Some physicochemical properties of tapioca starch during infrared heat treatment

P Uraives and P Choomjaihan

1Agricultural Engineering Department, Faculty of Engineering, King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand

E-mail: prasan.ch@kmitl.ac.th

Abstract. Applying infrared radiation heat treatment is an alternative production process of modified starch. The infrared radiation heat treatment for modifying tapioca starch was set at 170, 190 and 210 °C. The properties of starch including swelling power, total color difference and blue value were determined every 2 h until 20 h of heating. The results showed that increasing the heating temperature and time decreased the blue value of starch-iodine complex. Meanwhile, the swelling power and total color difference increased with the heating temperature and time.

1. Introduction

Infrared radiation (IR) heating has been widely used in agricultural and food products because it has variety of advantage, for instance, reduced drying time, alternative energy source, clean working. Moreover, the beneficial of IR compared with convection heating is higher heat transfer coefficient and lower cost of energy [1, 2]. Additionally, some agricultural materials dried using heat source as IR change some chemical properties such as decreasing in apparent amylose content and pH in chestnut starch [3] and IR heating increasing the extraction rate of anti-oxidant such as increasing amount of curcumin in IR dried turmeric [4] and also increasing lipid peroxidation and phenol contents of rice hull [5].

Dextrin was one type of modified starch hydrolyzed by enzymes with acid, heat or acid with heat in mixing container, heated by steamed or oil jackets. The different conditions of temperatures, times and catalyst agents allow producing three different types of dextrin (white dextrin, yellow dextrin and British gums). Principally, the properties of dextrin are less viscosity and solubility in cold water. Dextrin, then, has been used in food, textile, paper, foundry, mining industries and so on. Dextrin is also suitable for being the component of pill due to its seizing property. Solubility property is used to add in soup powder for improving the solubility and stickiness, while retrogradation property is used as liquid glue behind stamps [6, 7].

Mostly, the dextrin production has used convection and conduction of heat to heat the starch and dextrin properties have been examined. However, some dextrin properties (microstructure, viscosity, solubility and total soluble solid content) using IR heating for dextrin production has been studied by Uraives and Choomjaihan [8]; nevertheless, there are still more properties has not extensively studied such as swelling power, total color difference and blue value. Therefore, the purposes were to study the effect of infrared heating (temperature and time) on changes in some properties that may be important for dextrin production.
2. Materials and methods

2.1. Materials
Tapioca starch samples were obtained from ‘Thai-Tam’ factory, Chonburi, Thailand. The initial moisture content of tapioca starch was 12.17±0.45% dry basis.

2.2. Infrared heat treatment on dextrin production
The starch heat treatment stainless steel chamber was designed in cylindrical shape with the diameter of 0.5 m and 0.6 m in length. Potentiometer and timer switch were used to control speed and time of rotational. 5 kg of tapioca starch samples were heated by ceramic infrared heater (0.45 m in length) which was installing inside the chamber. The temperatures were controlled by microcontroller to ensure the power supplied to ceramic infrared heater were 1100, 1320 and 1540 watts for generating three heating temperatures of 170, 190 and 210°C, respectively. Starch samples were heated for 20 h and were randomly collected for measuring its properties every 2 h. Experimental diagram was showed in figure1.

2.3. Swelling power measurement
The swelling power (SP) was determined by applied method of Dubois et al. [9]. Starch solutions (1% weight/weight) were prepared in graduated centrifuge tubes. The starch solution samples were placed in a water bath heated at 90°C while gently shaking until being gelatinization. The gelatinized samples were held at in 90°C water bath for 30 min. The samples were cooled to ambient temperature, then centrifuged at 5000×g for 30 min. After centrifuging, the supernatant was removed from sediment and filled in metal dish. Supernatant was, then, dried at 105°C for 1 h. The weight of dry supernatant was used for calculating the solubility (Sol) by using equation (1). The weight of sediment was used for calculating the swelling power by using equation (2).

\[
Sol (\%) = \frac{weight\ of\ dry\ supernatant \times 100}{weight\ of\ starch\ sample}
\]  

\[
SP (\text{g/g}) = \frac{weight\ of\ sediment \times 100}{weight\ of\ starch\ sample \times (100 - Sol)}
\]
2.4. Total color difference
The color of the sample was measured using CIE color scale by Hunter Lab, MiniScan, XE Plus. The color indexes of Lightness (L*), Redness (a*) and Yellowness (b*) were collected for 3 replications. L* = 100 represent white and L* = 0 for black, +a* represent red and a* for green and +b* represent yellow and b* for blue. The total color difference (TCD) was calculated by equation (3) where Lt*, at* and bt* are the values of treated starch and L0*, a0* and b0* are the values of native starch, respectively.

\[ TCD = \sqrt{(L_t^* - L_0^*)^2 + (a_t^* - a_0^*)^2 + (b_t^* - b_0^*)^2} \]  

(3)

2.5. Blue value
Blue value of starch was determined by method of Gilbert and Spragg [10]. A 0.1 of tapioca starch was weighed into a boiling tube and 10 ml of distilled water was added, the solution was then heated in water bath for 10 min. Then made volume up to mark in 100 ml volumetric flask. 1 ml of 1 M of acetic acid was taken in 5 ml of starch solution. Followed by 0.2 g I2/2.0 g KI/100 ml of stock iodine for 2 ml. Then made up to 100 ml in standard flask with distilled water. The solution was left for 20 min for fully developed color. The absorbance was monitored at 620 nm with a Thermo Scientific™ GENESYS 10S UV-Vis spectrophotometer. The pure iodine solution of same concentration was used in the reference cell. The blue value of the heated tapioca starch at various temperatures was calculated by using equation (4).

\[ BV = \frac{\text{absorbance} \times 4}{\text{concentration (mg/dl)}} \]  

(4)

3. Results and discussions
3.1. Changing of swelling power during infrared heat treatment
The water holding capacity of starch was indicated by swelling power to describe the difference between various types of starch [11]. Swelling volume is the ratio of the sediment gel and the dry weight of starch. Figure 2 show the increasing value of swelling power of heated treatment starch. Swelling power of unheated starch was 23.84±0.96 g/g and continuously increased by heat treatment at all temperatures. At 20 h of heat treatment, the swelling powers were 35.81±0.57, 50.38±1.67 and 56.50±1.08 g/g by infrared heating at temperatures 170, 190 and 210 °C, respectively. Moorthy [12] reported the swelling power of tapioca starch was vary from 42 to 71 (g/g).

![Figure 2. Swelling power of tapioca starch with standard deviation error bars during IR heat treatment.](image-url)
Heat treatment increased a swelling power because starch granules become weakened and the bonds between starch molecules become distorted. The result of this effect made water molecules become more contact to molecules of starch leading to a higher water uptake [11]. The result of infrared heat treatment disruption on granules was described by the higher swelling power. The impact on starch granule disintegration is the breaking of crystalline molecular structure and the disruption on covalent bonds of tapioca starch [13]. Alam and Abid [14] showed the swelling power of heated moisture Taro starch was increased with increasing heating temperature. Timothy and Abigail [15] also reported the swelling power of soaked ogi powder increased with increase in temperature of drying temperature.

3.2. Changing of color during infrared heat treatment

L*, a* and b* of native starch were 95.49±1.12, -0.28±0.01 and 2.05±0.10, respectively. Figure 3 showed time and temperature were affected to the changing of starch color. Heating temperature at 210 °C for 20 h gave the most change of total color difference 12.30±0.40, 15.70±0.22 and 20.08±0.89 for 170, 190 and 210 °C, respectively.

![Figure 3. Total color difference of tapioca starch with standard deviation error bars during IR heat treatment](image)

![Figure 4. Lightness of tapioca starch with standard deviation error bars during IR heat treatment](image)
Figure 4-6 show the effect of infrared heat treatment on L*, a* and b* values at various conditions. The changing of L* by heat treatment at various temperatures were indicated by the darker color of starch samples from unheated starch. L* values of tapioca starch at 170, 190 and 210°C of heating temperature for 20 h of heat treatment decreased to 83.39±0.01, 80.61±0.24 and 80.19±1.12, respectively. Therefore, a slight increase in a* was indicated by minus to plus of a* values. At 20 h heat treatment of tapioca starch at 170, 190 and 210°C of heating temperature were 0.50±0.02, 0.51±0.02 and 0.54±0.01, respectively.

An increasing of b* component was also observed during heat treatment. This was indicated by positive value where b* values at 20 h heat treatment of tapioca starch at 170, 190 and 210°C of heating temperature were 4.08±0.02, 6.97±0.04 and 14.99±0.45 respectively.

The changing on color of starch during the heat treatment was the effect of “Maillard” reaction that is one type of non-enzymatic browning. Buckholz et.al [16] described “Maillard reaction involves a reaction between the carbonyl group of a reducing sugar with a free, uncharged amine group of an amino acid or protein with the loss of mole of water”. Sarifudin and Assiry [17] reported extrusion at 134.67°C with 70.3 rpm of screw speed was changed value of L*, a* and b* from 97.52, -0.53 and 5.34 of native starch to 83.57, 0.64 and 14.13, respectively. The changing of color of dextrin was also
studied by Ueno et al. [18], the conventional roasting at 190°C for 4-8 h was turn starch from white to yellow. Greenwood [19] heated starch at 150 to 220°C for 6 to 18 h with acidic catalysts, the result showed the color of dextrin appear yellow to brownish.

3.3. Blue value of starch-iodine complex
Starches contain two polysaccharide components, amylose and amyllopectin. Amylose consists of a straight chain which has a strong affinity for iodine. Amylose forms a helical structure with wide central cavity. The cavity provides enough space to accommodate iodine atoms and gives a deep blue complex. The helical structure of amylose line up to produce a linear polyiodide, a chain length also observed deeply colored due to the presence of polyiodide. Amylopectin which consists of a branched chain has little affinity for iodine and gives a red color [20].

![Figure 7. Blue value of tapioca starch with standard deviation error bars during IR heat treatment](image)

Figure 7 shows the blue value of starch-iodine complex. The blue value of unheated starch was 0.295±0.001. The blue value was tending to decrease while increasing of heating time and temperature. At 20 h of heating time, the blue value of 170, 190 and 210 °C were 0.230±0.004, 0.201±0.001 and 0.165±0.004, respectively. Louis and Gabriel [21] reported the blue value of native tapioca starch was 0.375 and also reported increased starch derivatization by carboxymethylation and cyanoethylation methods reduced amylose ability to bind iodine that decreased the blue value to 0.159 and 0.127, respectively. As the starch properties depend on the crystalline structure, it is assumed that weaker amyllopectin and amylose of structures in tapioca starches are easily destroyed by heating. The chain length of amylose was disrupted by heat treatment is the cause of shorter helical structure of amylose. Decreasing of blue value as a result of amylose produces less linear polyiodide. This affects gelatinization properties of starch and effect to the use of starches industrially especially in adhesives, binders and other end-use products [22, 23].

4. Conclusions
IR was used to modify tapioca starch instead of dry heat process of British gums. Swelling power, total color differences and blue value were monitoring during IR heat treatment. The results showed swelling power and total color different were increased when increased time and temperature heat treatment while blue value of was decreased. At 20 h with 210°C of heating temperature gave the most change for every parameter. The higher of swelling power and lower of blue value with indicated a higher solubility in water of modified starch that has been used as adhesive in paper, carton and packaging industry.
5. References

[1] Krishnamurthy K, Khurana H K, Jun S, Irudayaraj J, and Demicri A 2009 Food Processing Operations Modeling Design and Analysis Food Science and Technology Series 2nd ed (Boca Raton FL: CRC Press) 13-142

[2] Nowak D and Lewicki P P 2004 Innovative Food Science and Emerging Technologies 5 353-360

[3] Umar S, Adil G, Bilal A, Asima S, Idrees A and Farooq A 2016 International Journal of Biological Macromolecules 84 166-173

[4] Saetan P, Pratinthong N and Swasdisevi T 2013 TSAE International Conference 6 123-126

[5] Seung C, Jeong H, Seok M, Dong R, Jung U, Nam K C and Ahn D U 2003 Journal of Agricultural and Food Chemistry 51(15) 4400-4403

[6] Radley J A 1976 Industrial Uses of Starch and its Derivatives (Netherland: Springer Science and Business Media)

[7] Whistler R L, BeMiller J N and Paschall E F 1984 Starch: Chemistry and technology 2nd ed (Orlando Florida: Academic Press)

[8] Uraives P and Choomjaihan P 2016 TSAE Journal 22 17-23

[9] Dubois M, Gilles K A, Hamilton J K, Rebers P A and Smith F 1956 Analytical Chemistry 28 350–356

[10] Gilbert G and Spragg S 1964 Methods in Carbohydrate Chemistry (Orlando Florida: Academic Press) 168–169

[11] Gunaratne A and Corke H 2007 Cereal Chemistry 84(1) 30-37

[12] Moorthy S N 2002 A Review Starch 5 559-592

[13] Jambrik A R, Herceg Z, Šubarić D, Babić J, Brnčić M, Brnčić S R, Bosiljkov T, Čvek D, Tripalo B and Gelo J 2010 Carbohydrate Polymers 79 91

[14] Alam F and Abid H 2009 Agriculturae Conspectus Scientificus 74 45-50

[15] Timothy B O and Abigail O O 2017 Annals. Food Science and Technology 18 20-28

[16] Buckholz L, Daun H and Stier E 1980 Journal of Food Science 45 547-554

[17] Sarifudin A and Assiry A M 2014 Journal of the Saudi Society of Agricultural Sciences 13 100-106

[18] Ueno Y Izumi M and Kato S 1976 Staerke 28 77–83

[19] Greenwood C T 1967 Advances in Carbohydrate Chemistry 22 483–515

[20] Saenger W 1984 Naturwissenschaften 71 31–36

[21] Louis N and Gabriel O 2014 African Journal of Pure and Applied Chemistry 8 89-93

[22] Bailey J M and Whelan W J 1961 Journal of Biological Chemistry 236(4) 969-973

[23] Van H P, Maeda T and Morita N 2007 Starch/Stärke 59 125-131

Acknowledgements

The author wishes to acknowledge the Department of Agricultural Engineering, Faculty of Engineering, King Mongkut’s Institute of Technology Ladkrabang for location and equipment for experiment.