Pasting properties of jack bean (Canavalia ensiformis) modified starch with heat moisture treatment

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Abstract. Jack bean is a local legume that can grow in suboptimal land and potential to be developed in Indonesia. Jack bean seed has 33.32% of protein and 61.15% of carbohydrate so it can become a starch source for the food industry. Native starch has a limited application on food products because of its weak characteristics such as being unstable to heat and shear. Heat Moisture Treatment (HMT) starch modification is needed to overcome the weaknesses. HMT is a natural modification because it does not leave a chemical residue. The objective of this research was to investigate the effects of heat moisture treatment (HMT) with various moisture content and time on the pasting properties (peak, trough, breakdown, final, setback viscosity, peak time, and peak temperature) of jack bean modified starch. This research used Factorial Completely Randomized Design (FCRD) with two factors, varying moisture content (27%, 30%, 33%) and time (10 h, 13 h, 16 h). The results show that the various moisture leads to increase peak time, pasting temperature and decrease peak viscosity, through viscosity, breakdown, final and setback viscosity. In addition, higher HMT time could increase peak time, pasting temperature but decrease peak, trough, breakdown, final and setback viscosity.

1. Introduction
Jack bean (Canavalia ensiformis) is one type of local legume that can be used as food and feed [1]. Jack bean has profitable prospects to be developed in Indonesia. The average productivity of jackbean reaches 7 tons/ha with a potential yield of 12 tons/ha. Meanwhile, the area of the jack bean reaches 1,590 hectares with an average production of 5 tons per year. The demand for jack beans in Central Java reaches 100-200 tons per month and farmers in Temanggung, Central Java are able to produce 4–8 tons of jack beans per harvest [2]. Jack bean contains 32.32% protein, 61.15% carbohydrates, and 34.73% starch so that it can be used as a source of starch and protein [3].

Starch is a carbohydrate reserve in plants that can be found in leaves, flowers, fruits, seeds, tubers, and roots. Starch consists of two polymers, which are amylose and amylopectin. Amylose is a straight chain of -1,4 glucan bonds, few branched chains at -1,6 and has 15–30% of the starch content. On the other hand, amylopectin consists of straight-chain glucose units linked to -1,4 glycosidic and multiple branched chains at -1,6. The content of amylopectin in starch is 70–85% [4]. Some sources of starch are cereals (wheat, corn, rice), legumes (red beans, chickpeas, cowpeas, soybeans), unused legumes (jack bean and pigeon beans), roots and tubers (cassava, potatoes, sweet potatoes), and unripe fruit (bananas, mangoes). Starch is a high demand material by both food and non-food industries. Starch was used to form food texture and viscosity, to maintain gel strength and clarity, to make edible coatings, and to...
stabilize emulsions. Utilization of starch from underutilized legumes such as jack beans could increase demand for starch by using new sources of polysaccharides [5].

The use of native starch in food has limitations on the properties of gelatinization, pasting, solubility, swelling, and digestibility [5]. According to Hoover [6], native starch is rarely used in the food industry because of its instability to heat and stirring. Thus, it is necessary to modify starch to improve the properties of jack bean starch, especially its instability to heat and stirring so that it can expand the use of starch in food processing.

Modification of starch can be done by physical, chemical, enzymatic, and genetic modifications. Modification of starch that can increase the stability of starch to heat and stirring is heat moisture treatment (HMT) [7]. HMT is a physical modification using hydrothermal treatment techniques. HMT is carried out by heating starch with low water content (<35%) at a relatively high temperature (80-140°C) for a certain period of time (15 minutes-16 hours) [6]. According to Zaidiyah and Hakim [8], HMT can reduce the solubility of starch and according to Varatharajan et al. [7], in addition to lowering starch solubility, HMT also reduces swelling power, amylose leaching and peak viscosity, and increases pasting temperature. HMT modification is considered more natural and safer than chemical modifications that leave chemical residues.

The HMT treatment at 110°C affected the Amylograph properties of the HMT modified starch, which resulted in the highest gelatinization temperature of 94.0±0.7°C with a gelatinization time of 19.3±0.5 minutes and the highest return viscosity of 3,292.0±280.8 Cp compared to other temperature treatments. Meanwhile, the peak viscosity of HMT-modified starch could not be observed because the viscosity of HMT-modified starch increased with increasing temperature and stirring. From the results of this study, the heating temperature of 110°C was used in this study to determine the effect of variations in moisture content (27%, 30%, and 33%) and HMT modification time (10, 13, and 16 hours) on the properties of the jack bean starch paste.

2. Materials and methods

2.1. Materials

The main material used in this study is jack bean (*Canvalia ensiformis*) seed. It was obtained from Local market in Pasar Legi, Surakarta. Aquadest was also used in this research to modify the starch and pasting properties test.

2.2. Starch extraction

The starch extraction was performed using Yao Method [9] with modification. The jack beans were soaked for 9 hours in water with 0.45% Na-metabisulphite to reduce the HCN content and the browning reaction. Then, peeling the skin of the jack bean seeds was carried out manually and continued with the destruction of the jack bean using a blender with the addition of distilled water: jack bean (3:1). The solution of the jack bean was filtered with a filter cloth to get filtrate. The obtained filtrate was precipitated for 1 hour and decanted between starch and water. The wet starch was dried in a cabinet dryer at 50°C for 4 hours. The dried starch was ground with a blender and sieved using a 100 mesh sieve.

2.3. Starch modification with HMT

Modification of jack bean starch was carried out based on the Barua and Srivastav [10] method with modification. The jack bean starch was added with distilled water until the moisture content becomes 27%, 30%, and 33%. Starch with adjusted moisture content was placed in a closed container and stored at a temperature of 6–9°C for 24 hours. Then, it was heated with an oven at 120°C to get a starch temperature of 110°C for 10, 13, and 16 hours. Then the starch was dried again at 40°C for 8 hours so that the starch weight was constant and remained dry. The starch was ground using a blender and sieved through 100 mesh sieves.
2.4. Pasting properties
Pasting properties were determined using a rapid visco-analyzer (RVA) Super 3 (Newport Scientific, Warriewood, Australia) based on Wang et al. [11] method. Jack bean starch (3 gr) was added into RVA canisters and then added with 25 ml of distilled water. All parameter of pasting properties of the starch such as Peak Viscosity (PV), Breakdown Viscosity (BD), Trough Viscosity (TV), Pasting temperature, Final Viscosity (FV), pasting time, stability ratio and Setback Viscosity (SB) were got from the RVA data.

3. Results and discussion

3.1. Peak viscosity (PV)
Peak viscosity (PV) is the peak viscosity of the dough in the heating process or conditions where the starch granules reach the maximum until starch granules will be damaged. PV can be used as an indicator of ease of cooking and shows the strength of the dough formed on gelatinization when application in food [12]. PV reflects the swelling power of starch [13]. The HMT modification resulted in a lower PV of starch than the native starch. After HMT, the highest PV at HMT 27% + 16 Hours is 2,428.67 cP, while the lowest PV at HMT 33% + 16 Hours is 1,534.00 cP. This is consistent with the HMT of African yam bean starch [14], red sorghum starch, rice starch [15] and breadfruit starch [16]. The decrease in PV can be caused by an increase in amylose-amylose and amylose-amylopectin chain interactions [16]. This interaction causes the rearrangement of the starch granule structure so that the amylose-amylose, amylose-amylopectin, and amylopectin-amylopectin bonds become stronger [17]. Also, according to Marta and Tensiska [12] the decrease in PV occurred because HMT decreased the ability to pump and caused the polymer to separate during heating (amylose leaching).

The higher the initial moisture content of the starch and the longer the HMT time lead to lower the PV value during HMT. The combination of heat and moisture during HMT promotes partial breakdown of the starch chain structure and rearrangements of damaged molecules [13]. The previous studies, the sweet potato starch HMT has a lower PV at a longer HMT time. This is because HMT encourages the interaction of molecules in the amorphous and crystalline parts so that the starch molecules become denser. This denser starch molecule will reduce water penetration into the starch thereby limiting swelling and resulting in low viscosity [18]. The highest PV can be attributed to higher swelling power as it promotes hydration in the amorphous site [19].

3.2. Trough viscosity (TV) dan breakdown viscosity (BD)
Trough viscosity (TV) is the maximum viscosity when the temperature is constant on the RVA profile. TV was measured as the ability of the paste to withstand damage during cooling [20]. The HMT modification resulted in the lower TV than the native starch. The highest TV with HMT has 2150.00 cP (27% HMT + 16 hours) and the lowest was 1,363.00 cP (HMT 33% + 16 Hours). This is in accordance with the HMT of sweet potato starch by Pranoto et al. [18] and water yam starch Tiamiyu et al. [21]. In the research of Pranoto et al. [18], the value of TV decreases with increasing HMT time. In Table 1, it can be seen that there is a downward trend in TV from HMT samples with increasing time for HMT, except for samples with moisture content of 27%. Also, the BD value of HMT was also lower than native starch. The highest BD value was at HMT 27% + 10 Hours (525.67 cP) and the lowest was at HMT 33% + 10 Hours (116.67 cP).

Breakdown viscosity (BD) describes the stability of starch granules against heating and stirring [16]. During the BD phase, starch macromolecules and swollen starch granules break down, resulting in a decrease in viscosity [22]. BD was obtained from the difference between PV and TV [20]. The decrease in BD in the HMT of jack bean starch was in accordance with the HMT of African yam bean starch [23] and breadfruit starch [16] where this decrease in BD indicated that the HMT increased the stability of starch to mechanical and heat treatment. The increase in starch stability is the result of the stronger amylose and amylopectin bonds [15]. The higher variation of moisture content and longer time will
decrease BD of HMT samples. These results were in agreement with the previous studies [13–15,19]. The decrease in BD value in HMT starch indicated that the starch was stable in heating and stirring [13].

Table 1. Pasting properties of jack bean modified starch with various moisture and time

| HMT      | PV (cP) | TV (cP) | BD (cP) | FV (cP) | SB (cP) | Time (Min) | PT (°C) |
|----------|---------|---------|---------|---------|---------|------------|---------|
| Native (unmodified) | 2,666.33 | 2,122.00 | 544.33 | 3,798.67 | 1,676.67 | 4.89        | 86.03   |
| HMT 27% + 10 h | 2,326.67 | 1,901.00 | 425.67 | 2,746.33 | 845.33 | 6.02        | 92.73   |
| HMT 27% + 13 h | 2,334.67 | 1,809.00 | 525.67 | 2,649.67 | 840.67 | 5.40        | 91.93   |
| HMT 27% + 16 h | 2,428.67 | 2,150.00 | 284.67 | 2,909.67 | 759.67 | 5.58        | 91.33   |
| HMT 30% + 10 h | 2,078.33 | 1,942.67 | 135.67 | 2,467.00 | 524.33 | 5.78        | 93.87   |
| HMT 30% + 13 h | 1,999.33 | 1,728.33 | 271.00 | 2,356.00 | 627.67 | 5.47        | 93.02   |
| HMT 30% + 16 h | 1,878.33 | 1,585.33 | 293.00 | 2,231.33 | 646.00 | 5.69        | 93.33   |
| HMT 33% + 10 h | 1,638.33 | 1,521.67 | 116.67 | 1,957.00 | 435.33 | 6.04        | 94.60   |
| HMT 33% + 13 h | 1,628.33 | 1,464.33 | 164.00 | 2,057.00 | 592.67 | 5.71        | 93.90   |
| HMT 33% + 16 h | 1,534.00 | 1,363.00 | 171.00 | 1,948.00 | 585.00 | 5.67        | 94.70   |

3.3. Final viscosity (FV)

Final viscosity (FV) is the ability of starch to form a viscous paste. FV can be related to gel hardness where the higher gel hardness leads to the higher the FV [24]. FV can also be interpreted as the capacity of starch to form a thick paste in the cooling phase after the cooking process [25]. The HMT modification resulted in starch with a lower FV than the natural starch. The highest FV results are at HMT 27% + 16 Hours (2,909.67 cP) and the lowest was at 33% HMT + 16 Hours (1948.00 cP). This is in accordance with the HMT of sweet potato starch with a moisture content of 15% [13], the decrease in FV occurred due to an increase in the molecular bonding force in the starch chain. The force was increased because the swelling power of starch HMT decreased and the starch granules were more stable against mechanical breaking.

3.4. Setback viscosity (SB)

Setback (SB) is a measure of the tendency of retrogradation starch which was characterized by the presence of liquid droplets in the starch gel [14]. SB or viscosity change during cooling was obtained from the difference between the viscosity of the cold paste and the viscosity of the hot paste. A high SB value indicates tendency to retrograde [12]. This phenomenon is due to the cohesive nature of the paste, whereas a low SB value indicates an incohesive paste with a low tendency of retrogradation upon cooling [20]. HMT modification resulted in lower SB of HMT sample than native starch. The highest SB was at 27% HMT + 10 Hours (845.33 cP) and the lowest was at 33% + 10 Hours HMT (435.33 cP). This is consistent with the HMT of African yam bean starch [14], sweet potato starch [28], and breadfruit starch [16]. The decrease in SB after HMT was caused by the presence of swollen, stiff and unfragmented granules, the amount of amylose leaching, amylose chain length, and starch granule size [16]. SB was influenced by amylose content. Amylose has a better ability to rearrange after gelatinization, so that starch with low amylose content has a low SB value [24]. The higher the moisture content variation and the longer time caused the lower the SB value of HMT sample. This is because the longer HMT time supports the lipid-amylopectin complex, thereby reducing retrogradation [15].
Low SB is important for starch applications in confectionery and bakery products, as well as cold and frozen foods [19].

3.5. Peak time dan pasting temperature (PT)
Peak time was a measure of the cooking time or the time required for starch to form a paste [29]. Meanwhile, pasting temperature (PT) is the temperature when starch begins to thicken or form a paste [14]. PT is an indication of the minimum temperature required to cook a food ingredient to form a gel, determines energy costs, and other components. High PT will cause higher energy costs [28]. Modification of HMT on jack beans produced starch with a higher peak time and PT than the native starch. The highest peak time was at HMT 33% + 10 hours (6.04 minutes) and the lowest was at HMT 27% + 13 hours (5.40 minutes) while the highest PT was at HMT 33% + 16 hours (94.70 °C) and the lowest was at HMT 27% + 16 Hours (91.33 °C). The increase in PT after HMT corresponds to the HMT of African yam bean starch [14], rice starch [15] and breadfruit starch [16]. According to Tiamiyu et al. [21], the increase in peak time and PT after HMT was associated with an increase in crystallinity which was the result of reorientation of starch granules. Thus, the heat required for starch to damage the structure and form a paste is higher [14,15]. According to Adebowale et al. [14] and Li et al. [13], PT increased along with the higher initial moisture content of starch before HMT. This is because the starch structure is getting stronger so it requires higher heat for degradation and formation of starch paste.

3.6. Stability ratio (SR)
Stability ratio describes the resistance of starch paste to damage due to stirring [30]. SR was obtained from the ratio of the definite paste viscosity at the beginning of cooling (TV) to the peak viscosity (PV) [31]. Modification of HMT on jack bean starch resulted in a higher SR of starch than the native starch. These results are in accordance with the research of Sharma et al. [30], where the SR value of millet starch increased from 0.54 to 0.59–0.81 after HMT modification. This increase indicates that HMT starch is more stable than natural starch. Variations in moisture content and time of HMT affect the value of SR. The greater the moisture content of starch leads to higher the SR value, while the longer the HMT time causes lower the SR value. Sharma et al. [30] also reported that the moisture content has a significant effect on the SR value and the SR value increases with increasing moisture content.

4. Conclusion
Jack bean modified starch with HMT has lower peak viscosity, trough viscosity, breakdown, final viscosity, and setback values than native jack bean starch. On the other hand, the peak time, and pasting temperature are higher than native jack bean starch. Variations in water content in HMT modifications result in an increase in peak time, pasting properties and a decrease in peak viscosity, through viscosity, breakdown, final viscosity, and setback viscosity. Also, the longer HMT time results in an increase in peak time, pasting temperature and a decrease in peak viscosity, through viscosity, breakdown, final viscosity, and setback viscosity. The results suggest using HMT starch as a raw material to make food products, such as the sauce industry.

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