Modifications Of Banana Starch And Its Characteristics: A Review

Tsani Adiyanti, Edy Subroto

Abstract: Banana is a potential source of starch. Many researchers have studied banana flour as a source of starch with various modifications, including physical, chemical, and biological modifications. This review aims to discuss several methods of modification of banana starch, characteristics of modified banana starch, and the benefits and applications of modified banana starch. Physical modification can be conducted by the heating method, including through heat moisture treatment (HMT), dual retrogradation (DR), annealing (ANN), drying modification by oven method and freezing method. Chemical modification can be conducted by esterification of octenyl succinic anhydride (OSA) and oxidation, and biological modification is performed by adding enzymes in banana starch. All the modification treatments were compared with the native starch so that it can be shown changes in starch characteristics from each modification. This modification in banana starch caused changes in the morphology of starch granules, amylase content, starch crystal structure, emulsifier properties, and even digestibility. Changes in the modification have better benefits compared to native banana starch and can be applied more broadly for various food and other products.

Index Terms: Banana starch, starch modification, resistant starch, digestibility

1 INTRODUCTION

Bananas are a potential source of starch, but bananas are subject to changes in physicochemical properties during the ripening process. This fruit has a short shelf life after harvesting until the beginning of ethylene production. In addition, in terms of the food industry, native banana starch applications have several disadvantages, including low heat stability, and ease of retrogradation during storage [1], [2]. However, it is necessary to modify banana starch, both physically, chemically, or enzymatically [3], [4]. The process of modification of banana starch can be done through the modification of environmental conditions, especially the temperature and atmosphere to extend the shelf life [5]. Modification of banana starch can also be done physically like the Heat Moisture Treatment (HMT), Dual Retrogradation (DR), and Annealing (ANN) methods [1]. HMT modified starch is usually used for foods with low water content, while the ANN method can be used for materials that have a higher water content where the temperature is adjusted below the gelatinization temperature but above the glass transition temperature [6]. Various modifications of banana starch affect several characteristics of banana starch. Physical methods can change the morphological shape of granules, crystallinity, viscosity, and digestibility [1], [7]. In addition to physical modification, chemical modification, and biological modification, especially enzymatically, are also widely carried out [8], [9]. Biological and enzymatic modification has more effect on the amylase content in starch [5], [9], while the chemical modification is very influential on the chemical structure, which results in an increase in the hydrophobic nature of starch and is used to stabilize the emulsifier [10]. The physicochemical characteristics of starch, such as amylase content and crystallinity, are believed to be responsible for the susceptibility of starch to enzymatic degradation [11].

Apart from these changes, modified starch can also turn into resistant starch. Resistant starch is starch that can not be digested, which has a low glycemic index that is often used in a variety of functional food preparations and is well consumed by diabetics [12].

2 MODIFICATION OF BANANA STARCH

2.1 Physical modification

Physical modification is generally by heating treatment, including the method of heat moisture treatment (HMT), dual retrogradation (DR), and Annealing (ANN). Hydrothermal treatment such as HMT is conducted by adjusting the initial water content of flour/starch to a low water content followed by heating at high temperatures [13]–[15]. In the research conducted by Cahyana et al. [1], banana flour was added to 30% distilled water; then, the flour was conditioned in a refrigerator at 4-5 ºC for 24 hours, then heated at 100 ºC for 8 hours. Modification of Annealing (ANN) is conducted by the addition of distilled water in high amounts, but heating using relatively low temperatures [16], [17]. A study conducted by Cahyana et al. [1] modified banana flour with the ANN method through the addition of distilled water up to 70%, followed by heating on a water bath at 55 ºC. While the modification of Dual Retrogradation (DR) is conducted on flour by adding less water than the HMT method, then heated to high temperatures with a shorter time than the HMT method. In his research, the ratio of water and flour was (1:5 w/v) then heated at 100 ºC for 30 minutes, followed by storage at 4 ºC for 48 hours [1]. In addition to the heating method, physical modification of banana starch can be conducted by the drying method [18], [19]. Pico et al. [20] conducted a study of fresh bananas that were stored at 4 ºC for 4 hours before peeling and slicing. This temperature was used to minimize the effects of the α-amylase activity and to avoid oxidation reactions during the heating process. Bananas are then processed by two different methods, namely the oven-based drying method and freeze-drying method. The results showed that the dried banana flour in the oven produced banana flour containing a phenolic compound, especially Epicatechin, which experienced a significant decrease whereas freeze-drying treatment produced digestible starch, which can be digested faster than oven drying. In another study, it was explained that cold storage before the heating process affected starch
degradation during processing at high temperatures [5].

2.2 Chemical Modification

Chemical modification of banana flour/starch can be carried out by esterification using octenyl succinate anhydride (OSA). This modification produces biopolymers that can be used to stabilize emulsions in various products [21]– [23]. OSA starch can be obtained by the esterification reaction between the starch hydroxyl group and octenyl succinate anhydride. The most widely used synthesis pathway is the reaction in liquid media with slightly alkaline conditions. This modification basically reduces hydrogen bonds between starch chains through the formation of alkoxide functional groups and starch -OH groups, causing swelling of the starch granules and diffusion of OSA molecules in starch granules [8]. Other chemical modifications of banana starch include oxidation method, which can produce banana starch which is a low viscosity, excellent adhesive capacity, stable to heating, and high clarity [2], [24], [25].

2.3 Biological modification

Biological modification of flour or starch is using enzymes. Reddy et al. [9] in their research modified banana starch by adding the enzyme pullulanase (40 U/g dried starch), then incubated in a water bath at 60 ºC for 10 hours while stirring. Pullulanase is an enzyme used to break α-1,6 bonds in carbohydrate macromolecular groups such as starch. This enzyme collaborates with α-amylase to hydrolyze carbohydrate or starch molecules completely. This method can be done by heating the starch in water for 10 minutes using a water bath before enzymatic hydrolysis. The addition of this enzyme can be used for preparations in making retrogradation banana starch [9]. Another biological modification is through enzymatic hydrolysis of banana starch using amylase to produce maltodextrin and glucose syrup. The results obtained show that the physical and chemical properties of maltodextrin and glucose syrup from banana starch are almost the same as those obtained from maize starch [26]. Apart from some of these modifications, the addition of phosphate fertilizer was also able to affect the characteristics of banana starch as was conducted in the study by Mesquita et al. [27] which reported that bananas cultivated in experimental gardens were first analyzed in the soil, then phoshating was fertilized. In this treatment, we must pay attention to the process of irrigation, thinning and removal of dry leaves, weed control, fertilizing, controlling pests and diseases, eliminating banana hearts, removing pistils, and cutting pseudostem after harvest. The results showed that fertilization with phosphate causes an increase in granule size and phosphorus content, decreased the degree of crystallinity and resistant starch content, changed the pasting properties, including decreased in the peak viscosity, final viscosity, breakdown viscosity, and setback viscosity.

3 CHARACTERISTICS OF MODIFIED BANANA STARCH

The results of the modification of banana starch by heating the process can be seen from the characteristics of crystallization using X-Ray Difractometry (XRD). Banana flour treated with Annealing shows the results that the flour still maintains its crystallinity structure [1]. While the morphological characteristics of the granules were observed using a scanning electron microscope (SEM) of 1000x magnification, it was found that the native banana flour granules had a size of around 10-40 µM. Granules appear as elongated oval-shaped solids. These results were not significantly different from the Annealing (ANN) method, but there were significant changes in the HMT and DR treatment. In the HMT treatment obtained an amorphous-like shape with a cohesive structure and not too dense, while the results of the DR treatment showed a cohesive structure. In the DR treatment, the results of SEM showed that the morphology of the starch granules was almost the same as the HMT treatment, but more aggregated or clustered. These morphological changes can cause differences in enzymatic digestibility. In addition to changes in the morphology of the granules, also changes in decreasing solubility [1], [4], [28]. The pasting properties of banana flour were analyzed using Rapid Visco Analyzer (RVA), the results showed that the characteristics of the modified banana starch paste changed by heating. The treatment of HMT was the most influential in changing the pasting properties compared to other treatments. This is due to the chain of starch polysaccharides is disrupted and reconnected during the heating process, then interactions between starch molecules are stronger than other treatments, so higher heat is needed to disrupt the structure of starch [1]. The drying method also affects the characteristics of bananas flour/starch, including the starch crystal structure [18]–[20]. The characteristics of starch obtained by the drying method also affect the phenolic profile present in the starch. The best quality banana flour in terms of the content of phenolic compounds is obtained by the combination of freeze-drying and extrusion methods. This is due to the freeze-drying can help preserve secondary metabolites such as epicatechin and extrusion, thereby increasing the bioavailability of flavonols in phenolic acids. In the case of food fiber, the freeze-drying method is also a better alternative than conventional oven drying. This is due to the inactivation of the effective endogenous α-amylase enzyme, which results in higher amounts of resistant starch [20]. In the modification of the drying method, it is first incubated at low temperatures before processing with the dry or freeze method. This is due to incubation at low temperatures affects the characteristics of the resulting banana starch. This is related to the activity of α-amylase and β-amylase enzymes. Low temperature is more likely to stimulate degradation of starch through the α-amylase pathway compared to the β-amylase pathway, which results in a different structure on the starch granules. At low temperatures, there are many rounded granules with holes in the surface and have a higher amylose content during incubation [5]. Biological modification with the addition of the pullulanase enzyme has been shown to increase the amylose content in banana starch. In addition, the results of the modification showed reduced viscosity and high thermal stability when compared to the native starch without modification [9]. The results of the esterification modification using OSA showed that the modified banana starch could be used as an emulsion stabilizer because this modification results in increased hydrophobic properties. Besides being able to be used as an emulsion stabilizer, this modified banana starch also has increased elastic properties compared to the native banana starch [10]. Modification through the addition of phosphate fertilizer during banana planting also affects several characteristics of the resulting starch. In experiments conducted Mesquita et al. [27], the addition of phosphate fertilizers gave changes in crystallinity, granule size, amylose, and resistant starch, as well as the
pasting properties and starch heat properties.

4 BENEFITS AND APPLICATIONS OF MODIFIED BANANA STARCH

4.1 Benefits of modified banana starch on digestibility
Modified banana starch can experience changes related to the digestibility of its starch, especially to resistant starch (RS) and slowly digestibility starch (SDS). Resistant starch is a starch that is beneficial for health and still has proper nutrition. Resistant starch is starch that escapes in the small intestine digestion then fermented by microflora in the large intestine resulting in the formation of short-chain fatty acids, especially butyric acid [29–31]. This resistant starch can also be used as food fiber. There are several factors that affect starch resistant to digestion, so resistant starch is divided into 4 [30], namely:

a. RS1: Starch which is physically inaccessible to digestion because it is trapped in a matrix that is difficult to digest
b. RS2: Starch that is not gelatinized in the cooking process
c. RS3: Starch retrogradation after being gelatinized
d. RS4: starch that is chemically modified so that the body's amylase does not recognize it

In this case, RS3 is the most interesting resistant starch for research development because this type of resistant starch is stable to heat making it possible to be used in a variety of dishes that are processed conventionally [12]. Starch has several characteristics in relation to the rate of digestibility; there are starches that can be digested quickly or rapidly digestible starch (RDS), starches that have slow digestibility or also called slowly digestible starch (SDS), there is also a resistant starch (RS) where starch is difficult to digest in the small intestine [7]. Banana starch, including starch which has a high content of resistant starch (RS), therefore banana starch can be used for high fiber food. This digestibility is affected by changes in the structural characteristics of the banana starch. But this digestibility is also affected by several factors, such as the source of starch, the size of the granules, the degree of crystallinity, and the long chain of amylopectin [11], [28].

4.2 Applications of modified banana starch
The results of chemical modification with the OSA esterification method on banana starch can be used for food, cosmetics, and health products, especially as an emulsion stabilizer [8], [21]. Modification of the heating method in banana starch is also beneficial for antidiabetic because it has a low glycemic index [9]. Starch granules are difficult to digest due to the short linear chain re-crystallinity that results from the cutting process of amylopectin branches. This converted flour during the heating process is effective in controlling glucose and lipid profiles in rat serum and shows hypoglycemic effects so that it can be used as a functional food ingredient [9]. The flour can also be used as starch resistant to starch which has the effect of slow digestibility [12]. Extruded banana starch can also be used as material for making bread. Banana starch used is the result of the modification of starch molecules by an extrusion process where the results obtained can encourage amylopectin to form SDS [32].

3 CONCLUSION
Some modification processes are carried out to get modified banana starch, which is better in terms of benefits and its components. Modifications can be conducted by physical, chemical, and biological methods. The physical modification was carried out by the method of heat moisture treatment (HMT), annealing (ANN), and dual retrogradation (DR), as well as oven drying and freeze-drying methods. In several studies, the effect of heating affects the morphology of starch granules, crystallinity, and other characteristics. Chemical modification is conducted by esterification by octenyl succinate anhydride (OSA) to produce biopolymers that can be used to stabilize emulsions in various products. Biological modification is one of them through enzymatic modification using pullulanase which will form resistant starch and increase the amylose content in banana starch.

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5 REFERENCES


