The potentials of Indonesian tubers for the development of potato starch substitute: A short review

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Abstract. Potato starch becomes one of the popular starches. It is preferred for use in various industries due to its unique characteristics such as a good film-forming ability and consistency. The high phosphate content causes potato starch to have the excellent ability of water binding, swelling, and good consistency. However, potato production in the developing country tends to decrease. Local tubers could be used to be an alternative to substitute it. The modification process could improve the physicochemical and functional properties of the native local tubers starch. Sweet potato has the potential to be developed to substitute potato starch because it comes from the Solanaceae family. Hydroxypropylation, succinylation, and phosphorylation are suggested in producing potato starch substitute.

1. Introduction
One of the essential crops in the world is potato due to its function for direct or intermediate consumption. It is also popular for its derivative products such as starch and flour [1]. However, potato production in developed countries has declined on average by one percent [2]. Nowadays, potatoes are processed as starch and flour to fulfill the demand from the fast food and food industries [2]. One of the products derived from potato that popularly used all around the world is potato starch.

Two major components of starches, namely amylose and amylopectin, will determine the starch properties. Protein, lipid, and other constituents are also found at starch in the low amount [3] which also have an influence in starch functionality. Other components that have a significant influence on starch functionality is the mineral, such as phosphorous. The phosphorous content of starch also affects its pasting properties and swelling ability [4–6]. Potato starch contains the largest amount of organic phosphate among tuber, which contributes to the unique properties of potato starch [4].

Potato could be substitute with other lower price and high availability commodities. It will become an alternative to overcome the problem of potato production as well as to increase local tubers values. The commodities with similar properties to potato and overcoming the limitations of native starch with modifying the starch is promising. Modified starch is done by chemical, physic, or enzymatic treating of native starch [7]. These methods could improve and alter the physicochemical characteristics. Thus the functional properties of modified starch could be tailor-made to industrial needs.
2. Modified starch

2.1 Native potato starch characteristics
The popularity of potato starch is based on its usage that superior over corn starch and other starches in some applications. The most essential characteristics of potato starch which make it ideal are (1) low gelatinization temperature, (2) excellent film making, (3) high consistency on pasting, and (4) good binding ability. Potato starch has kept its position in some applications over corn or tapioca starch because of its unique traits [8]. The ability to make highly swollen starches increase the firmness, smoothness, and elasticity of products, such as noodle [9,10].

Phosphorous in potato starch was found in high amount and may influence the unique properties of the starch. A high amount of phosphate in potato starch will affect the starch gels with high viscosity [11]. It exists during the development of tuber starch and increases along with the tuber maturity. The amylpectin of potato starch is richer in phosphorous content than amyllose with at least four phosphate groups in each amylpectin fraction [12]. The number of phosphate groups inside starch will influence starch clarity and a viscosity [13]. Tuber starches contain monophosphate esters with covalently bound to starch [14]. The high phosphate monoester content will increase starch clarity and slower the retrogradation process [15].

The differences between native potato starch and cereal starches are potato starch has lower lipid, less crystalline structure, and a lower ratio of amyllose. Potato starch granules average size vary between 5 to 100 µm [16] and exhibits B-type granule pattern [17]. The behaviour of potato starch suggests its application in foods products formulation, which require long shelf-life and high stability [18].

2.2 The potential of local commodities
Tubers contain starch (16–24%), water (70-80%), and trace elements, including protein and lipid (<4%) [19]. Tuber starch also has a blend of taste, light paste, and relatively stable [11]. For example, sweet potatoes could be used in place of potatoes because they are closely related to potatoes. They both come from the Solanaceae family. Another tuber with B-type pattern also potential to be used. The crystalline pattern characteristics of most tuber starches exhibit the pattern of B-type as the result of the x-ray diffraction tests [20]. The information about some commodities characteristics presented in Table 1.

| Sample      | Granule (µm) | Phosphorous  | Amylose (%) | Ref  |
|-------------|--------------|--------------|-------------|------|
| Potato      | 35.2         | 847.2 ppm    | 21.5        | [11] |
| Sweet potato| 19.4         | 231.3 ppm    | 23.4        | [11] |
| Yam         | 22.8         | 166.1 ppm    | 25.8        | [11] |
| Cassava     | 15.7         | 97.0 ppm     | 28.8        | [11] |
| Arrowroot   | 21.1         | 0.018 %      | 20.8        | [13] |
| Canna       | 42.3         | 0.031 %      | 31.7        | [13] |
| Ginger      | 15.8         | 0.007 %      | 26.5        | [13] |
| Maize       | 7.28         | 0.01 %       | 29.3        | [21] |
| Chayote     | 7.50         | 0.15 %       | 12.9        | [21] |
| Taro        | 10-50        | 0.02 %       | 29.3        | [22] |

Table 1. The component characteristics of some local commodities starches.

Some of the important characteristics of starches are pasting and thermal properties. Observing the viscosity changes is studied to understand the pasting characteristics. The tendency towards retrogradation, stability, and other parameters could be obtained from the pasting analysis. Most of the tuber starches exhibit weaker associative intragranular forces [11]. Starch chemical composition also
determines the characteristics of starch. The pasting characteristics of some commodities could be seen in Table 2.

Table 2. Pasting characteristics of some tuber starches.

| Sample                 | Peak viscosity (BU) | Pasting temperature (°C) | Viscosity at 95°C (BU) | Percent concentration (%) | REF |
|------------------------|---------------------|--------------------------|------------------------|----------------------------|-----|
| Solanum tuberosum      | 2150                | 62                       | 1300                   | 6                          | [23]|
| Ipomea batatas         | 550-560             | 66.5-68                  | 550-560                | 4                          | [24]|
| Dioscorea alata        | -                   | 81-85                    | 25-80                  | 4.5                        | [25]|
| Manihot esculenta      | 590                 | 62                       | 290                    | 6                          | [26]|
| Pueraria tuberosa      | 245                 | 70                       | NA                     | 5                          | [27]|
| Dioscorea alata        | No peak             | 74                       | 100                    | 5                          | [28]|
| Dioscorea alata        | No peak             | 69                       | 282                    | 10                         | [28]|
| Colocassia esculenta   | 700-1400            | 70-75                    | 600-1100               | 8                          | [29]|
| Maranta arundiacea     | 337-410             | 72.7-75.9                | NA                     | 5                          | [30]|

2.3 Modification of starch
Modified starches are starches that have been treated using chemical, physical, and/or enzymatic to improve their properties for a specific use [31]. Starch modification could be done in many ways, such as etherification, decomposition, esterification, crosslinking, or physic method using heat, moisture, or pressure. The enzymatic also could be applied to starch to alter its properties. A different method of treatment will result in specific physicochemical properties [32].

The physic method is preferred in foods because of its functional properties over those of its native. Moreover, this modification process could be safely used in various food products and other industrial applications. Various physical modification methods of potato starch include pre-gelatinization, high-pressure, heat/moisture, osmotic pressure, and annealing. Other methods, such as microwave and pulse-electric, sonication, and irradiation, are other novel physic methods that could be applied [7,33].

Heating starch in high temperature and pressure, alcohols and alkali could be used to make a cold-water-soluble starch. When compared with native gelatinized starch, it shows smoother texture, greater viscosity, and better process resistance [34]. Other methods with vacuum ball grinding machines are generally used for the manufacture of micron starches. This process will modify the granules with irregularly reduced in size by utilizing the force the grinding balls and starch [35]. Full pre-gelatinization starch could be produced by heating the starch solution above the gelatinization temperature and drying it. [36]. Pre-gelatinization method has a higher hydration and swelling capacity than its native starch, making it suitable for use in tablet formulations and porridge [33,37]. The hydrothermal treatments that are used to produce modified starch without the loss in starch granule integrity are annealing and high moisture treatment. A prominent feature of this method is that their processes will maintain the starch structure by occurring below the gelatinization temperature [38].

Derivatization is a modification method for producing the starch which suits in industrial-scale. The efficiency of these chemical modification is influenced by the starch origin, granule size, reagent type, and the structure [39,40]. The presence of channel and tunnels inside starch granule and the surface of starch also influence the effect of chemical modification. A larger surface area will be accessible by chemical reagents and give easier access for the reagents to the inner starch. However, the reagent could diffuse directly from the surface to the inner matrix [40].

Phosphate groups could be added into native starch as well. Esterification is a chemical modification which could be used to produce potato starch substitute. Some of the methods that could be used are crosslinking, acetylation, phosphorylation, fatty acylation, succinylation and cationization [41]. Crosslink starch could be made by the reaction between starch and another reagent such as sodium tripolyphosphate, epichlorohydrine, sodium trimetaphosphate, and phosphorichloride. These reagents are containing phosphate that could be used to add phosphate group into their starches. Another chemical
modification method, namely acetylation could be done by adding the acetyl group to the hydroxyl group of a glucose molecule [42]. The used of acetic anhydride and base catalysts such as sodium hydroxide are needed in this modification process [43]. Phosphorylation could be done by adding the phosphate groups on starch. It will improve the viscosity, paste clarity, and stability [44]. It also decreases the gelatinization parameters. This method will increase the steric hindrance by resulting in the monophosphate or diphosphate starch. Fatty acylation could be produced by reacting the fatty acids with starch. It will alter the optical activity and thermal properties of starch greatly. Succinylation is esterification process by adding octinyl succinic anhydride to starch. This modification will increase swelling starch ability, peak viscosity, and decrease the gelatinization properties [41].

Etherification is a chemical modification method that could be used to create a potato starch substitute. Hydroxypropylation could be made by adding the hydroxypropyl group on the starch resulting in the increases of peak viscosity, water binding, swelling power, solubility, and paste clarity. However, the gelatinization parameters will decrease by using this method. Hydroxyethylitation could be used to create starch with improving drug binding ability. Carboxymethylation is one of the etherification technique that will improve stability and prevent the recrystallizing ability of starch [41]. The residue is possibly attached to starches with the usage of chemical reagent. The safe chemical reagent is preferred. Besides, starches from various sources showed fundamental structural similarities. This will affect the ability of chemical reagent in altering the micro and ultrastructure to some extent [45].

3. Conclusions
Potato starch is widely used in the world for much industrial application. However, there is a limitation in the usage of native starch. There is also a declining of potato production which could be overcome by substituting potato with local tubers. Sweet potato as local commodities with the same family as potato is potentially developed to substitute potato starch. Starch modification could improve native starch physicochemical and functional properties. Hydroxypropylation, phosphorylation, and succinylation are suggested in the making of potato starch substitute.

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