Potential of durian seed (*Durio zibenthinus* Murr.) flour as the source of eco-friendly plastics materials: a mini-review

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Abstract. Currently, plastics from non-renewable sources are being used less due to environmental concerns and switching to eco-friendly plastics. Eco-friendly plastics are usually produced from renewable materials, such as durian seed flour (DSF). DSF is a product made from durian seeds, and currently, it is only limited to a substitute for other ingredients in food products systems. However, DSF contains specific constituents that can be used to create eco-friendly plastics, rarely discussed. Thus, this mini-review briefly discusses the chemical composition and potential of DSF as a source of eco-friendly plastic materials.

1. Introduction

Plastics derived from non-renewable sources have posed significant problems and challenges to the world today. It produces more than 400 Mt per year worldwide and takes a long time to decompose. As a result, nonrenewable-source plastics have unfriendly environmental properties that pollute humans indirectly [1]. So, the exploration of more eco-friendly plastic raw materials is needed to support creating a clean environment.

Indonesia is a tropical country with high plant biodiversity [2], including tropical fruit plants [3], [4], with 592 species spread across its islands. Durian is one of the fruit cultivated in Indonesia and has higher production. According to [5], the durian production in Indonesia reached 1169802 tons in 2019. Generally, the durian fruit consumed directly is only fruit flesh and only has a percentage of 30 -35% of whole durian fruit. Furthermore, with 20-25%, the other part is fruit seeds, and 40-50% is fruit skin [6], [7]. From this fact, it is known that more than 233960.4 tons of durian seeds as a by-product of durian refers to durian production data published by the 2020 Central Statistics Agency. However, the community consumed only a tiny portion of durian seeds as a snack by boiling the durian seeds, and the rest was not appropriately utilized [8]–[10]. Furthermore, durian seeds have complete nutritional content. Nevertheless, the disadvantage of durian seeds is that they have a relatively high moisture content [7], [9], so they are easily damaged and have a short shelf life. Further processing into durian seed flour (DSF) maintains durian seed nutrition and shelf life.

DSF is a product from the durian seed through a simple processing method [6], [11]. Many researchers reported that the DSF has high starch gum content and also contains trace elements and minerals [6], [11]–[17]. According to Thakur *et al.* [18], starch, gum, protein, and lipid are the constituent components in manufacturing bioplastics or biofilm. Eco-friendly plastics, known as bioplastics, are plastics made from biological materials from animals, plants, or microorganisms to overcome environmental problems due to plastic waste disposal [19]–[21]. The criteria for determining the quality of the plastics, both bioplastics, and synthetic plastics, are mechanical properties and thermal stability. Commonly, the best bioplastics must have high mechanical properties and thermal stability [19]. However, no in-depth review has been found to discuss the potential of DSF as a bioplastic material that has not been widely studied. Therefore, this short paper review will be discussed that.

2. Durian Seeds and Its chemical Properties

Durian seeds are a by-product of the durian fruit. Durian seeds range 20-25% from whole durian fruit [6], [7]. In Indonesia, the production of durian seeds is approximately more than 233960.4 tons when referring to data from the Indonesian Central Statistics Agency in 2020 [5]. The main composition of fresh durian seed flour is moisture content, ranging from 48 -51.5%. Moreover, the fresh durian seed also contains 2-3% protein content, the fat content of <1%, carbohydrate content of 43.6 -47%, and ash content of 1-2% [7], [9]. The trace minerals compiler of the fresh durian seed of Ca (17 mg 100 g^{-1}), P (68 mg 100 g^{-1}), Fe (1 mg 100 g^{-1}), Na (3 mg 100 g^{-1}), K (62 mg 100 g^{-1}), betacarotene (250 µg100 g^{-1}), riboflavin (0.05 mg 100 g^{-1}), and niacin (0.9 mg 100 g^{-1}) [9]. In another study, Kumoro and his colleagues [4] also reported that the seed kernel of durian had a carbohydrate content of 18.92%, the protein content of 3.4%, a fat content of 1.32%, the fiber content of 19.88%, ash content of 1.58%, and moisture content of 54.9%. Based on the Kusriani *et al.*.study [8], the dried durian seed had higher moisture, ash, protein, crude fiber content, and lower fat content than the other fruit, such as dried jack fruit seed. In contrast, the dried durian seed had lower ash, fat, protein, crude fiber, and high moisture content compared with dried avocado seed. The comparison data is listed in Table 1.

Table 1. The chemical properties of durian seed compared with jack fruit, and avocado seeds

Parameters	Unit	Durian seed	Jackfruit seed	Avocado seed
Moisture content	%	9.0	8.0	6.5
Ash content	%	4.0	3.0	6.0
Crude fat content	%	3.6	3.7	5.0
Crude protein	%	14.6	13.9	17.1
Crude fiber	%	8.9	8.6	9.1

Sources: Kusriani *et al.*. [8]

3. Durian Seed Flour, and it's potential as eco-friendly plastics raw materials

Durian seed flour (DSF) is a product made from durian seeds [7], [22]. In general, the durian seed flour processing follows: Firstly, the durian seed was washed using water to remove the dirt, peeling, slicing, and drying using the sunlight or artificial dryer. Moreover, the dry durian seed was ground using mechanical milling and sieve with 80 mesh to obtain the DSF [7], [17]. The composition of DSF is listed in Table 2.

Table 2. The Composition of DSF

Parameters	Unit	Content	Reference
Carbohydrate	%	70.99 – 87.24	[11]–[17]
Protein	%	0.10 – 8.12	[11]–[17]
Fat	%	0.02 – 3.07	[11]–[17]
Moisture	%	4.78 – 17. 86	[11]–[17]
Ash	% d.b	0.23	[16]
Amylose	% d.b	22.76	[16]
Resistant starch	% d.b	29.83	[16]
Yield of starch	% d.b	18.2	[16]
Starch	%	40.29	[6]
Gum yield	% d.b	55.44	[6]
Starch yield	% d.b	26.58	[6]

Eco-friendly plastics, known as bioplastics, are defined as plastics that can be biodegradable by the environment, usually made of biological materials derived from animals, plants, or microorganisms [19]–[21]. Commonly, derived plants used as raw materials are starch [18] or whole flour [23]. According to Thakur *et al.*. [18], starch, gum, protein, and lipid are the main constituents for the bioplastic former. The main component of the bioplastic former was further explained as follows:

1) Starch

Starch is composed of amylose and amylopectin, which are the main constituent components of durian flour. The hydroxyl group in starch plays a role in forming hydrogen bonds [3]. Amylose plays a role in creating the film's mechanical properties [4]. Starch is generally widely used in producing bioplastics. It makes an odorless, tasteless, transparent film with the same properties as synthetic plastics [5] but has weaknesses in mechanical strength and sensitivity to high humidity [6]. Based on Table 2, the starch content in DSF was 40.29% [6], with an amylose content of 22.76% d.b [16].

2) Gum

Gum is a polymer that can form a gel soluble in water to expand by absorbing moisture and creating a rigid gel [24]. The gum content in DSF was 55.44% d.b, based on Table 2. Gum in DSF has a vital role in forming pastes and gels [6].

3) Protein

Proteins are macromolecules composed of several amino acids with functional properties such as solubility, gel formation, and water binding [25]. Proteins can be used as an ingredient in the manufacture of films or combined with other materials such as polysaccharides and lipids [26]. Based on Table 2, protein content in DSF was 0.10 – 8.12% [11]–[17]. The addition of protein in film making will improve the mechanical properties and barrier properties against water vapor [27].

4) Lipid

Lipids are compounds that contain hydrophobic fatty acids. Lipids can be used as ingredients in the manufacture of edible films or together with other materials such as polysaccharides and proteins [26]. In DSF, containing of fat/ lipid content was 0.02 – 3.07% [11]–[17]. The function of lipid incorporation into the film will affect the barrier properties of water vapor. It causes lipids to withstand water vapor transmission rate [28].

Based on these criteria, DSF meets all. DSF contained relatively high starch content, amylopectin content, starch yield, and gum yield, as previously explained. DSF is an excellent potential source to be developed as a raw material for making eco-friendly plastics. This potential needs to be studied further through scalable experimental studies. The previous survey was conducted by Retnowati *et al.*. [23], which transformed DSF into a biodegradable film. Their results showed that biodegradable film had bad characteristics like the lowest modulus young, tensile strength, and elongation break. Thus, the enhancement properties of bioplastics from DSF might be incorporated by other components.

Other components to improve the bioplastic properties of DSF can be done by adding other polysaccharide components, plasticizers, natural extracts, and so on to achieve the desired bioplastic characteristics. The functions and effects of incorporated other materials to bioplastics are described as follows:

1) Polysaccharide

Polysaccharides are polymeric molecules with constituent monomers in sugars or disaccharides. Polysaccharides are soluble in water and their ability to form gels. Non-starch polysaccharides hydrocolloids or gums because they can form colloids when they are dissolved in water. Examples include agar, alginate, carrageenan, gellan gum, pectin, grain gum, xanthan gum. There is also a class of proteins that include hydrocolloids, namely gelatin. The function of polysaccharides is as a thickener, gelling, stabilizer, and film-forming [25]. The addition of hydrocolloids will reduce the gelatinization temperature of starch. Films with the addition of hydrocolloids have been carried out, which affect the gelatinization temperature with the addition of pectin, gum Arabic [17], guar galactomannan, carrageenan, guar gum, and xanthan gum [29], [30], [31], [32],

Chitosan is a linear polysaccharide of N-acetyl-D-glucosamine and D-glucosamine obtained by deacetylation of chitin that is insoluble in water but readily soluble in acid solutions, making it ideal for the production of less hydrophilic bioplastics [33]. Several studies reported that the addition of chitosan increased the thickness, decreased the water vapor transmission rate, and had no effect on water's transparency, water solubility, and bioplastic's compressive strength [33], [34]. In addition, the application of chitosan as a filler increased the tensile strength, density, and modulus of elasticity and decreased elongation break of bioplastics [34]–[37] and LDPE plastics [38]. However, in Harsojuwono *et al.'s* study [7], chitosan improved the tensile strength elongation break and decreased the modulus young in bioplastic.

Glucomannan is a neutral hetero-polysaccharide composed of D-glucose and D-mannose linked by -1,4 glycosidic bonds [39]. The primary source of glucomannan abroad is the konjac tuber and similar tubers that are widely grown in the plains of East Asia, such as China and Japan [40]–[42]. In addition, glucomannan can be obtained from schlep tubers [43] and porang tubers [44]–[46]. Incorporating glucomannan as a form of konjac extract in the edible film-based whey protein improved the thickness, tensile strength, elongation breaks, and water vapor transmission rate [47]. The incorporation of glucomannan in chitosan-lysozyme film decreased edible film's moisture content, L*, and whiteness index. Moreover, the addition of glucomannan increased in elongation break, a*, b*, ΔE, opacity and did not affect the thickness, water vapor permeability, and tensile strength [48].

2) Plasticiser

The addition of plasticizers in bioplastics aims to increase flexibility and reduce their brittleness by expanding the space between polymer chains to reduce intermolecular attractions, and usually, plasticizers are hydrophobic [49]. Commonly, plasticizers used for bioplastics are glycerol and sorbitol [35]–[37], [49]–[51]. Applying glycerol as a plasticizer (in 5-30%) in bioplastic or edible film decreased the density, tensile strength, and modulus elasticity and improved bioplastic's elongation break [36]. Moreover, applying 0.3% glycerol as a plasticizer in the konjac-based bioplastics decreased the tensile strength and enhanced the elongation break, water vapor transmission rate, and water solubility [49].

Another plasticizer used is sorbitol. The 10-50% application decreases tensile strength and enhances bioplastics' elongation breaks [35]. Sofiah *et al.*.[50] comparing the glycerol and sorbitol as a plasticizer in *Musa paradisica Formatypica* concentrate based bioplastic showed the bioplastics with sorbitol of 1-5 ml as plasticizer had the higher tensile strength and also had the higher elongation break at used sorbitol of 4-5 ml than glycerol. However, the trend of tensile strength of bioplastic decreased with the increase of both plasticizers. Furthermore, the direction of elongation break bioplastic with sorbitol as plasticizer increased as a function of increased sorbitol addition. The same trend was also found in bioplastics with glycerol as plasticizer until 3 ml and decreased. Fahrullah *et al.*. [51] also compared the glycerol, sorbitol, and polyethylene glycol as a plasticizer at 30% concentration in whey composite edible film. The results showed that whey composite edible film with glycerol as a plasticizer had a lower tensile strength and higher elongation break than the edible film with sorbitol and polyethylene glycol as a plasticizer. However, all the edible film samples had a similar thickness and water vapor transmission rate.

Asia *et al..* [52] added sorbitol and glycerol with a 1-4% concentration on the edible film. The film added with sorbitol is more rigid and harder the texture than film without plasticizers. While the film is added with glycerol, the resulting film is more elastic and has a flexible surface. The addition of 2% sorbitol and 2% glycerol resulted in the tensile strength of 41.60 MPa and 35.72 MPa, respectively. The results showed that the film from Belitung taro starch with the addition of glycerol as a plasticizer had a lower tensile strength when compared to the movie with the addition of sorbitol as a plasticizer.

3) Natural Extract

The addition of an additive, like natural extract, aims to improve their functionality as active bioplastics with specific purposes, like anti-microbial, anti-bacterial, anti-fungi, and so on. Generally, the natural extract incorporated in bioplastics is an essential oil (like clove oil and so on), crude, or fractionation extract. Ulyarti *et al..* [33], in their study, incorporated clove oil in bioplastics with concentration 0.3 **-**1.5%, and its effect in the increase of thickness decreased transparency water vapor transmission rate. It did not affect water solubility and bioplastic's compressive strength. Hashemi and Jafarpour [53] incorporated the ethanolic extract of *saffron petals* in konjac glucomannan-based edible film. The results showed that the increases of saffron petal extract decreased water vapor permeability, improved transparency, and moisture content, and did not affect the thickness of the edible film. Moreover, the increases of *saffron petal* extract from 1 to 5% significantly increased the inhibition zone in all bacteria observed, like *S. Typhi*, *E. coli*, *S. sonnei*, *B. cereus*, and *S. aureus* in the edible film. Umiyati *et al..* [54] reported that adding *Calophyllum inophyllum* extract 5-20% w/w into bioplastics increases tensile strength but has no effect on elongation at break and modulus of elasticity, reduces water solubility and water vapour permeability, inhibits the growth of *E. coli* and *S. Aureus* bacteria. Velasco *et al..* [55] added the carvacrol with a concentration of 0-10% into the film mixture and inhibited the growth of *S. aureus*. With the addition of 8% carvacrol, it had the best zone inhibition with 15.89 mm.

However, the formulation with other components like another polysaccharide, plasticiser, natural extract, etc., should be done to obtain the optimum or best condition for producing eco-friendly bioplastic from durian flour according to the application later.

4. Conclusion

The DSF had the potential as a new renewable source for eco-friendly plastics production. According to the chemical composition, the DSF was rich in starch, gum content, and other trace components like protein and lipids, which are constituents of eco-friendly plastics formers. However, the formulations with other constituents of eco-friendly plastic compiler need to be observed and researched to find the optimum or best condition for the different applications.

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