gumminess, and chewiness of sweet potato starch. These results are considered significant in that they provide a theoretical basis for improving the functional performance of starches, especially in the deep processing of sweet potato starch.

DECLARATIONS

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Conflict of Interest

No conflict of interest associated with this work.

Contribution of Authors

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them.

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