Characteristics of physico-chemical and functional properties of starch extracts from tubers

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Abstract. This research was aimed to determine the physico-chemical and functional properties of tubers starches and find out a suitable application in food products. Starch from tubers that analyzed were sweet cassava, bitter cassava, white sweet potato, red sweet potato, yellow sweet potato. The results of the physical analysis of Tubers starches were yield (10.86-17.57%), fineness (90.55-92.28%), whiteness (93.82-96.50). The results of chemical analysis of Tubers starches were water (6.51-8.70%), ash (0.31-0.43%), fat (0.27-0.37%), protein (0.14-0.16%), starch (82.46-89.05 %), amylose (15.47-17.55%), degree of acid (1.03-1.50 ml NaOH 1N/100g) and residual sulphite (31.44-38.10 ppm). The results of the functional properties analysis of tubers starches were water absorption capacity (0.884-0.951), oil absorption capacity (0.962-1.152), Freeze-Thaw Stability (18.85-40.53%), swelling power at 95°C (14.17-15.73 g/g), solubility at 95°C (8.40 to 17.16%), the beginning temperature of gelatinization (51-70.50°C), maximum viscosity (475-1733 BU), setback (30-487 BU) breakdown (188-850 BU), the stability of pasta (-90-(-390) BU).

1. Introduction
Food is a very important factor in human life. At the present time the needs of food in Indonesia is increasing, so need for other food sources that can replace the need for major food like tubers. Strived greater food supplies through food technology that can be done with two approaches. First, use the materials of agricultural products which until now its use is still limited. Second, it examines the characterization of the underlying material utilization and processing or improve existing traditional processes [1]. One of the food commodities were considered very large in Indonesia are tubers. Based on data from the Kementrian Pertanian RI, cassava production in Indonesia about 21.8 million tons, sweet potato about 2.3 million tons and 1.2 million tons of potatoes [2].

Based on the above data, the tubers can be used as a food ingredient alternative to rice in order to diversify food. Besides the amount of their production lots, tubers have a good nutrient content. According to Setiawan tubers is one of the local potentials to be developed [3]. Tubers have various advantages, including: has the nutrients and carbohydrates as a source of food, can grow marginal areas where other plants cannot grow and can be stored in the form of flour or starch.

As the material containing high carbohydrate, tubers can be utilized as a tuber flour, composite flour and starch. The processing of tubers into flour starch is one effort to preserve the tubers.

Starch is a type of carbohydrate that is mainly produced by the plant. Starch is composed of amylose and amylopectin, both of which are stored in the form of granules called starch granules [4].
functionality of starches in food or non-food products depend on the physical properties of the starch [5]. The physical properties of starch are affected by two main components in starch are amylose and amylopectin. The level of swelling and the texture of snacks (snack) are influenced by the ratio of amylose and amylopectin.

In the food industry, Tubers starches are widely used both as raw materials and additives as thickening (thickening agent), gelling (gelling agent), forming the film (filming agent) and a stabilizer (stabilizing agent) [4].

Starch of types of tubers were used in this research are cassava (sweet and bitter cassava) and sweet potatoes (white, red, and yellow). The types of tubers are tubers commercially in Indonesia, which analyzed the physicochemical and functional properties of starch tubers are to determine the appropriate application on food products.

2. Materials and methods

2.1. Materials
Sweet Cassava (Ketan), Bitter Cassava (UJ3), White Sweet Potato (Sukuh), Red Sweet Potato (Sawentar), Yellow Sweet Potato (Papua Salossa), was derived from West Sumatera.

2.1.1. Starch isolation (modification method of [1]). Tubers are peeled using a knife to separate the tuber flesh and skin and then washed with running water. Tubers grated with a grater tool to obtain the results of porridge coarse grater. Furthermore, water is added to the 1: 2 ratios of weight of the slurry coarse. The extraction process occurred by using a filter cloth squeezed and accommodated distillate on the container. The extraction process is done with 2 times the addition of water. The sedimentation process conducted for 6 hours and added with sodium metabisulfite as much as 0.1% of the initial weight of tubers. Then separated liquid with sediment. The sediment is dried using an oven temperature of 50°C for 6 hours. Sediment was dried and then mashed in a blender and sieved with 100 mesh sieve and the obtained starch that has been refined.

2.1.2. Physico-chemical and functional analysis. Starches were analyzed physico-chemical and functional properties, the analysis include:
- Physical analysis
  The Yield [6], Color and Whitness [7], Passes 100 Mesh Sieves [8].
- Chemical Analysis
  Water, Protein, Fat, and Ash Content [9], Starch Content [10], Amylose Content [11], Degree of Acid [8], Residual Sulphite [9].
- Functional Analysis
  Water Absorption Index [6], Oil Absorption [8], Freeze-Thaw Stability [12], Swelling Power and Solubility [13], Amylograph Properties [11].

3. Result and discussion

3.1. Physical properties
The yield of tubers starches obtained ranges from 10.86-17.57% (Table 1). The highest yield is bitter cassava starch and the lowest is red sweet potato. The yield of starch obtained directly proportional to the carbohydrate content in the tuber. The higher the carbohydrate content in the tuber, starch yield obtained will be higher.

The fineness (passes 100 mesh sieve) of Tubers starches obtained ranges from 90.55-92.28% (Table 1). Quality requirement refers to SN1 (Standar Nasional Indonesia) Tapioca Flour 01-3451-1994 which require passes 100 mesh sieves at least 95%. The fineness of starches obtained does not meet with SN1 Tapioca Flour, because the starches obtained was grinded by manually so that they have lower fineness.
Table 1. Physical properties of starch from various types of tubers.

| Starch sources          | Yield (%) | Fineness (%) | Color (hunter lab scale) | °hue | Whiteness |
|-------------------------|-----------|--------------|--------------------------|------|-----------|
|                         |           |              | L | a   | b |          |             |
| Sweet Cassava           | 16.10     | 90.55±0.12   | 95.37 | -1.49 | 2.89 | 117.25 | 96.10±0.07   |
| Bitter Cassava          | 17.57     | 91.10±0.38   | 96.78 | -1.61 | 2.54 | 122.43 | 96.50±0.14   |
| White Sweet Potato      | 12.99     | 91.54±0.17   | 94.77 | -1.73 | 3.79 | 114.47 | 95.25±0.02   |
| Red Sweet Potato        | 10.86     | 91.15±0.18   | 93.42 | -0.85 | 5.56 | 98.70  | 93.82±0.15   |
| Yellow Sweet Potato     | 13.23     | 92.28±0.09   | 94.20 | -1.52 | 3.58 | 112.98 | 95.43±0.10   |

Color is one of the important attributes for food product. The system can be used to determine the color of starch in this study is the Hunter system. Color test analysis results are shown in Table 1. At the Hunter system there are three parameters: L *, a *, and b *. Notation L* shows the reflected light produces white, gray and black. The notation a* shows the value of the chromatic red (positive values) and green (negative values). Notation b* indicates the chromatic colors yellow (positive values) and blue (negative). As for the color hue shows the proportion contained on the materials. Value hue grouped as follows:
°hue 342-18: Red purple
°hue 18-54: Red
°hue 54-90: Yellow red
°hue 90-126: Yellow
°hue 126-162: Yellow green
°hue 306-342: Purple

Color measurement results from Tubers starches showed varying results. L value on starch tubers about 93.42-96.78 which shows that Tubers starches have high brightness. While the color of starch obtained are yellow, yellow-green and red-purple.

Whiteness is a main quality factor from starch. Whiteness of a material is ability to reflect light from the material of the light incident on the surface. Whiteness of the starch obtained ranges from 93.82-96.50 (Table 1). Quality requirement of whiteness which refers to SNI Tapioca 3451: 2011 is 91 [8].

3.2. Chemical properties
The moisture content of the Tubers starches were obtained (Table 2) are still below the value set on the moisture content on SNI Tapioca Flour 3451: 2011 is maximum 14% [8]. The moisture content of starch products depends on the relative humidity (RH) of the atmosphere in which they have been stored. The ash content of Tubers starches obtained in this research ranges from 0.20-0.48% (Table 2). The ash content obtained are still below the maximum ash content on SNI Tapioca Flour 3451: 2011 is maximum 0.5%. The ash of commercial starches contains mainly sodium, potassium, magnesium and calcium as metal compound.

The fat content of starch obtained ranges from 0.27 to 0.37% (Table 2). The highest fat content is white sweet potato starch and the lowest fat content is sweet cassava starch. Fat content in starch can interrupt the process of gelatinization because the fat is able to form a complex with amylose thus inhibiting the release of amylose of the starch granules. Besides, most of the fat will be absorbed by the surface of the granules that form hydrophobic layer of fat around the granules. The fat layer will inhibit the binding of water by the starch granules. This causes the thickness and viscosity of starch is reduced by the amount of water is reduced to the swelling starch granules [1].

The protein content of the starch ranges from 0.14 to 0.16% (Table 2). The content of protein obtained is very small. Starch with high protein content causes the starch viscosity decreases, this causes the starch quality decreases so do not expect in utilization. Titi and Richana stated that protein and starch will form a complex with the surface of the granules and cause the viscosity of starch to decrease, and
resulted in the low gel strength [1]. This is less expected due to the utilization of applications; starch is widely used as thickening agents.

Table 2. Chemical properties of tubers starches.

| Starch sources | Moisture Content (%) | Ash content (%) | Fat Content (%) | Protein Content (%) | Starch Content (%) | Amylose content (%) | Amylopectin Content (%) |
|----------------|----------------------|-----------------|-----------------|---------------------|-------------------|---------------------|-------------------------|
| Sweet Cassava  | 6.51±0.40            | 0.31±0.05       | 0.27±0.11       | 0.14±0.01           | 89.05             | 17.55±0.91          |                         |
| Bitter Cassava | 8.52±0.22            | 0.32±0.01       | 0.28±0.08       | 0.15±0.24           | 86.59             | 16.21±1.10          |                         |
| White Sweet    | 7.88±0.61            | 0.41±0.09       | 0.37±0.04       | 0.16±0.29           | 85.75             | 15.47±1.05          |                         |
| Red Sweet      | 8.70±0.46            | 0.43±0.10       | 0.31±0.06       | 0.15±0.40           | 82.46             | 16.19±0.40          |                         |
| Yellow Sweet   | 8.38±0.48            | 0.42±0.03       | 0.32±0.05       | 0.16±0.17           | 87.20             | 16.15±0.38          |                         |
| Potato         | 7.10±0.38            |                 |                 |                     |                   |                     |                         |

Based on the results of research (Table 2) obtained starch content of Tubers starches ranged from 82.46-89.05%. The results obtained above minimum requirements on SNI Tapioca is 75%. High starch content indicates the quality of the starch product because it contains little other components that could interfere the functional properties of starch. The good starch isolation will produce more pure starch.

The results of measurements of amylose content ranged from 15.47-17.55% (Table 2). The highest amylose content is the sweet cassava starch (17.55%) and the lowest amylose content is white sweet potato starch (15.47%). Comparison of amylose and amylopectin will affect the solubility and degree of starch gelatinization. The greater the amylopectin content of the starch will be wet, sticky and tend to be slightly absorb water [14].

3.2.1. Degree of acid and residual sulphite. The degree of acid obtained from the research that ranged from 0.97-1.50. These results meet the requirements of Tapioca SNI 3451:2011 maximum is 4.

The acid level is affected by processing, especially during the extraction process, which is at the stage of separation between the water with starch. In the process of separating the starch with the water carried through sedimentation for hours, the occurrence of natural fermentation process by microbes. As longer sedimentation of the starch then organic acids produced from fermentation of the starch to be more so the starches have high degree of acid [14].

Table 3. Degree of acid and residual sulphite.

| Starch sources    | Degree of Acid (ml NaOH 1N/100g) | Residual sulphite (ppm) |
|-------------------|----------------------------------|-------------------------|
| Sweet Cassava     | 1.10±0.55                        | 32.31±1.27              |
| Bitter Cassava    | 1.11±0.65                        | 31.44±0.44              |
| White Sweet Potato| 1.33±0.68                        | 38.10±0.69              |
| Red Sweet Potato  | 1.50±0.75                        | 36.51±4.89              |
| Yellow Sweet Potato| 1.03±0.52                      | 36.50±2.67             |
In the sedimentation of starch in this research conducted by addition sodium metabisulfite at a concentration 0.1% of the initial weight of the material. Results of residual sulphite are shown in Table 3. Results of the analysis showed that residual sulphite contained in starch ranged from 31.44 to 38.10 ppm. Sulphites are food additives are allowed to be used by several countries, including Indonesia with maximum residue limits is 200-500 ppm [14]. addition of sodium metabisulphite in the production of starch which is to prevent the reaction of enzymatic and non-enzymatic browning so it can preserve the color of starch.

3.3. Functional properties

3.3.1. Water Absorption Index (WHI). Water absorption capacity related to the composition and physical properties of the starch granules after being added with some water. The results of the analysis of water absorption index can be seen in Table 4.

| Starch sources   | WHI (g/g) |
|------------------|-----------|
| Sweet Cassava    | 0.951±0.01|
| Bitter Cassava   | 0.913±0.02|
| White Sweet Potato| 0.919±0.02|
| Red Sweet Potato | 0.884±0.03|
| Yellow Sweet Potato| 0.947±0.04|

The high amylose content can increase the absorption of water [1]. Besides, water absorption index is influenced by the presence of fiber, because fiber properties which easily absorb water. Water absorption index determines the amount of water available for gelatinization of starch during heating. When the amount of water is less than the gel formation cannot reach the optimum condition. Thus, the low hydration capabilities are less suitable for refined products that require a high degree of gelatinization. Water absorption index also affects the easy of dough starch homogenize when mixed with water. The level of homogeneity of the dough will affect the quality of steaming results. The dough is homogeneous, after steaming will undergo gelatinization uniform marked the absence of dots on a white or pale-yellow starch dough steamed [14].

3.3.2. Oil Absorption Capacity (OAC). The mixture of oil and starch will affect the physical properties of starch because oils and fats can form complexes with the amylose which inhibits swelling of starch granules so difficult to gelatinization [15]. The results of the analysis of the oil absorption of Tubers starches can be seen in Table 5.

| Starch sources       | OAC (g/g) |
|----------------------|-----------|
| Sweet Cassava        | 0.962±0.04|
| Bitter Cassava       | 1.020±0.05|
| White Sweet Potato   | 1.150±0.08|
| Red Sweet Potato     | 1.055±0.18|
| Yellow Sweet Potato  | 1.152±0.13|

Based on this research, oil absorption capacity of Tubers starches ranged from 0.962-1.152. The highest oil absorption capacity is yellow sweet potato starch (1.152 g/g), and the lowest oil absorption capacity is sweet cassava starch (0.962 g/g). This indicates that the starch has a high amylose has a low oil absorption, it can be seen in Table 5. But no one has claimed that the amylose content affects the absorption of oil. According to Charles et.al. (2016) Oil absorption capacity reflects the emulsifying capacity, a highly desirable characteristic in products such as mayonnaise. High oil absorption properties are also required in meat replacers and extenders, doughnuts, baked goods and soups
3.3.3. Freeze-thaw stability. Freeze-thaw stability is important in the food industry. In cold chain storage, thermal fluctuations and consequent phase changes of water are the main causes of deterioration in frozen foods, especially in the gel matrix of starch. During cold storage, the reorganization of starch molecules may result in the release of water (or syneresis) and this may affect the functional properties in terms of viscosity or gel behaviour [16].

Table 6. Syneresis percentage of tubers starches.

| Starch sources      | Syneresis (%) |
|---------------------|---------------|
| Sweet Cassava       | 40.53±0.29    |
| Bitter Cassava      | 39.72±6.80    |
| White Sweet Potato  | 24.56±0.67    |
| Red Sweet Potato    | 35.33±0.42    |
| Yellow Sweet Potato | 18.85±2.20    |

Based on the results obtained syneresis percentage ranged from 18.85-40.53%. The highest syneresis percentage is sweet cassava starch and the lowest is yellow sweet potato starch. This indicates that the starch analyzed is not stable when in storage freezing temperatures so it is not properly used in food products are frozen. Syneresis directly proportional to the percentage of retrogradation, because one of effect of retrogradation may cause syneresis.

3.3.4. Swelling power and solubility. Swelling power is the ability of starch to expand when heated at a certain temperature and time. Azima et al stated that swelling power is a volume ratio of the dry weight of starch paste [14]. In general, swelling power will increase with increasing temperature measurements. The result of analysis of swelling power can be seen in Table 7.

The difference value of swelling power of starch can occur because of differences in the ratio of amylose and amylopectin. Factors such as amylose-amylopectin ratio, the molecular weight distribution and long chain, as well as the degree of branching and conformation determine the swelling power and solubility. This is evident from the results of the analysis of swelling power, sweet cassava starch has the highest amylose content (17.55%) than other tubers starches, directly proportional to the value of its swelling power (15.73 g/g).

Table 7. Swelling power of tubers starches.

| Starch sources    | Swelling Power (g/g) |
|-------------------|----------------------|
|                   | 55°C | 65°C | 75°C | 85°C | 95°C |
| Sweet Cassava     | 4.39 | 11.80 | 12.44 | 13.30 | 15.73 |
| Bitter Cassava    | 3.66 | 8.87 | 11.23 | 11.68 | 15.70 |
| White Sweet Potato| 2.41 | 11.46 | 12.71 | 13.22 | 14.86 |
| Red Sweet Potato  | 3.62 | 9.78 | 10.06 | 12.92 | 14.17 |
| Yellow Sweet Potato| 3.59 | 9.57 | 12.04 | 13.79 | 14.95 |

The solubility is the weight of starch dissolved and can be measured by drying and weighing the amount of supernatant. According to Pomeranz, the solubility of starch will increase with increasing temperature and the speed of increase in solubility is typical for each starch [17]. Starch solubility analysis results are presented in Table 8.

Table 8. Solubility of tubers starches.

| Starch sources    | Solubility (%) |
|-------------------|---------------|
|                   | 55°C | 65°C | 75°C | 85°C | 95°C |
| Sweet Cassava     | 7.32 | 7.47 | 11.11 | 12.40 | 17.16 |
| Bitter Cassava    | 2.02 | 7.89 | 12.28 | 14.69 | 16.56 |
| White Sweet Potato| 3.41 | 6.74 | 6.79  | 6.85  | 8.40  |
Red Sweet Potato    3.58  6.56  6.69  7.03  8.60  
Yellow Sweet Potato  2.47  5.88  5.89  7.09  8.26

In general, the starch with high swelling power having high solubility as well. The potato starch has a swelling power higher than nuts starch also have high solubility. In this study, it appears that the amylose content is directly proportional to the solubility of starch.

However, the solubility of the sweet potato starch obtained lower than other starches although the amylose content in sweet potato starch is higher than the yam bean starch. It can be caused by a higher fat content in sweet potato starch which inhibits solubility. Amylose content is not always directly proportional to solubility. The existence of complexes between amylose with lipids can reduce the solubility of amylose.

3.3.5. Amylograph properties of starch. Measurement amylograph properties of Tubers starches used Brabender Viscoamylograph including measuring the beginning temperature of gelatinization (SAG), the temperature of the maximum viscosity (SVM), the maximum viscosity (VM), the viscosity of the beginning and ending when the temperature is maintained, and the viscosity of the beginning and end when the temperature is lowered, Whereas for the setback, breakdown and the stability of the paste is the result of the calculation. Amylograph parameter analysis results can be seen in Table 9.

There are differences amylograph curve on each starch tubers. During the heating process from 30°C to 95°C is maintained at a temperature for 20 minutes, the viscosity of starch suspension increased very sharply where aqueous starch suspensions become more viscous. After the reached the peak viscosity, viscosity decreased until the end of the heating temperature of 95°C. Amylograph curve starch tubers can be seen in Figure 1.

Table 9. Amylograph properties of tubers starches.

| Parameter | A     | B    | C     | D     | E     |
|-----------|-------|------|-------|-------|-------|
| SAG       | 51    | 70.5 | 66.3  | 69.8  | 68.5  |
| VM        | 1733  | 1291 | 475   | 910   | 1400  |
| SVM       | 75.5  | 76.6 | 80.7  | 82.7  | 79.5  |
| V1,95°C   | 1235  | 889  | 377   | 830   | 940   |
| V2,95°C   | 998   | 767  | 287   | 640   | 550   |
| VD        | 1485  | 1201 | 402   | 890   | 580   |
| VB        | 487   | 434  | 115   | 250   | 30    |
| VJ        | 735   | 524  | 188   | 270   | 850   |
| SP        | -237  | -122 | -90   | -190  | -390  |

A : Sweet Cassava, B: Bitter Cassava, C: White Sweet Potato,  
D : Red Sweet Potato, E: Yellow Sweet Potato,  
SAG : The beginning temperature of gelatinization (0C)  
VM : Maximum viscosity (BU)  
SVM : Temperature of maximum viscosity (0C)  
V1950C : Viscosity at temperature 95oC  
V2950C : Viscosity at temperature 95oC (BU)  
VD : The viscosity of the final cooling to a temperature 500C (BU)  
VB : Setback (BU) (VD - V2950C)  
VJ : Breakdown (BU) (VM - V2950C)  
SP : Stability of Pasta (BU) (V2950C - V1950
8

4. Conclusion
The results of the physical analysis from Tubers starches were yield (10.86-17.57%), fineness (90.55-92.28%), whiteness (93.82-96.50). The results of chemical analysis from Tubers starches were water (6.51-8.70%), ash (0.31 - 0.43%), fat (0.27 - 0.37%), protein (0.14 - 0.16%), starch content (from 82.46-89.05%), amylose (from 15.47-17.55%), degree acid (1.03-1.50 ml of 1N NaOH/100 g) and residual sulphite (31.44 – 38.10 ppm). The results of the functional analysis Tubers starches were water absorption index (0.88-4.95 g/g), oil absorption capacity (0.962-1.152 g/g), freeze-thaw stability (18.85-40.53%), swelling power at 95°C (14.17-15.731 g/g), the solubility at 95°C (8.26-17.16%), the beginning gelatinization temperature (51-68.5°C), maximum viscosity (475-1733 BU), setback (30-487 BU), the stability of the pasta (-90(-390) BU).

It should be further research on the application of products from starch tubers are appropriate based on the physico-chemical and functional properties.

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