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Effect of temperature and time treatment of Ultrasound-assisted extraction on the properties of bengkoang water-soluble polysaccharides

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Abstract. Zero Hunger as the SDG program aims to prevent global need with innovation to exploit and promote local food uses of all available underutilized food crops. A water-soluble polysaccharide is included in bengkoang (*Pachyrhizus erosus*) soluble fibres. Previous studies reported that ultrasound-assisted extraction impacts starch depending on several factors such as temperatures and times. The research aims to obtain bengkoang oligosaccharide compounds by ultrasound-assisted extraction with different treatment of temperatures and times. The results of the moisture degree were decreasing the moisture degree might be attributed to the increasing temperature and time treatment of ultrasound-assisted extraction. It increases the water absorption capacity of the modified starch by sonication and is also related to the size of the starch granules. The results of the FTIR graph test show that some of the granules have cracks and small depressions on the surface that are visible in the middle and corners after being treated with sonication. The results of the morphological observation show that after treatment of sonication in water appear minor cracks and scratches. Some water-soluble polysaccharide granules are transformed into gelatinization form that makes granule shape irregular and has small visible cracks in the central part.

1 Introduction

The Food of Agriculture Organization (FAO) job desk reviews the worldwide food systems within the Zero Hunger as one of the Sustainable Development Goals (SDG). The United Nations adopted it (U.N.) General Assembly in 2015. Zero Hunger's second SDG program

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aims to prevent prolonged global desire, manage the food security system, and encourage sustainable and integrated agriculture. Precisely, the integration of objects on sustainable agricultural technology in the overall effort to complete need represents a long-overdue recognition that industrial and agricultural technology threatens critical schemes on food production industrial [1]. FAO's annual report depicts decreasing the number of a hunger people globally, and it is frequently in a pandemic of the COVID-19. Starvation has been rising globally in several countries. So, it causes the undernourishment of millions of our civilization. The present research on Hunger in developing countries requires development effort and innovation to exploit and promote other local food uses of all available underutilized food crops. Most of Indonesia's local crops are indigenous under external factors like local weather, chemical, and land physic [2].

Today, food science has developed globally by raising the potential local foods to add health value and identify properties of local foods as functional food. The prebiotics, an active food compound, such as Inulin and oligosaccharides, are obtained from natural sources of local foods like bengkoang (*Pachyrhizus erosus*). [3] shows that bengkoang water-soluble polysaccharide granules can encourage ultrasound-assisted extraction (37 kHz; 60ºC; 30 min) as a prebiotic compound. Other studies [4] reported that the bengkoang extracted method could develop by the solvent of hot water and precipitation with ethanol to produce water-soluble polysaccharides. The treatment of sonication is part of the physical technique of the starch modification method at present. Moreover, It always used on either native starch granules suspended in solution or on modified starch.

Previous studies [5] reported that the ultrasounds-assisted extraction impact on starch granules depends on the treatment of temperature and time, sonication power and frequency, and properties of the starch. In some cases, sonication leads to a physical degradation effect for native starch granules. According to [6,7], sonication treatment of grains and vegetables such as corn, oat, wheat, rice, and potato starches in water solution lead to changes in the functional attribute and porosity of granules. This study investigated the characteristics of the bengkoang water-soluble polysaccharide granules with sonication treatment at different temperatures and times.

2 Materials and method

The material of Bengkoang (*Pachyrhizus erosus L*) was harvested in ten months, and originality was obtained from Bhakti Karya village, Binjai Selatan district, North Sumatra, by a variety of Bengkuang Gajah. The analytical method was provided with water, morphological properties, functional group, and inulin content.

2.1 Extraction of Bengkoang water-soluble polysaccharides

It starts with bengkoang water-soluble polysaccharides was extracted from fresh bengkoang with modification method [3,4]. Bengkoang was washed at first, peeled the skin, and cut into small shapes. Then it was suspended in water (1:2) to be a puree using a blender. The purees were suspended in distilled water (1:1) and treated with sonication water bath Elmasonic S10H (Elma, Germany) at 60ºC for 30 min (37 kHz). Then, the purees were strained by a cloth filter double-layered to obtain a bengkoang filtrate.

Moreover, the crude fibre from the cloth layered was removed, and the bengkoang filtrate was treated with ultrasound extraction at temperature T1 (60 ºC), T2 (80 ºC), and time P1 (60 min), P2 (120 min). The filtrate was separated to obtain a pure compound and precipitated by ethanol 80% in 40% of volume. The solutions were stored at -20 ºC for 12 h and thawed to isolate supernatant and natant fractions. The natant particles were dried at 4 ºC for 12 h, crushed, and sieved by an 80 mesh sieve-shaker to obtain the bengkoang water-soluble polysaccharide granules. The functional group was assessed with FTIR and morphological properties with SEM.

2.2 Moisture Degree

The samples were weighed at 1-2 g, transferred to a plate, and dried in an oven (105°C) until constant weight. The pieces dried in range (105°C) for 3-5 h and cooled off in a desiccator. Then the plates were weighed and heated more time in the oven for 30 min. This treatment was repeated to reach stable values.

2.3 SEM observation

The Hitachi SU3500 N series (Japan) was a type of Scanned Electron Microscope equipment used to observe the morphological properties of bengkoang water-soluble polysaccharide granules at an accelerating potential of 5 kV. They were coated using a sputter coater with a thin gold film.

2.4 FTIR

A functional group analyzer (FTIR) was performed by using Thermo Scientific Nicolet iS5 (USA). Characterization of FTIR aimed to determine an active group of bengkoang water-soluble polysaccharide granules. The powder samples were performed on a film sheet. All the pieces were scanned at a transmittance of the frequency range in 4000–400 cm^{-1}.

2.5 Inulin Content

Preparation sample- samples (0.1 g) were measured and transferred into volumetric flasks (10 mL). Then samples were suspended in a hot distilled aquadest at 60-70°C. The solutions were treated with ultrasound for 5 min and filtered on a 0.45 μm millipore membrane to obtain an original compound (transparent). A 1.0 mL Filtrate was transferred into a volumetric flask (50.0 mL) and diluted with the mobile phase.
Preliminary of standard solution- stock solution of inulin standard (10 mg/mL) was suspended in hot water and dilute to be a standard solution containing 0.5; 1.0; 1.5; 2.0; 2.5; 3.0 mg/mL for the stock standard solution.
HPLC- The inulin content was measured by HPLC Agilent 1260 Infinity II (USA) with HPX-87C Aminex Ion-Exclusion (250mm x 4mm) column and detector of refractive index (RID). A mobile phase used distilled aquades with flow rate speed (0.5 ml/min), injection volume (20 μl), column temperature (60°C), and detector temperature (40°C).

3 Results and discussions

3.1 Moisture Degree determination

Moisture degree is the total amount of water in a product. It can affect physical properties, including weight, density, water absorption, and others. The method of calculating the moisture content is to be determined by weight loss during drying. In this study, the moisture degree of water-soluble polysaccharides (WSP) of bengkoang was carried out from [3] as a standard, and the treatment with ultrasound at temperature T1 (60 ºC), T2 (80 ºC), and time P1 (60 min), P2 (120 min) can be seen in Fig 1.

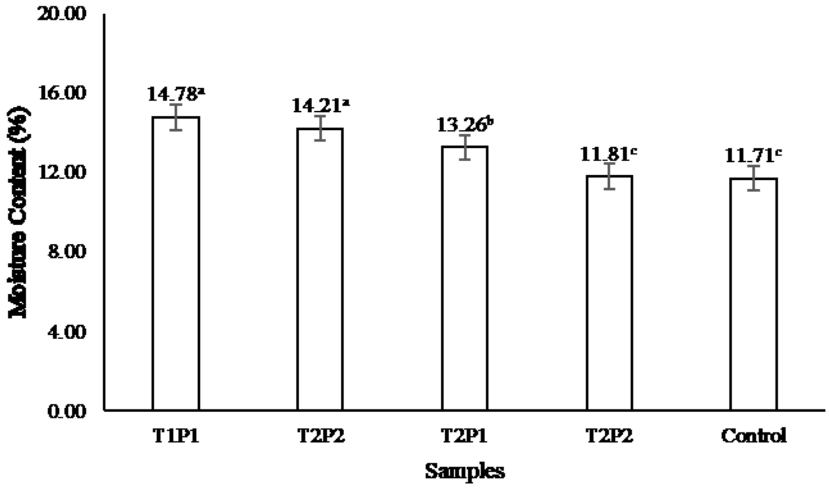


Fig. 1. The moisture content of bengkoang WSP with ultrasound treatment

Decreasing the moisture degree might be attributed to the increasing temperature and time treatment of ultrasound-assisted extraction. Moreover, it increases the water absorption capacity of the sonicated starch and is also related to the size of the starch granules [9].

3.2 Morphology of bengkoang water-soluble polysaccharide

Morphological properties observation of bengkoang water-soluble polysaccharide granules can see the shape and size of the granules in three dimensions using Scanning Electron Microscopy (SEM). The observation results with SEM for native starch of bengkoang can be seen in Fig. 2.

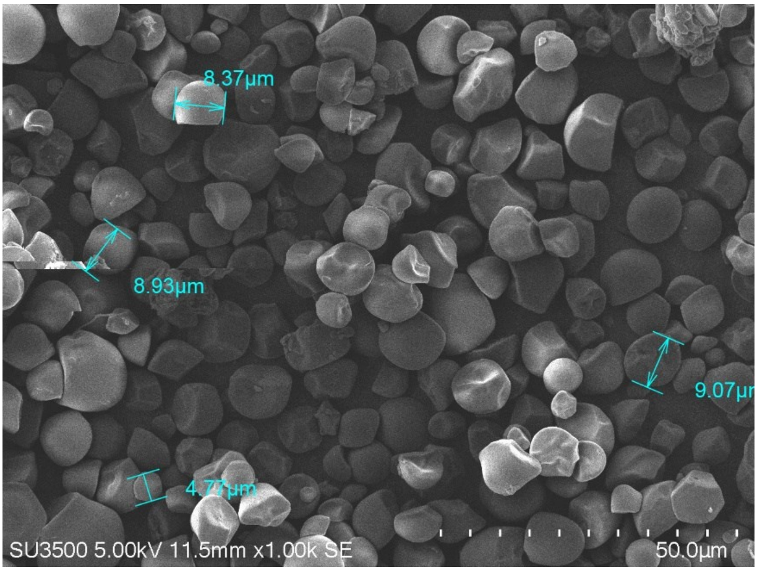


Fig. 2. SEM micrographs of native starch of bengkoang granule.

According to Fig. 2, it showed that the shape and size of native starch of bengkoang granule are the same as that of corn, namely round and polygonal, and the surface is uneven, although there are some smooth surfaces with a diameter of about 3–20 µm. SEM micrographs of water-soluble polysaccharide granules after modification with ultrasounds in water are presented in Fig. 3.

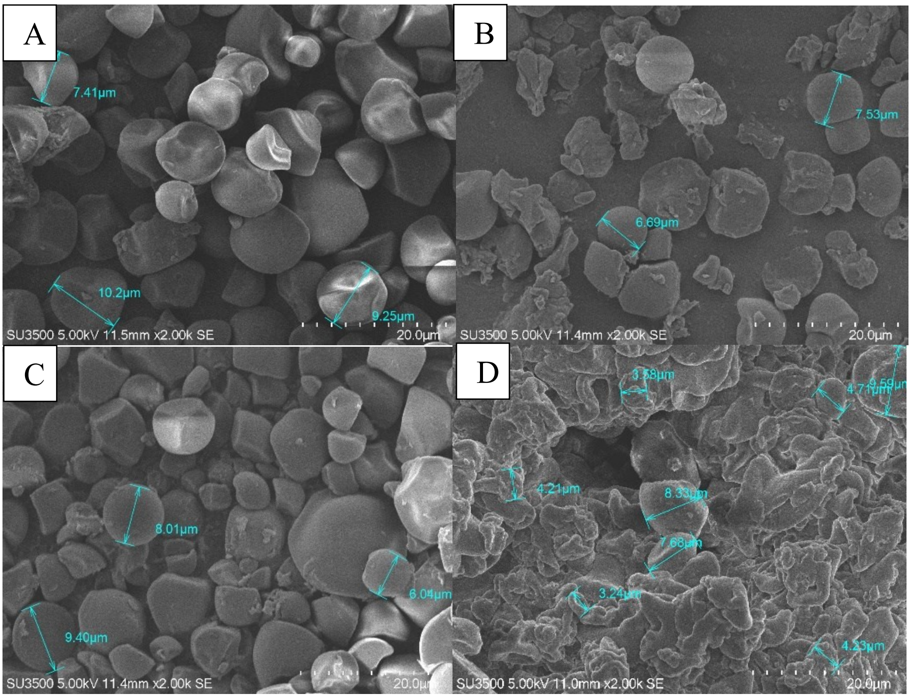


Fig. 3. SEM micrographs of bengkoang water-soluble polysaccharide granules with the treatment of temperature and time – A (T1P1), B (T1P2), C (T2P1), and D (T2P2).

Some of bengkoang water-soluble polysaccharide granules had small visible cracks in the central part. After treatment with ultrasounds, some granules showed small fissures and depressions on the surface, especially in water. The research of [6,7,8] showed that the sonication technique could give scars and increase the formation of granules to become porous so that they have a higher absorption capacity. After sonication in water, numerous cracks and scratches could be observed on bengkoang water-soluble polysaccharide granules (Fig. 3A and C). Meanwhile, some water-soluble polysaccharide granules are transformed into gelatinization form that makes granule shape irregular (Fig. 3B and D). This phenomenon occurs due to the length of time used for sonication. Although actually at a temperature of 60 ºC, the bengkoang water-soluble polysaccharide granules (Fig. 3B) can still be identified. Another critical factor is the formation of gas bubbles in the suspension medium, which bombard the bengkoang water-soluble polysaccharide granules called cavitation. The rapidly bursting bubbles can also create forces that can break the chains of polymers such as starch so that the sonication technique works by damaging the plant cell wall to facilitate the release of the extracted compound and increase the mass transfer of solvent from the continuous phase into the plant cell [10].

3.3 Functional group of bengkoang water-soluble polysaccharide

The chemical structure of bengkoang water-soluble polysaccharide granules was studied with FTIR characteristics using FTIR (Thermo Scientific, USA) with a long-range (4000-400 cm^{-1}) resolution of 4 cm^{-1}. Fig. 4 shows the FTIR graph spectrum of the bengkoang water-soluble polysaccharide granules, sonicated with sonication time and heating temperature treatment. All FTIR charts show a similar pattern. Sonication does not result in the emergence of new functional groups but can shift the intensity of the transmission pattern.

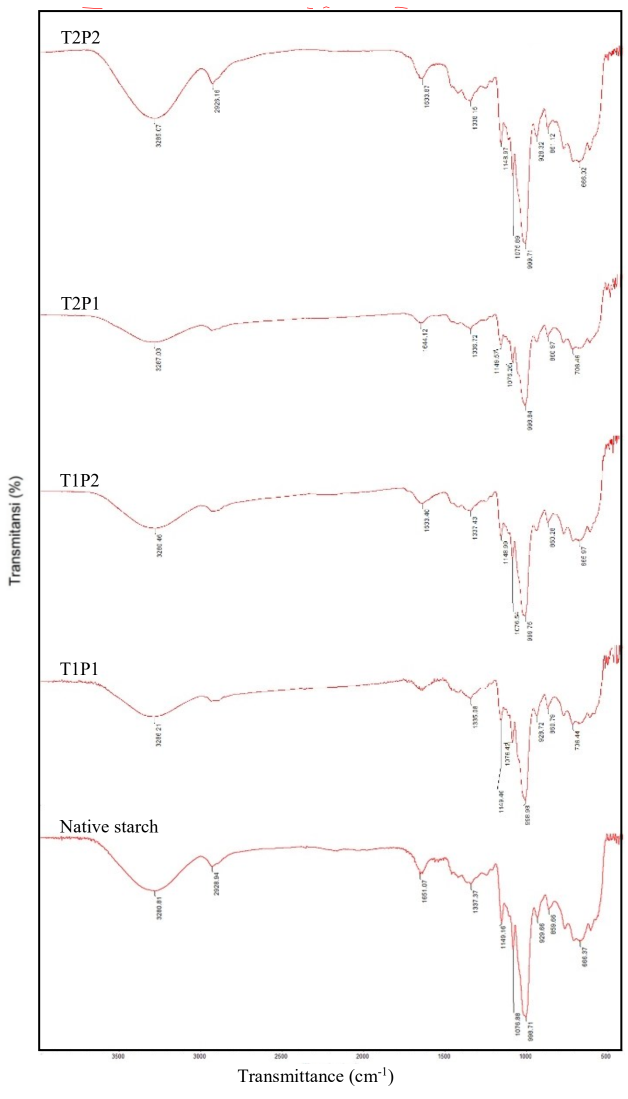


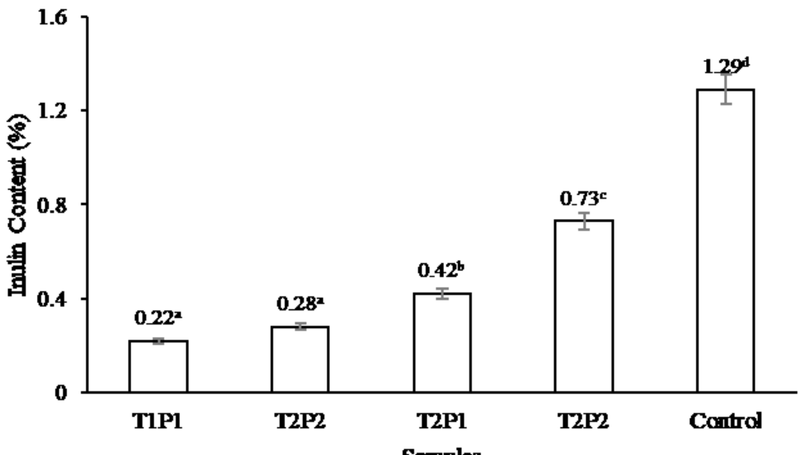
Fig. 4. FTIR graph spectrum of the bengkoang water-soluble polysaccharide granules

A peak from Fig. 4 at a wavenumber of cm^{-1} indicates the stretching of the (-O.H.) group in all of bengkoang water-soluble polysaccharide granules. It can be seen that the curve on the FTIR graph widens in almost all samples in that wave [11]. It indicated an excellent formation of hydrogen bonds in the bengkoang water-soluble polysaccharide granules treated with a certain length of sonication time and temperature. After being treated with a particular sonication time and temperature, the wavenumber shifted to a minor direction. So, the other wavenumbers identified around 2900 cm^{-1}. This wave number indicates the vibration of the functional group from C-H [12]. The water absorption active group is 1640 cm^{-1} in the area. Almost all samples of water-soluble polysaccharides showed peak water absorption. The figure shows that on the FTIR graph, bengkoang water-soluble polysaccharide granules with a temperature treatment of 60 ºC and a sonication time of 60 min have the lowest transmittance. With low transmittance, water absorption can be dominant.

Meanwhile, at high transmittance at the wavenumber of bengkoang water-soluble polysaccharide granules, it causes the opposite phenomenon. For groups at wavenumbers around 1400-1300 cm^{-1}, it indicates aromatic ring vibrations from lignin compounds. As supported by previous research, the lignin component is still present in the bengkoang water-soluble polysaccharide granules [13]. The cluster at a wavenumber of around 1000 cm^{-1} indicated the presence of a strain group from C-C.

3.4 Inulin content determination

Inulin is one of the prebiotic compounds which is included insoluble dietary fibre. It is usually used as a fat replacer and texture modifier in food products. Many scientists have developed isolation and characterization of inulin-type fructans with the new ultrasound-assisted extraction process of the polysaccharides from roots [3,4]. In this research, the increasing effect of temperature and time treatment is attributed to the expanding inulin content. However, on the chromatogram at the retention time of 10-12 seconds, it appears that there is a peak appearance which indicates that the compound is a fructooligosaccharide. Similar results were reported by [14] for *Dioscorea esculenta*.



(a–c) – different superscripts within a column are significantly different at $P < 0.05$.

Fig. 5. Inulin content of bengkoang WSP with ultrasound treatment

4 Conclusions

Ultrasound-assisted extraction of bengkoang starches in water resulted bengkoang water-soluble polysaccharide granules that the shape and size are the same as corn with a diameter of about 3–20 μm. Based on the results obtained, decreasing the moisture degree is attributed to the increasing temperature and time treatment of ultrasound-assisted extraction, increasing water absorption capacity, which is a benefit feature in many food applications. It was similar to the expanding impact of temperature and time treatment attributed to the rising inulin content. The results of the FTIR graph test show that some of the granules have cracks and small depressions on the surface that are visible in the middle and corners after being treated with sonication. Sonication does not change of new functional groups but can shift the intensity of the transmission pattern. In further research, it is necessary to optimize the extraction of water solvents at temperatures below high temperatures.

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