

# CURRENT BIOPLASTIC FILM PRODUCTIONS DERIVED FROM AVOCADO (*Persea americana* Mill.) WASTE: A MINI-REVIEW

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## ABSTRACT

Avocado (*Persea americana* Mill.) is one of most favorite fruits for Vietnamese and along with consumption, the large amount of avocado waste is releasing and contributing significantly to environmental pollution. Recently, scientific reports indicated that avocado waste including seeds and peels contains starch, cellulose and antioxidants, which are useful to generate biofilms. Many studies have been implemented to figure out starch isolation methodologies and characterization from avocado seeds, and the additives to enhance biofilm performance such as plasticizers, fillers like chitosan, cellulose, etc. Moreover, avocado peel is also used for biofilm formation and exhibits some impressive results. These biofilms also verified their biodegradability within a short period of time, approximately 30 days after landfilling. Therefore, in this review, we summarize the methodologies of avocado seed starch isolation and corresponding biofilms quality assessment in presences of additives, including mechanical properties and biodegradability. This review would be a considerable reference to leverage avocado waste, an abandoned bioplastic-input source, aiming to deflate manufacturing cost in green-plastic production.

*Keywords:* Avocado seed starch, biodegradation, biofilm, *Persea americana* Mill., mechanical properties.

## 1. INTRODUCTION

Large amounts of food waste or agricultural waste are generated every day, significantly impacting the environment. These disposals are not recycled and directly treated by incineration or landfilling [1]. Minimizing the waste or recycling agriculture available resources would benefit the sustainable economy and cut down the input fee during the manufacturing process.

There is growing attention on the development of biopolymer materials due to their biodegradability and safety to the environment [2]. The key advantages of this material are widely available in nature and completely degradable. Various sources such as cereals, seeds, tubers, palms and roots have been utilized for biopolymer material productions. Notably, starch is believed to be an emerging source for biopolymer production and demonstrates its potential versus others. Starch can be obtained from fruits, stems, leaves, grains or seeds, and consequently chemically or physically modified to form the biopolymer and being employed into various applications [3, 4].

Avocado (*Persea americana* Mill.) is popular to Vietnamese daily life serving as a fruit. However, avocado waste including seed and peel is also valuable to bioplastic production. Numerous studies have reported that starch from avocado seed can be used as a source for biofilm production [5-10]. Indeed, treatments such as heat combined with moisture or additives modify starch structure, enabling transformation into biodegradable plastics. Other evidence suggests Chitosan with glycerol enhances plasticity of biofilm derived from Avocado starch [5-7, 11]. Besides, avocado peel is believed to create biofilm with impressive results [12]. The key obstacles in this early industry are figuring out the standard operating procedures (SOPs) in bioplastic production, collecting enough quantity of avocado waste from individual households or food firms and establishing large-scale production at minimum cost.

In this review, we summarize accessible methods at mini-scale bioplastic production that applies for avocado wastes including seed and peel. We list out the main additives that contribute to bioplastic mechanical properties, also providing the update about biodegradation tests of avocado waste derived biofilm. These findings would premise the new green concept in bioplastic production, that comes from a widely available source such as avocado in Vietnam and create a first step to optimize the SOPs for bioplastic production, a considerable green business-model.

## 2. AVOCADO VIRTUES IN BIOPLASTIC PRODUCTION

### 2.1. Avocado seed starch serves as bioplastic materials

Many studies have indicated that bioplastics can be made from starch of various sources such as potato, jackfruit seed, mango, rice, durian seed., etc. [13-15]. Avocado is one of the most popular fruits in Vietnam and its daily consumption is remarkable. Consequently, avocado waste such as peel or seed is releasing to the environment considerably. Stemming from such reality, avocado waste has been employed for numerous studies to produce starch, which is valuable for biodegradable plastics [16]. Ginting *et al.* 2015 suggests the procedure to isolate starch from avocado seed as described in Table 1 [5]. The starch extract-yield is 24.2%, containing 67.69% total starch including 32.47% amylose and 35.32% amylopectin. The other method generates the same starch extract yield but higher total starch (73.62%). In brief, avocado seed is chopped into 2 mm slices, rinsed with clean water and dehydrated under sunshine for 6 h. Afterwards, slurry is made by blending avocado slices with water (ratio 1:5, v/v). In the dehydrating step, the starch suspension is filtered, cooled and precipitated for 24h. Finally, starch is dried at 50 °C /24 h before sieved via 100-mesh (Table 1). However, mostly avocado seed starch is made by amylopectin (99.90%) [6].

In general, starch is composed of two types of glucose polymers, amylose and amylopectin. Amylose is a linear polymer, tends to parallel and form hydrogen bonds to each other, with less-water soluble structure and consequently increases hydrophobic property of starch [3]. In contrast, amylopectin is a highly branched polymer, forming intramolecular helical structures, driving the crystallinity of starch. Therefore, amylose level determines starch gelling capacity, decreasing viscosity due to its hydrophobic and increasing elongation at break, whereas amylopectin nets controls water-holding capacity. Both amylose and amylopectin are important to bioplastic derived-starch functionality and the amylose/amylopectin ratio decides physico-chemical properties of starch and as a result, dominate the mechanical properties of bioplastic. Typically, amylose accounts for 15-30% and amylopectin ranges from 70-85% among starch have been tested [17]. Evidence showed that higher amylose in starch is preferable and enhances bioplastic functionality compared to higher amylopectin [4] Therefore, methods generating more amylose from avocado seed would be a good reference for following studies about avocado seed starch bioplastics (Table

1). Moreover, evidence also showed that avocado seed paste after blending is encouraged to be treated with Sodium metabisulfite (SMBS) (0.015-0.03%) for 24h to avoid enzymatic oxidation, mainly by polyphenol oxidase and phenolates, preventing browning reaction and affects the color of bioplastics [9, 10, 18] (Table 1).

Grisales-Mejia *et al.* proposed a simplified procedure to isolate avocado seed starch, and all the blended paste is employed to bioplastic casting [19] (Table 1). Seeds are washed, disinfected and transferred into disc mill, followed by dehydration at dry oven 45 °C /24 h. Afterwards, the dried material size is further reduced by blade mill with No.140 Sieve and stored in desiccator. Despite the convenience during starch purification, this method resulted in the heterogeneous granule size, which may lead to reduced mechanical strength due to decreased interaction with plasticizers [20]. Therefore, the simplified method to purify high yield starch from avocado seeds is critical to large-scale bioplastic production, however, the uniformed granule size is also important to ensure flexibility and mechanical strength of bioplastic.

## **2.2. Avocado seed starch-based bioplastics and additives**

### *2.2.1. Plasticizer*

Starch granules from different sources exhibit different sizes and chemical composition (amylose and amylopectin percentage, for instance). Moreover, native starch films are fragile and tend to be crystallized, therefore the supplement of plasticizers such as glycerol, sorbitol or urea are critical to incorporating the starch granules [21]. Plasticizers increase biofilm flexibility by reducing intermolecular forces between starch molecules, thus enhancing chain mobility and reducing brittleness, forming hydrogen bonds [22]. On the other hand, plasticizers also lower glass temperature, preventing starch retrogradation [23]. These effects highlight the importance of plasticizers during biofilm casting.

Jimenez *et al.* isolates avocado seed starch with the yield 11.38% and followed by supplementing glycerol serving as a plasticizer to form biofilm [8]. Results showed that the addition of glycerol increases the elongation rate, up to 4 folds versus without glycerol, while enhancing water vapor permeability (WVP) and brightness of bioplastic versus the one made from sweet potato or banana starch (Table 2). This data suggests that the addition of plasticizers during casting process is a must and enhances biofilm quality.

Table 1. Procedures of Starch preparation and characterization summarized

Starch Preparation					Starch Characterization			Composition					Ref.
Material /Water ratio (w/v) before blending	Precipitate condition	Starch Drying Condition	Mesh # or Sieve Size	Yield (%)	Amylose (%)	Amylopectin (%)	Average granule Size (µm)	Total starch (%)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	
1:1	30 min stand Repeat twice	70 °C/ 30 min	Mesh #100	24.2	47.97	52.03	n/a	67.69	1.09	1.01	1.86	10.44	[5]
1:5	24 h stand	50 °C/ 24 h	Mesh #100	24.2	0.1	99.90	5-35	73.62	16.6	0.23	1.09	2.16	[6]
1:1	24-48 h stand	70 °C / 30 min	Mesh #100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	[7]
1:1	30 min stand	60 °C / until dried	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	[11]
0.3: 1	1 h stand/ filter 12 h stand	42 °C / 6 h	Sieve 80 µm	11.38	n/a	n/a	n/a	n/a	12	0.16	n/a	n/a	[8]
1:1 with 0.02% SMBS for 24 h	24h stand	40 °C / 48 h	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	[9]
1:2 with 0.03% SMBS for 24 h	Filter/ 1hr stand Spin wash 1200 rpm/10 min Repeat 3 times	50 °C / 24 h	Sieve 80 µm	18.3	16.80	83.2	n/a	86.63	12.7	0.67	n/a	n/a	[10]
1:1	Filtrate stand 1 h Wash with Distill water repeat 3 times	60 °C / 24 h	Mesh #100	16	0.1	99.90	n/a	73.62	16.6	0.23	1.09	2.16	[30]
5:1 with 0.015% SMBS for 24 h	Milled and filter	Vacuum filtration	Sieve 50 µm	13.1	31.4	68.6	3-30	n/a	n/a	n/a	n/a	n/a	[18]
Disc mill seeds and dehydrate at 45 °C /24 h and proceeding blade mill			Mesh #140	n/a	n/a	n/a	1.4-31.4	62.7	10.9	1.9	2.6	3.7	[19]

n/a: not analyzed as experiment design

SMBM: Sodium metabisulfite

Table 2. Bioplastic casting and mechanical property evaluation

Bioplastic casting				Biofilm properties					Ref.
Plasticizer /Filler	Starch: Additives (w/w)	Pasting temp	Drying condition	Tensile strength (MPa)	Elastic Modulus (MPa)	Shear stress	Elongation (%)	Water Vapor Permeability (mg/m.d.Pa)	
Glycerol 0.2 mL/g	Starch: Chitosan (7:3)	90 °C	60 °C / 24 h	5.096	36.359	n/a	14.016	n/a	[5]
Ethylene glycol 0.2 mL/g	Starch: Chitosan (7:3)	91.55 °C	45 °C / 24 h	22.5	1000	n/a	2.5	n/a	[7]
Glacial acetic acid (solubility) 0.25 mL, Sorbitol 0.75 g/g	Starch: Chitosan (0.1: 4)	70 °C	RT	n/a	n/a	n/a	n/a	n/a	[11]
Glycerol 0.25 mL/g	n/a	80 °C	30 °C / 72 h	10.78	n/a	n/a	13.09	3.98	[8]
Glycerol 0.315 mL/g + Gelatin 0.625 g/g	Starch: Nano-chitosan (4:5)	50 °C	45 °C / 24 h	n/a	n/a	n/a	n/a	n/a	[9]
Glycerol 0.3 mL/g	Starch: Cellulose Fiber (7:3)	85 °C	50 °C / 24 h	n/a	n/a	194 Pa/ 85 °C	n/a	n/a	[10]
Glycerol 0.2 mL/g	Starch: MCC (8:2)	85 °C	60 °C / 24 h	14.9		n/a	3.6	n/a	[30]
0.105 g Glycerol/0.3g Starch	Starch: SNC (w/w 0.3:0.003)	95 °C	RT	6.4	400	n/a	16.7	9	[18]
Glycerol: Starch (1:4, w/w)	Starch: Antioxidant (3:0.04)	85 °C	45 °C / 4 h	PExBIO: 6.6 PExIND: 9.1	PExBIO: 687 PExIND: 901	n/a	PExBIO: 5.2 PExIND: 3.5	PExBIO: 0.032 PExIND: 0.029	[19]

n/a: not analyzed as experiment design

MCC: Microcrystalline Cellulose

CNC: Cellulose Nanocrystal

SNC: Starch Nanocrystal

RT: room temperature

### 2.2.2. Chitosan

Chitosan is a deacylated derivative of chitin, which is a common structural material in animals and fungi kingdoms [24]. Chitosan can form complexes with certain metal ions, potentially enhancing or prolonging its antimicrobial activity. Furthermore, chitosan is soluble in mild-acidic aqueous solution, enzymatic degradation and gel/film forming capacity, which are beneficial to bioplastic production. Ginting *et al.* evaluated the role of chitosan at different gelatinization temperatures (80 °C, 85 °C, 90 °C), to overcome the fragileness of starch-based biofilm [5]. Results indicate that starch: chitosan (7:3, w/w) and gelatinization temperature at 90 °C, would reinforce biofilm through significantly increasing tensile strength and Elastic modulus index versus starch: chitosan (9:1) (Table 2). It has been reported that chitosan increases the compactness and bonding to starch as temperature raising [14] and consequently tensile strength of bioplastic is firmly empowered. However, Elongation at break favors lower temperatures and lower chitosan quantity [5]. Therefore, there is a tradeoff between mechanical properties and elongation at break as supplementing chitosan during bioplastic casting.

Further study generating biofilm with avocado seed starch: chitosan (7:3, w/w) and ethylene glycol serving as plasticizer [7]. Results showed that both tensile strength and elastic modulus are boosted dramatically as compared to the same amount of glycerol 20% (Table 2). However, elongation at break percentage is notably reduced. This finding indicates that ethylene glycol enhances mechanical properties more effectively than glycerol under the same conditions. Any innovation enhancing elongation rate would make ethylene glycol most beneficial to bioplastic plasticizer. In contrast, Fathurohman *et al.* switch the level starch (minority) and increase chitosan ratio (majority), creating a biofilm with fast-degraded (Table 2) [11]. Nevertheless, there is no clear comparison about biofilm properties, between main compositions as Avocado seed starch and another type of chitosan (majority). However, economic feasibility and complexity in material preparation are critical factors in choosing appropriate biofilm production procedures.

Some evidence showed that chitosan in larger granule size, exhibits low solubility [25], and as a result, affects biodegradation and biofilm casting progress. Recently, Suhartini *et al.* suggested a procedure generating bioplastic from nano-chitosan and avocado seed starch (Table 2) [9]. This study pointed out the method to generate nano-chitosan (Figure 1), which is believed to increase bioplastic stability [24]. Further tests showed that this bioplastic film can reduce moisture loss and prolong the shelf life of strawberries by 3–4 days at room temperature.



Figure 1. The combination between nano-chitosan and avocado seed derived-starch in biofilm production. (Adopted from Suhartini *et al.*)

2.2.3. Cellulose based materials

Natural cellulose fibers are environmentally friendly and have been used for many applications such as package materials [26]. These fibers or synthetic polymers like polyvinyl alcohol can combine with carbohydrate-based materials, creating sustainable materials [10]. Indeed, evidence shows that synthetic polyvinyl alcohol when mixed with pinto bean starch produces a composite film, which exhibit anti-bacterial properties [27]. Moreover, some reports also indicate that cellulose fiber can be supplemented into bioplastic casting and form eco-friendly products [28, 29].

Alemu *et al.* 2022 showed that extracted cellulose fiber powder might be used to create blend film in combination with starch derived from avocado seeds [10]. The blend consists of starch and cellulose fiber (7:3, w/w) with 0.3 mL/g glycerol as a plasticizer (Table 2). Further experiments indicate that this blend would increase gelatinization temperature while viscosity and shear stress reduced, compared to starch only. This result indicates a weaker interaction between starch and cellulose particles, leading to the lower viscosity and reduced shear stress during processing [10]. Therefore, the addition of cellulosic particles might be considered, depending on bioplastic purposes.

Another group pointed out that the addition of microcrystalline cellulose (MCC) during biofilm casting may strengthen the interaction between cellulose and starch particles [30]. MCC is a type of non-fibrous cellulose form that is partially depolymerized by a given solvent [31]. Evidence showed that MCC can reinforce bioplastic in a dose-dependent manner [32] and its combination with starch is validated by some reports [33-35]. Sartika *et al.* suggests a procedure to convert sugar palm fibers into MCC (Figure 2) [30]. Further analysis showed that starch in combination with MCC (7:3), plus with plasticizer glycerol 0.1 mL/g creates the best bioplastic among various conditions surveyed. Therefore, MCC could be a good additive during Avocado seed derived-starch bioplastic casting. However, the study also indicates that increasing the MCC content in starch-based bioplastic may reduce elongation at break.

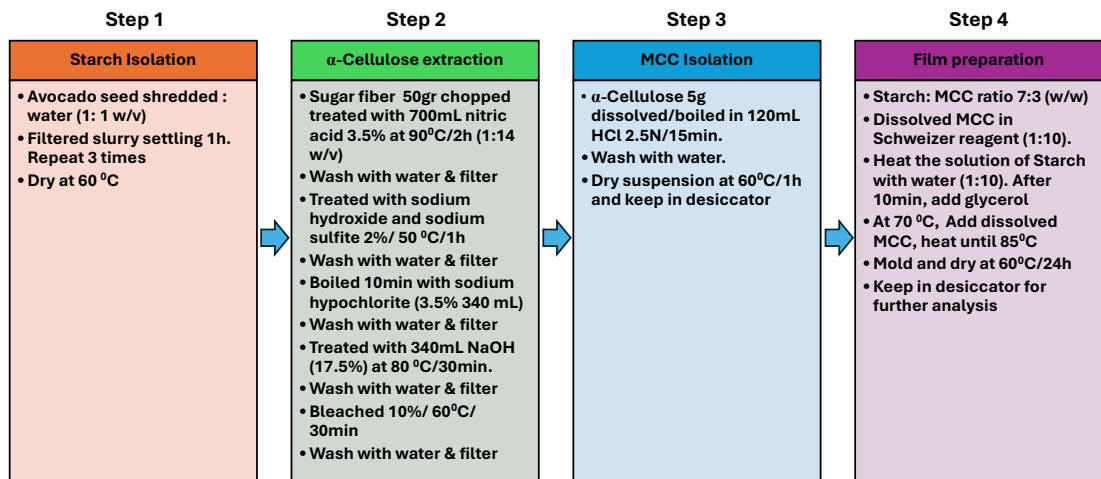


Figure 2. Starch and microcrystalline cellulose in bioplastic production (Adopted from Sartika *et al.*)

2.2.4. Avocado Seed Starch Nanocrystal

Starch nanocrystals (SNC) are crystalline platelets obtained by selectively hydrolyzing and removing amorphous regions of starch granules via acid hydrolysis [36, 37]. SNC exhibits beneficial properties including biodegradability, biocompatibility, renewability, and strong mechanical reinforcing capability, which are essential to biofilm formation. Furthermore, SNC

would generate a scaffold that evenly diffuses forces throughout biofilm, leading to the increase of tensile strength, decrease of water solubility [38]. Muñoz-Gimena *et al.* suggest the procedure to purify and apply avocado seed-starch nanocrystal (SNC) to starch based-bioplastic casting [18]. Results indicated that glycerol and SNC existences particularly produce thicker biofilm. This occurs because the film matrix becomes less dense, allowing greater mobility of starch polymer chains. Regarding mechanical properties, increase of glycerol/starch (15-45%) in casting composition significantly reduces elastic modulus and tensile strength while increasing elongation at break by approximately 10-fold. By contrast, SNC/starch (1-3%) accelerates the biofilm mechanical properties. Further analysis indicates that glycerol/starch (35%) combined with SNC/starch 1% is the best condition, maintaining low water vapor permeability while disintegrating within 48 h lab-scale composting. These results affirm that the combination of SNC with glycerol could be an effective strategy for reinforcing biofilms.

### 2.2.5. Antioxidant extracts

The key mission of food biofilm is to extend the shelf life of food and slow down the oxidation reaction. To attain that, natural antioxidants are good additives to bioplastic production since their safety and no side effects [18, 39]. Grisales-Mejia *et al.* employs the antioxidants from its own avocado peel (epicarp) during bioplastic casting (Table 2) [19]. Either by subcritical water extraction (PEXIND) or biorefinery process (PEXBIO) significantly increases water solubility of bioplastics as compared to control group (without antioxidants). This result indicates an increased tendency of bioplastics to dissolve in water. In contrast, the additions of CaCl<sub>2</sub> or cellulose nanofibers are reported to decrease water solubility [12, 40]. However, the higher water solubility also allows biofilm disintegration to occur faster and avoid negative impact on ecosystems. Further analysis indicated that biofilms with antioxidant extracts PEXIND or PEXBIO result in higher total phenolic compounds and antioxidant capacity versus to the control, consequently secure the shelf life of food from microbial growth.

## 2.3. Avocado peel fiber-based film

Avocado peel (AP) accounts for 13% of the total dry weight and is composed of cellulose (28%), hemicellulose (25%), and lignin (4%) [12]. These constituents would significantly minimize the cost for input sources in bioplastic production and benefit the environment sustainability. Ahmed *et al.* suggested the procedure to isolate the extract from avocado peel (APE), which is feasible for biofilm production [12]. Briefly, Avocado peel is washed and blended before proceeding lignin removal step (Figure 3). Next, the fiber is under whitening step by Alkaline solution, followed by washing, drying at 50 °C overnight and blending before swelling step. APE afterwards, goes through dissolution and crosslinking steps. APE is poured into the tray, coagulated with 500 mL ethanol, gently agitated and immersed in distilled water and 5% glycerol, respectively for 5 min. The film is dried at 28 °C for 24 h before characterization. This protocol proved that 0.3g CaCl<sub>2</sub> addition during bioplastic film processing plays an important role in cross-linking between polymer chains and reducing water solubility of biofilm by minimizing the interaction between hydroxyl group in biofilm to water molecules and therefore, CaCl<sub>2</sub> can slower moisture absorption and increase biofilm stability. Moreover, tensile strength is intensified once 0.3 g CaCl<sub>2</sub> is added during crosslinking step even higher than that of conventional polyethylene film (up to five-fold, however, elongation at break was significantly reduced. These features suggest APE is an ideal source for bioplastic film production. However, 0.3 g CaCl<sub>2</sub> supplement would dramatically reduce elongation at break. Therefore, it is necessary to test more conditions to extend the elongation at-break rate, to make this bioplastic film more beneficial.

### 3. BIODEGRADATION CAPACITY

Bioplastics are degraded by soil microorganisms, which consider biopolymers such as starch or chitosan as carbon and energy sources [41, 42]. The degradation of bioplastics, therefore, occurs faster than regular synthetic polymers. Currently, there is no evidence testing bioplastic degradation made by avocado seed starch. However, Fathurhoman *et al.* have evaluated the bioplastic degradation in the soil, made of chitosan (majority) and containing a small proportion of avocado seed starch and plasticized with sorbitol (Table 2) [11]. This study mainly examines the role of Avocado seed derived starch in bioplastic degradation. Bioplastic weights are examined every 2 days after cleaning and drying. Results showed that within 12 days of survey, bioplastics degrades approximately 76% of weight. Furthermore, the study also found that avocado seed derived starch significantly promotes the degradation of bioplastic, evidenced by the value slope of weight. This result suggests that avocado seed derived starch not only provides renewable material for bioplastic production but also accelerates the bioplastic degradation in soil.

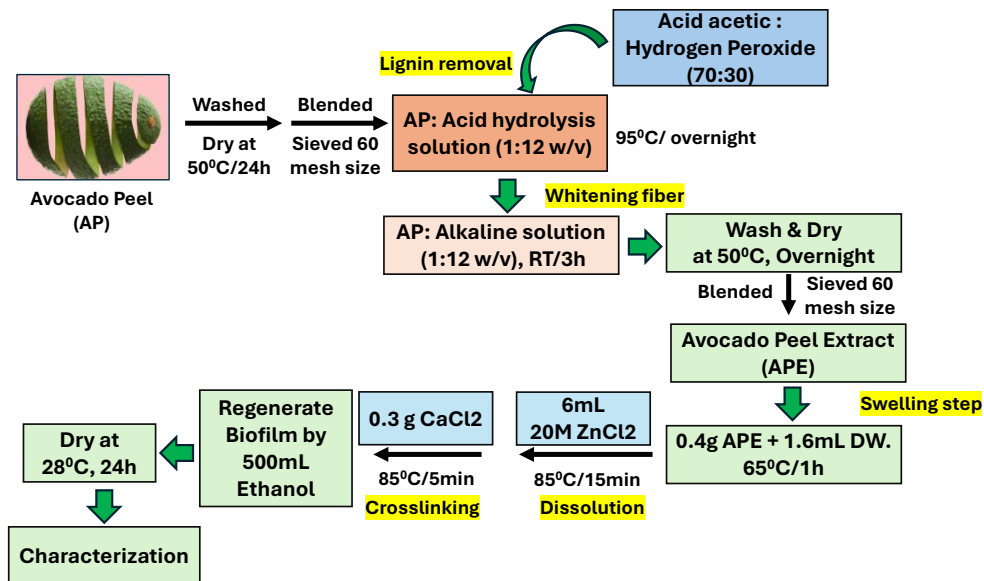


Figure 3. Procedure to generate bioplastic film from Avocado peel (Adopted from Ahmed *et al.*)

Similarly, bioplastic films derived from avocado seed starch, with and without antioxidant supplements, demonstrated rapid biodegradation [19]. Bioplastic films are less disintegrated in antioxidant supplemented group as compared to the control film at day 4 and day 8. The slow disintegration might be explained that phenolic compounds in antioxidants supplemented, might partly limit the decomposition of bioplastic film. However, the difference in biodegradation between groups became negligible by day 12. Therefore, the supplement of antioxidants during biofilms casting is only resistant to the integration at short period of time (below 12 days of survey) while significantly improving bioplastic mechanical properties and serving as anti-bacterial growth in food biofilm.

In the other type of bioplastic derived from avocado peel, Ahmed *et al.* evaluated the biofilm in the moisture soil 20% for over 28 days of survey [12] and results showed that this type of biofilm possesses disintegration beyond 77% for 28 days and half-time life about 3-5 days. This result is an incentive for bioplastic film production and incredible versus synthetic plastics. Nevertheless, the addition of  $\text{Ca}^{2+}$  to the materials would reduce disintegration while increasing the half-time life of biofilm. These encouraging disintegration rates are incredible

compared to the other starch derived-bioplastics degradation tested, which range from 29.5 to 79% [29]. Therefore, the utilization of avocado waste can significantly contribute to solving persistent environmental issues related to plastic waste.

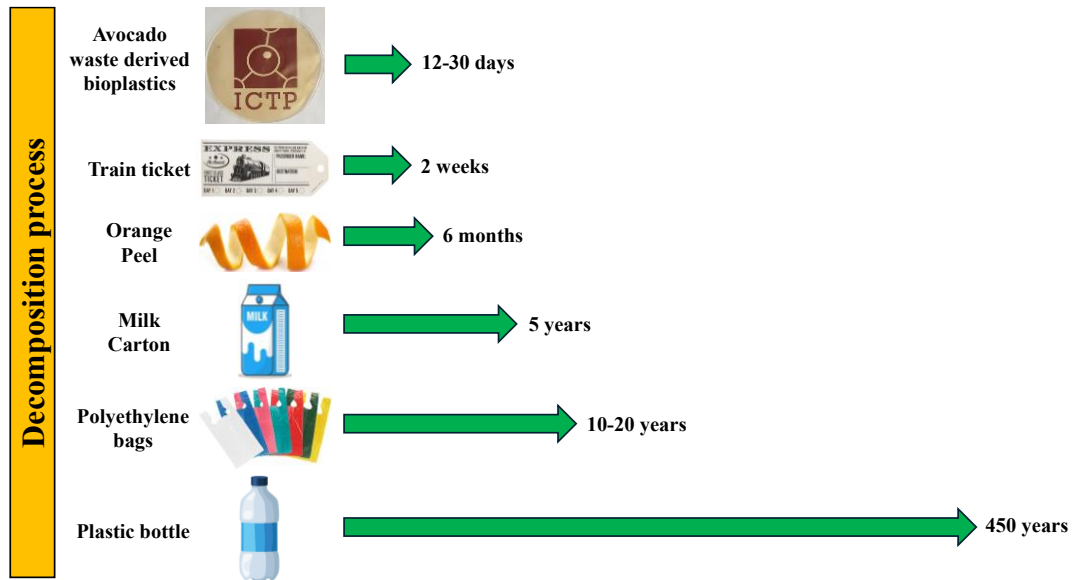


Figure 4. The process of bioplastic decomposition in comparison to conventional plastics.

#### 4. CONCLUSION

The potential of avocado waste in bioplastic production is extremely high and significantly reduces the negative environmental impact of avocado related food industry. The main sources to produce bioplastics from avocado are the seed and peel, which contain the ingredients such as fiber and starch necessary to form biofilms. Different strains of avocado and different methods might result in different yields of starch extraction. However, recent evidence suggests that higher levels of amylose in starch material input would be preferable. The biofilm from both avocado seed and peel exhibits the essential properties of biofilm such as high tensile strength and elastic modulus and elongation at break. Furthermore, the addition of plasticizers plays an important role in biofilm viscosity and flexibility. Additives such as chitosan, cellulose based materials, starch nanocrystal, antioxidants and  $\text{CaCl}_2$  are surveyed, and each additive contributes distinct improvements in biofilm properties. These findings are premises for mini-scale bioplastic production and innovation to combine and optimize these additives are necessary. Balancing elongation and mechanical properties remain challenging during biofilm casting, however, the involvements of nanofillers including nano-chitosan, MCC or SNC could be a good choice for advancing biofilm quality. Moreover, the addition of antioxidants during biofilm casting would be an advanced step to maintain food moisture, preventing microorganism growth and extending the food life longer. Regarding biodegradation, bioplastics derived from avocado waste exhibit rapid disintegration compared to other conventional plastics in landfill condition (Figure 4). These pieces of evidence demonstrate the potential of avocado waste as a replacement for conventional plastics. Future research should focus on scaling up these processes to commercial levels and evaluating their techno-economic feasibility. Once large-scale production is standardized, avocado waste-derived biodegradable plastic will be present in every sector of our lives, and the negative environmental impact of conventional plastics could be significantly mitigated. To reach that goal, there is still a long way to go in research and development (R&D) and in campaigns aimed at changing plastic consumption habits.

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## TÓM TẮT

### CẬP NHẬT NHỮNG NGHIÊN CỨU HIỆN TẠI VỀ QUÁ TRÌNH SẢN XUẤT MÀNG SINH HỌC TỪ CHẤT THẢI QUẢ BƠ (*Persea americana* Mill.)

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Quả bơ (*Persea americana* Mill.) là trái cây yêu thích và được sử dụng hàng ngày tại Việt Nam. Tuy nhiên với nhu cầu sử dụng lớn, lượng chất thải từ vỏ và hạt bơ là rất nhiều, đóng góp đáng kể vào rác thải dân sinh và công nghiệp. Nhiều nghiên cứu chỉ ra rằng, sản phẩm phụ từ quả bơ chứa tinh bột, cellulose và các hợp chất chống oxy hóa, những chất này rất cần thiết cho quá trình tạo màng sinh học (biofilm). Nhiều nghiên cứu đã được thực hiện để tìm ra phương pháp chiết xuất tinh bột từ hạt bơ và đánh giá chất lượng tinh bột, dùng làm nguyên liệu đầu vào sản xuất màng sinh học, đồng thời các chất phụ gia như glycerol, chitosan, cellulose, v.v..., nhằm tăng cường tính chịu lực của màng sinh học cũng được khảo sát. Ngoài ra, vỏ của quả bơ cũng được tận dụng, để tạo ra màng sinh học và đạt được những kết quả khả quan. Quan trọng hơn, kết quả nghiên cứu còn cho thấy rằng, những màng sinh học này tự phân hủy trong đất với thời gian rất ngắn (khoảng 30 ngày). Trong phạm vi bài viết này, chúng tôi tổng hợp lại những phương pháp hiện nay, dùng để tách chiết tinh bột từ hạt quả bơ, dùng để tạo nên các màng sinh học tương ứng. Thêm vào đó, chúng tôi cũng đánh giá vai trò của các chất phụ gia thường dùng để pha trộn khi đổ khuôn. Bài tổng hợp này sẽ là tài liệu tham khảo hữu ích trong khâu quản lý chất thải từ việc tiêu thụ quả bơ và nền tảng cho tối ưu hóa sản xuất công nghiệp màng sinh học.

*Từ khóa:* Tinh bột quả bơ, phân hủy sinh học, màng sinh học, *Persea americana* Mill., đặc tính cơ học.