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THE UTILIZATION OF DIOSCOREA TUBER IN SELF-RISING STARCH: A REVIEW

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Abstract*. Self-rising starch is a development product of self-rising flour. This product minimizes the process of weighing salt and leavening agent, so that time for the serving process reduce. Self-rising flour is generally made of wheat flour. Currently, due to some medical considerations, many people cannot consume this product. Some research results, so that gluten compound in wheat flour or wheat triggers the development of type-1 diabetes. This fact has caused Indonesia to globally rank fifth for diabetic disease. One of the ways to overcome this problem is utilizing the raw materials originating from Indonesia, namely tubers. Indonesia has a variety of tubers, some of them, have not been explored. Tubers function as good sources of carbohydrates, bioactive compounds and functional values, such as water soluble polysaccharides (WSP), diosgenin, inulin and glycemic index. Moreover tuber increase the functional properties of the produced starch. The tuber that has not been cultivated is the genus Dioscorea. Various tubers that are included in the dioscorea family are uwi, gembili, gadung, tomberoso and jebubuk. They are good sources of carbohydrates. Uwi, gembili and gadung have been cultivated by people for many years. In contrast tomberoso and jebubuk tubers grow wildly in the forest and are only eaten by wild animals. The starch derived from the dioscorea tubers can be used as self-rising starch because it can function as a food developer. Moreover,it contains high carbohydrates and bio-active compounds, so that it is healthier to consume.*

Keywords: *self-rising flour; dioscorea; starch; bio-active compounds*

1. Introduction

Self-rising starch is a product derived from self-rising flour. The difference is in the raw materials used; self-rising starch is form starch, while self-rising flour with raw materials is from flour. Starch and flour are two very different raw materials even though they are made of the same material. According to Wang *et al.*, (2020) flour basically comes from sliced materials, such as tubers dried at a 40°C temperature and 100 mesh sieves. Starch is made of extract materials that have undergone a crushing process by using a blender, precipitating and drying it, successively at the temperature of 50°C for 48 hours (Behera, 2022).

The self-rising flour arises with the main consideration of a practical and minimal presentation process. This product has become a solution to produce various types of food, such as cakes and cookies. Currently, many self-rising flours have increased the sale on the market.

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Therefore, more investigations on self-rising flour sholud be done. Self-rising flour is a type of wheat flour that is widely used (Singh *et al.*, 2017; Tejinder *et al.*, 2015; Ma & Baik, 2018; Guo *et al.*, 2016; Aguirre *et al.*, 2021; Chowdhury, 2018; Chikpah *et al.*, 2021) in all kinds of foods products.

However, some people can not consume gluten from wheat flour called celiac (gluten intolerance) due to health considerations. The celiac disease includes gastrointestinal symptoms, non-gastrointestinal symptoms, or no symptoms. The classic symptoms associated with the gastrointestinal tract include diarrhea, steatorrhea, and weight loss due to malabsorption. A strict gluten-free diet for life (GFD) is a solution to lead to symptom improvement and recovery (Lebwohl *et al.*, 2018).

In addition, gluten has been identified as a trigger for type 1 diabetes, two diseases continuously increase in Indonesia (Marietta *et al.*, 2013; Slidorf *et al.*, 2012). According to the International Diabetes Federation (2021) approximately 19.46 million Indonesians suffer from this disease. This number indicates an increase of 81.8% compared to that in 2019. Indonesia is the fifth highest country with diabetes in the world (after China, India, Pakistan, and the United States). Moreover, Indonesia is the only Southeast Asian country that is included in the top 10 countries with the most diabetes cases.

Research on self-rising flour has been carried out by (Nugraheni *et al.*, 2017) who have discovered functional manufacture of self-rising flour in arrowroot flour that has undergone type 3 resistant starch and then mixed with composite flour. They observe the proximate value of self-rising flour and tested experimental animals. Therefore, there is a new idea to utilize other carbohydrate sources from domestic potentials.

A tuber is a type of local food that is widely available in Indonesia and applicable to support national food security. Local food ingredients are not only available in large quantities but also have a high productivity value and good nutritional content. Therefore, increasing the contribution of root crops as an alternative food source to meet the need for healthy food can significantly affect food security. Tubers also have functional values, including resistant starch, inulin, anthocyanins, glucomannans, and low glycemic index (Hatmi & Djaafar, 2014). One type of tuber that has not been widely used is dioscorea. These tubers grow wild and are easy to cultivate. According to Padhan *et al.* (2020), some of these wild species of dioscorea have better nutritional composition, such as carbohydrates, protein, and fiber, with high minerals. Some wild dioscorea species also -have significantly high anti-nutrient compounds, such as diosgenin, amylase, and trypsin inhibitors. According to Purnomo *et al.* (2012), several types of dioscorea tubers, constitute uwi, gembili, gadung, tomboreso, and jebubuk.

The use of dioscorea tubers, especially in self-rising starch products, can increase economic values. Dioscorea tubers are known broadly, and more people are interested in cultivating them because they provide bio-active compounds and functional values. This article will discuss in more detail self-rising flour, dioscorea tubers, and leavening agent.

2. Self-Rising Flour

Tejinder *et al.* (2015) define self-rising flour as flour that contains leavening agents, such as bicarbonate, and produces CO_2 when made into dough and baked due to the aeration process and dough expansion with beneficial effects on the taste, texture, and color of the product. One of the advantages of self-rising flour is a high ash level, and shows a high mineral level (Nugraheni, *et al.*, 2017). Self-rising flour provides convenience to users because it can save time and energy to eliminate difficulties in measuring and providing the desired quality for the product (Tejinder *et al.*, 2015).

Self-rising flour is strongly influenced by storage conditions, therefore it must be considered to maintain its quality which will affect the resulting product. The shelf life of self-rising flour is three months if stored at a low temperature with acceptable microbiological quality. This flour has different yeast but still contains calcium phosphate; moreover, it will produce higher quality cookies, muffins, and cakes within three months of storage than fresh flour (plain flour) within 1 and 2 months of storage (Singh *et al.*, 2017).

During the storage of self-rising flour, changes occur directly, which will affect the baking process and rheological characteristics of the dough. During the storage, flour aging occurs naturally (Miranda-Garcia, 2013). Due to the oxidation of flour components, including fatty acids and proteins (Cenkowski *et al.*, 2000). Several factors that affect flour maturation are temperature, time, humidity, relative humidity (RH), packaging materials, and microbial activities including the storage environment which is a pivatol factor in flour aging (Wang & Flores, 1999).

3. Dioscorea Tubers

The tubers used in this self-rising starch are a dioscorea group because they contain bio-active compounds and functional values, so that the produced starch is more valuable. Mignouna (2009) asserts that dioscorea tuber species are categorized as understudied and underutilized tubers. Approximately 600 species of the dioscorea family have been identified from various origins, both tropical and subtropical origins. In general, dioscorea is vines, (Kamaruddin *et al.*, 2020; Nasriyah *et al.*, 2011) and contains about 75-84% of starch that includes small compounds, such as proteins, vitamins, lipids, and minerals (Shajeela, 2011). The active compounds in dioscorea, such as steroidal sapogenins, glycans, alkaloids, tannins, and saponins, give the characteristic of spicy and bitter tastes (Prakash *et al.*, 2014).

The nutritional contents of dioscorea are 25% starch, 0.1-0.3% fat, and 1.3-2.8% protein so that dioscorea potentially produces carbohydrates. Dioscorea tubers also contain inulin, which can function as a prebiotic (Winarti *et al.*, 2011). Inulin is a polymer of fructose units with a terminal group of glucose. The fructose units in inulin are linked by (2-1) glycosidic bonds, so that they cannot be digested by enzymes in the mammalian digestive systems but reach the large intestine without undergoing structural changes; finally inulin can function as a prebiotic (Roberfroid, 2005). Dioscorea tubers have quite high inulin, between 2.88-14.77%; the highest inulin content is found in Dioscorea esculenta (gembili) tubers (Winarti *et al.*, 2011).

3.1. Uwi (Dioscorea alata)

Uwi is a plant that is rich in health properties, so that it can be utilized. These tubers, apart from being high in carbohydrates, also contain protein but are low in sugar (Lebot *et al.*, 2006). According to Senanayake *et al.* (2012), the chemical contents of uwi include carbohydrates 86.81%, protein 2.10%, lipids 0.43%, and ash 0.33%.

Hsu *et al.* (2006), suggest that uwi is beneficially consumed for intestinal microflora health and provides an antioxidant. Uwi has antioxidant content equivalent to or higher than 100 g BHA (butylhydroxyanisole) and -tocopherol (Lubag *et al.*, 2008). Uwi starch granules have a size distribution between 6-100 µm (Peroni *et al.*, 2006; Riley *et al.*, 2006; Yeh *et al.*, 2009) for this fairly large size range, the effect of granule size on physical and chemical characteristics is unknown. The chemistry of uwi starch, and its relationship with the functional properties of starch have been identified (Nadia *et al.*, 2013). Chirantika (2022) state that the shape of starch granules from Dioscorea alata tubers is round. The fiber and resistant starch content in this tuber are 6.83% and 4.65 g/100 g dry weight, respectively. The form of starch granules of uwi tuber under the scanning electron microscope (SEM) is described in Figure 1.

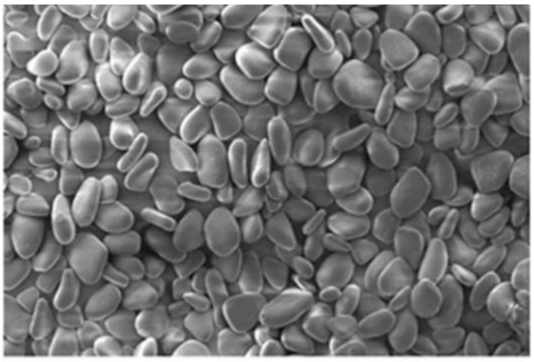

Figure 1. Form of starch granule Discorea alata with 300X magnification using SEM (Oliveira *et al.*, 2021)

3.2. Gembili (Dioscorea esculenta)

Gembili is a dioscorea tuber that is cultivated by people althought it has not been done on a larger scale (Prabowo *et al.*, 2014). The largest nutrient component of gembili tubers is carbohydrates at 21.44% (Richana & Sunarti, 2004). Gembili also contains bio-active compounds that are beneficial for health, such as water-soluble polysaccharides, dietary fiber, diosgenin and inulin. WSP from the dioscorea group contains polysaccharides, especially glucomannan, with a molecular weight between 200,000-2,000,000. Glucomannan is a hydrocolloid polysaccharide and is composed of D-mannose. D-glucose units in a ratio of 1.6:1 are linked together in -1.4 bonds. Glucomannan has some special physical properties, its development can reach 138-200% and occurs quickly, and its starch only expands by 25% (Ha *et al.*, 2000). The fiber and resistant starch content of Discorea esculenta are 38.42% and 9.54% in dry weight, respectively. Fiber and resistant starch are very beneficial for health, especially for the digestive system (Chirantika *et al.*, 2022).

Diosgenin is a class of natural saponins found in nuts and tubers of the dioscorea sp. Diosgenin is a precursor of various synthetic steroids that are widely used in the pharmaceutical industry (Raju & Rao, 2012). Previous studies, have revealed that diosgenin is absorbed through the intestines, and regulates cholesterol, therefore it reduces the risk of heart disease, especially lung cancer and blood cancer (Okwu & Ndu, 2006), as well as has estrogenic and anti-tumor effects (Moalic *et al.*, 2001).

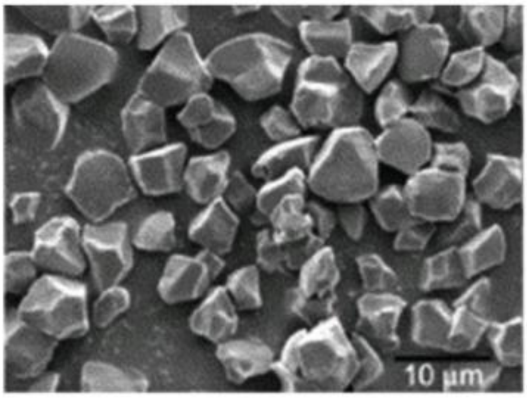

Figure 2. Gembili starch granules at 10 µm (Odeku, 2013)

Inulin can function as a soluble fiber that can reduce blood cholesterol levels (Nasar *et al.*, 2013). Gembili also contains oligosaccharides, namely lactulose, inulin, and raffinose by 0.231%, 2.541%, and 1.485%, respectively. Oligosaccharides can act as prebiotics and support probiotics with an optimal prebiotic index at 24 hours of incubation time (Khasanah *et al.*, 2019). Prabowo *et al.* (2014) assert that starch from gembili tuber granules has a polygonal shape of 0.75%

(Chirantika *et al*., 2022). Its size is smaller than those of tubers of canna, suweg, and coconut sweet potatoes. The shapes of starch granules are shown in Figure 2.

3.3. Gadung (Dioscorea hispida)

Gadung contains quite high carbohydrates, about 18 grams in every 100 gram of wheat tubers (Pambayun, 2008). The starch value of gadung tubers is 38.80% with an amylose starch content of 8.92% while the starch granule size of gadung starch is 4.32-4.25 µm (Santoso, 2015). Dioscorea hispida tubers contain dioscorine that can be poisonous to humans if consumed; the symptoms range from vomit, nausea, stomach pain, and health complications (Gunawan *et al*., 2019). Dioscorine is an alkaloid compound that is soluble in deep water and has the molecular formula of $C_{13}H_{19}O_2N$. The toxic content in gadung must be removed before being consumed (Irmayadani *et al*., 2019). Dioscorea hispida tubers are natural fibers with abundant starch sources as well as contain it contain lignin, cellulose, hemicellulose, and fiber (Hamid *et al*., 2019). The amount of dioscorine toxic in Dioscorea hispida can be reduced by immersion in sodium chloride or distilled water (Kresnadipayana & Waty, 2019).

Dioscorin is a protein found in the tubers of tropical plants from the family of dioscorea spp. Dioscorin functions as a protein reserve in yam tubers (Hou *et al*., 1999). Diosgenin is a major precursor in the production of synthetic steroids in the pharmaceutical industry. The biological activities of diosgenin, other steroidal saponins, and alkaloids have been tested in vitro. The anti-cancer bio-activity of diosgenin is related to the presence of hetero-sugar bonds and 5.6-double bonds in its structure. The structural conformations at C-5 and C-25 carbon atoms also play an important role in the biological activity of diosgenin (Raju & Rao, 2012). The shape of gadung starch granules is shown in Figure 3.

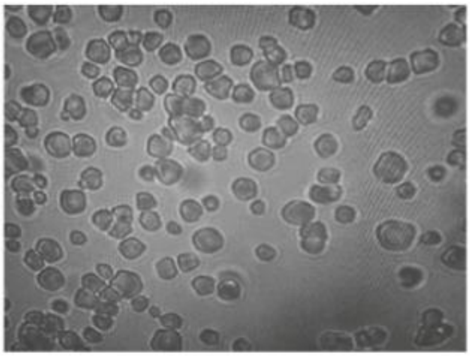

Figure 3. The shape of gadung starch granules with 1000X magnification
(Santoso *et al*., 2015)

3.4. Tomberoso (*Dioscorea pentaphylla L.*)

Discorea pentaphylla contains a lot of carbohydrates (85.65%) and little fat (0.03%) with no fiber. This tuber has high carbohydrates of lower nitrogen, which indicates that it is pure and quality starch (Sharlina *et al.,* 2017). According to Lazim *et al.* (2021), the gelatinization temperature of starch from tomberoso tubers is 81.04 ± 0.02 °C, and gelatinization will not occur below 76 °C. This type of tuber does not contain toxicity, so that it can be an excellent raw material for various industries. The amylose contents in tomberoso starch are 64.10 ± 1.15% and amylopectin 35.90 ± 1.15%. The crystallization degree of tomberoso tubers is 32.90 ± 2.59%. The starch granule shape of Dioscorea pentaphylla tubers is oval which represents 1.89 ± 0.44% of its starch content. Tomberoso tuber is a type of tuber that grows wild in the forest and is rarely used or consumed, so that it is mostly eaten by wild animals (Maneenoon *et al.*, 2008). The flesh of the tomberoso tuber is yellowish-white and yellowish. Tomberoso tubers are a source of carbohydrates and are used as a substitute for corn and sago. It, however, must be noted that before being consumed, tomberoso must be processed first to neutralize the cyanide acid (Purnomo *et al.*, 2012). The shape of the tomeroso tuber granules is shown in Figure 4 below.

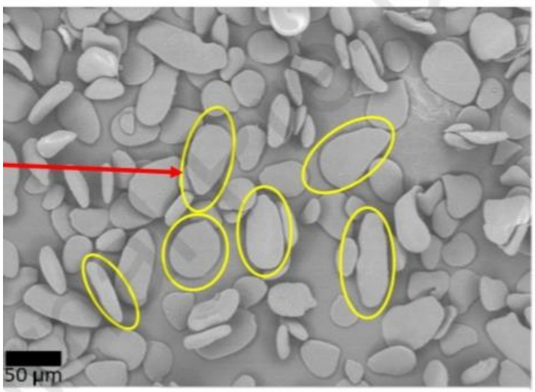

Figure 4. The form of starch granules from Discorea pentaphylla tubers
(Lazim *et al.*, 2021)

2.5 Jebubuk *(Discorea numularia)*

Purnomo *et al.*, (2012), describe jebubuk tuber as a type of tuber that grows wild in the forest and has multiple shapes. The powder of jebubuk tuber is a source of carbohydrates and is effectively used as a medicine. Jebubuk tuber tastes a bit bitter. The chemical content of jebubuk tubers includes water 71.9%, energy 443 KJ, proteins 2.04%, vitamin A 17 ug, and Zn 0.5 mg (French, 2006). The percentage of dry matter is quite high, at 33.11% and the starch content is 82.81% (Lebot *et al.*, 2016). The grain of Dioscorea nummularia tuber starch is triangular, but sometimes oblong to ovoid, with a width-length ratio of 0.6 to 45 mm (Fullagar *et al.*, 2006). (Figure 5)

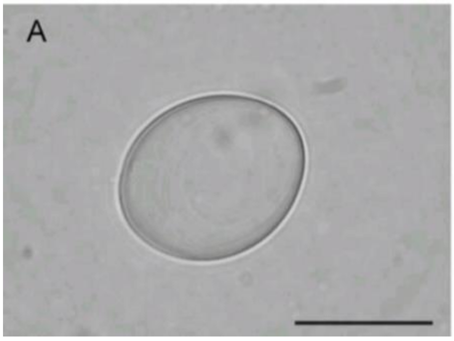

Figure 5. Starch grains from Discorea numularia with a magnification bar scale : 20 m (Fullagar *et al.*, 2006)

4. Leavening agents

The leavening agents used in self-rising flour are in the form of chemical yeast, and bicarbonate, which are very useful in the baking process. Arepally *et al.*, (2020), explain that gas will be produced when leavening agents are used in food. This gas is useful for development and will affect the texture of the product during combustion. Some of the widely used chemical leavening agents are baking powder (a mixture of sodium bicarbonate and acid), sodium pyrophosphate, sodium bicarbonate ($NaHCO_3$), and ammonium bicarbonate (NH_4HCO_3). The sodium bicarbonate dissolves and reacts with the acidulant in the dough and produces CO_2 as shown in Equation 1.

$$2NaHCO_3 + H+ \rightarrow Na+ + CO_2 + H_2O \qquad (1)$$

The timing of CO_2 to release is pivotal in the establishment of a uniform cell structure. When heated, the CO_2 is released and expands, while the volume will increase and produce the desired texture resulting in high quality baked goods. Some carbon dioxide carriers are used in baked goods. The three bicarbonates used as yeast bases are sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$), and ammonium bicarbonate (NH_4HCO_3). Potassium and calcium carbonate (K_2CO_3 and $CaCO_3$) are also very useful (Brose & Becker, 2001).

In general, chemical yeast is considered as a process that introduces CO_2 to a dough CO_2 expands when heated. During the baking process, with the action of saturated steam from water and hot air. Ammonia gas is also generated outside of carbon dioxide gas, which is important in the development of the dough during the baking process as it has been introduced early during the mixing process. There are two basic types of chemical yeast decomposition and chemical neutralization. In the decomposition, the chemical leavening agent is broken down in water or high temperatures and acquires a site to provide yeast gas in the system. In a neutralization system, the bicarbonate chemical is balanced in an acid, such as calcium phosphoric acid. The combination of yeast acids such as calcium phosphoric acid with bicarbonate chemicals, is very important, to determine the rate and reaction rates for optimal yeast effects. Acidic calcium phosphoric acid acts quickly if it is reacted with bicarbonate. The acidic calcium phosphoric acid results in the release of 80% of yeast carbon dioxide gas during the dough handling and proofing (Lajoie & Thomas, 1991).

Brose & Becker (2001) also report that different chemical leavening agents improve product quality. The combination of different bicarbonates and acids, with different acid levels, releases gases from different yeast, and it is suitable for bakery products. Product attributes, such as color, taste, texture, and overall acceptability, are affected by the reaction of the leavening agents, acid and flour components. The choice of bicarbonate and the acid content can affect the physical and chemical characteristics of the product (Lajoie & Thomas, 1991; Lajoie & Thomas, 1994).

5. Conclusion

Self-rising starch is starch that has been added with a developer and salt. It can be used for various food products to reduce the use of flour. Dioscorea is one of the tubers that can be used in the production of self-rising starch and provides more health benefits when consumed. In addition to being a source of carbohydrates, dioscorea contains bio-active compounds that healthier to consume. The bio-active compounds include water-soluble polysaccharides (WSP), low glycemic index, dioscorin, diosgenin, and inulin. The use of a leavening agent in self-rising starch will aid in the development of the product through a heating process. The leavening agents that can be used as food product developers are sodium bicarbonate, potassium bicarbonate, ammonium bicarbonate, potassium, and calcium carbonate.

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