A Critical Review on Tropical Fruits Peels as Eco Enzyme: A Case of Indonesian Exotic Fruits

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Abstract. Indonesia has a tropical climate rich in exotic fruits, such as pineapples, bananas, oranges, papaya, mangoes, watermelons, and pomegranates. Apart from its abundant production, these fruits also have parts of the fruit that are rarely used, such as seeds and peels. The peel of exotic fruits can be used as an eco-enzyme because of its enzyme content. Eco-enzymes are a type of natural compound that can usually be extracted from fruit peel or waste. Eco-enzymes are vinegar made by fermenting food waste with sugar to form alcohol. This review focuses on the potential use of exotic fruit peels and the enzymes they contain, which are used as eco-enzymes. Eco-enzyme production reduces the accumulation of organic waste and has several other benefits, including cleaning floors, equipment, etc. Extensive research in the industrial sector must also be carried out to improve the nutritional and functional potential of the peel of this exotic fruit.

1 Introduction

Indonesia is the largest archipelagic and maritime country in the world. It is located in a tropical region with an area of 7.81 million km2 and a total area of 2.01 million km2 of land [1]. Its tropical climate makes Indonesia one of the wealthiest countries in terms of biodiversity, where Indonesia has 40,000 plant species [2]. This biodiversity also includes more than 450 fruit species, which shows large market potential [3]. Fruit is a plant widely consumed by humans and animals as a food source [4] . Often, the peel of the fruit is the part that is not eaten because it is considered less nutritious or challenging to digest [5]. However, recent research shows that fruit peel contains natural enzymes that can be used in eco-enzyme production [6].

Based on annual data on commercial fruit production capacity available on the Indonesian market [7], there are 26 that are considered exotic fruits, of which seven are the primary fruit commodities, namely pineapple, banana, orange, papaya, mango, watermelon, and pomegranate (Table 1). Although almost every province in Indonesia contributes to its production, Java and Sumatra are reported to be the primary producers of these fruits with

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more than 70%, namely bananas (84.17%), mangoes (80.70%), and oranges (73.21%) [7]. Most exotic fruits in Indonesia are eaten ripe or unripe, such as bananas and mangoes.

Table 1. Indonesian exotic fruit production in 2022.

No	Type of fruit	Production (ton)		Growth (%)	Peel content (%)	Ref
		2021	2022			
1	Pineapple	28.860.573	32 037 752	9.92	15	[8]
2	Banana	87.409.534	92 454 270	5.46	40	[9]
3	Orange	24.010.632	25 519 988	5.91	50	[10]
4	Papaya	11.682.359	10 895 781	-7.22	8.5	[11]
5	Mango	28.353.909	33 088 947	14.31	15-20	[12]
6	Watermelon	414.242	367.816	-12.62	50-60	[13]
7	Pomegranate				26-30	[14]

2 Indonesian Exotic Fruit

2.1 Taxonomy

The scientific classification of seven selected Indonesian exotic fruits is shown in Fig. 1.

2.2 Pineapple Peel

Pineapple (Ananas comosus) a fruit widely produced in Indonesia and belongs to the Bromeliaceae family. Pineapples have short stems and slender, tough leaves that grow into medium to large fruit [15]. Pineapples grow best in subtropical and tropical areas where the weather is warm but cool at night [16]. Pineapples are widely consumed because they taste sweet and sour and vary whether consumed fresh, cooked, made into juice, or preserved [17] and leave residue in the form of peel. Pineapple peels contribute 15% of the total weight of fresh pineapple [8].

Classification	Pineapple	Banana	Orange	Papaya	Mango	Watermelon	Pomegranate
Kingdom	Plantae	Plantae	Plantae	Plantae	Plantae	Plantae	Plantae
Subkingdom	Tracheobionta	Tracheobionta	Tracheobionta	Tracheobionta	Tracheobionta	Tracheobionta	Tracheobionta
Super division	Spermatophyta	Spermatophyta	Spermatophyta	Spermatophyta	Spermatophyta	Spermatophyta	Spermatophyta
Division	Magnoliophyta	Magnoliophyta	Spermatophyta	Magnoliophyta	Magnoliophyta	Magnoliophyta	Magnoliophyta
Class	Liliopsida	Liliopsida	Dicotyledonae	Magnoliopsida	Magnoliopsida	Magnoliopsida	Magnoliopsida
Subclass	Commelinidae	Commelinidae	Rosidae	Dillebiidae	Rosidae	Magnoliidae	Rosidae
Order	Bromeliales	Zingiberales	Sapindales	Violales	Sapindales	Cucurbitales	Myrtales
Family	Bromeliaceae	Musaceae	Rutaceae	Caricaceae	Anacardiaceae	Cucurbitaceae	Punicaceae
Genus	Ananas	Musa	Citrus	Carica	Mangifera	Citrullus	Punica
Species	Ananas comosus	Musa paradisiaca	Citrus nobilis	Carica papaya	Magnifera indica	Citrullus lanatus	Punica granatum L.

Fig. 1. Scientific classification of exotic fruits in Indonesia

2.3 Banana Peel

Banana (Musa paradisiaca) is a fruit plant widely cultivated in tropical and subtropical areas, with consistent yearly harvests. The average weight of a banana is 125 grams, of which around 75% is water and 25% dry matter content [18]. Bananas are often consumed raw, cooked, or dried and ground as flour and used in cakes [11]. They are only used in the flesh,

leaving residue in the form of peel. Banana peels account for 40% of the total weight of fresh bananas [9].

2.4 Orange Peel

Oranges (Citrus sinensis) are a popular type of fruit grown in tropical or subtropical climates and are a popular fruit commodity on the world market. Over half of the world's oranges are produced in Asia and the Americas [19]. Oranges are often consumed directly or processed into juice, while in industry, they are mainly used to make jams, jellies, and flavor enhancers for drinks [20]. Oranges contribute residue in the form of fruit peel, which reaches almost 50% of the total weight [10].

2.5 Papaya Peel

Papaya (Carica papaya) is the most famous member of the Carica genus fruit and is widely cultivated in tropical regions. Papaya flesh is often consumed directly, while in the industrial world, it is frequently used to make soap, jam, candy, pickles, and jelly [21]. Generally, people only consume the flesh of the papaya fruit, while other components, such as the flesh and seeds, are considered waste. Papaya provides by-products in the form of peels, reaching 12%, and seeds at 8.5% of its total weight [22, 23], which can be beneficial prospectively considering the content and nutrients available. Papaya peels is usually used for cosmetic beauty and skincare products [24, 25], so it can minimize environmental pollution and make papaya peel valuable waste.

2.6 Mango Peel

Mango (Mangifera indica) is a type of fruit in the Anacardiaceae family that grows in tropical and subtropical areas [26, 27]. Mango is the second fruit crop that produces the most significant production in the world after bananas [28]. Mangoes are generally consumed as a dessert fruit served as ice cream, jam, juice, nectar, powder, puree, and canned mango slices in syrup [29-32]. Mangoes produce by-products in the form of peel and seeds, which contribute about 15% to 20% of the fruit's weight [12].

2.7 Watermelon Peel

Watermelon (Citrullus lanatus) is a climbing fruit plant from the Cucurbitaceae family. Watermelon is popular in tropical Asia, America, India, China, and Iran [33]. This fruit grows optimally in tropical areas under sunlight and high temperatures above 25°C [34]. Watermelon contains about 93% air, 6% carbohydrates, 0.2% fat, 0.6% protein, lycopene, vitamins, and minerals (0.2%) [35, 36]. Watermelon is often consumed in juice form, and generally, only the flesh is used, while components such as the peel remain waste. Watermelon rinds generate large amounts of food waste (50-60%) from watermelon production to watermelon consumption, causing many environmental challenges [13].

2.8 Pemogranate Peel

Pomegranate (Punica granatum) has become a significant concern in agriculture and health. Initially, consumption was limited due to the complicated extraction process. However, with advances in scientific research, this fruit is becoming more widely known [37]. Apart from being eaten directly, pomegranates are also processed into juice, wine, oil, and jam products.

One exciting thing about this fruit is the peel waste, which, in the juice-making process, accounts for around 26–30% of the total weight of the fruit [14, 38]. So, researchers and industries have paid attention to increasing the use of pomegranate peels in various life applications, including in beauty and skincare products [39]. In this way, pomegranates provide health benefits when consumed directly and when the waste is used for other purposes that benefit humans.

3 Nutritional Potential of Indonesian Exotic Fruit Peels

Apart from seeds, remaining pulp, core, stem, and leaves, fruit peel can be considered a prominent by-product and can be utilized in the fruit processing industry. The fruit found in Indonesia has various variations and sizes. However, based on Fig.1, Indonesia has seven exotic fruits with high productivity every year, such as pineapple, banana, orange, papaya, mango, watermelon, and pomegranate. These fruits have great potential as the main source of making eco-enzymes. Several studies have been carried out on the nutritional content of the peels of these seven exotic fruits, and it was discovered that these fruits contain enzymes that can be used as the main ingredient for making eco-enzymes. The enzyme content found in the peel of this exotic fruit, in the form of bromelain enzyme, lipase enzyme, and protease enzyme, is tabulated in Table 1.

Table 2. Enzyme content of exotic fruit peels in Indonesia

No	Type of Fruit Peels	Enzim Bromelain (%)	Enzim Lipase (%)	Enzim Protease (%)	Ref
1	Pineapple	45.2	-	49.7	[40, 41]
2	Banana	-	6	58.62	[42, 43]
3	Orange	-	-	29.5	[41]
4	Papaya	-	-	52.4	[41]
5	Mango	-	-	24.6	[41]
6	Watermelon	-	-	45.2	[41]
7	Pomegranate	-	-	54.28	[43]

Table 2 shows that the bromelain enzyme content in pineapple peels is the only fruit with this content compared to other fruits. The 45.2% bromelain enzyme in pineapple peel can be used as an eco-enzyme because of its anti-inflammatory, antibacterial, antifungal, and anticancer properties [44]. Apart from that, pineapple peels also contain 49.7% of the protease enzyme and is the fourth most abundant fruit peels that contains this content. According to [45], the bromelain enzyme contained in pineapple peels works by stimulating phagosity and inhibiting exposure to bacteria when testing the fungus Candida albicans with trypsin in vitro. Eco-enzymes can be degraded because eco-enzymes from pineapple peels contain multi-active hydraulic enzymes such as protease, bromelain, and abundant vitamin C [46]. Table 1 shows that banana peel contains 6% lipase enzyme and 58.62% protease enzyme. Banana peel is the only exotic fruit containing the lipase enzyme and has the highest potassium enzyme content compared to other fruits. According to [47], the contents of these two enzymes can be used as an eco-enzyme liquid, which can be used as a disinfectant, insecticide, floor cleaner, and gutter cleaning liquid; the resulting residue can be used as organic fertilizer.

Regarding the content of the protease enzyme contained in Table 1, papaya peel, and pomegranate peel stands out with their high content, amounting to 52.4% and 54.28%, respectively. These two types of fruit peel offer great potential as a source of eco-enzymes in

degrading organic waste and environmental pollutants. The eco-enzyme resulting from using the protease enzyme in papaya fruit will be acidic with a low pH value [48]. Therefore, its use is usually combined with other organic materials to produce maximum results. Its use is usually combined with other organic materials to produce maximum results. The protease enzyme content in pomegranate peel and papaya peel shows antibacterial power against Pseudomonas aeruginous, Shigella sp., E. coli, and Salmonella typhi [49]. However, several other types of fruit peels also contain protease enzymes that are worth considering. Watermelon peel, orange peel, and mango peel have relatively high protease contents, respectively 45.2%, 29.5%, and 24.6%. Although the protease enzyme content in mango peel and orange peel is lower than others, these fruits still contribute as a source of eco-enzymes in applications that require proteolytic activity [50]. Thus, various fruit peels offer potential as a valuable source of eco-enzymes for cleansing, anti-inflammatory, antibacterial, antifungal, anticancer, and disinfectant efforts. While some types of fruit peel stand out with the highest enzyme content in one or more types of enzymes, others also have significant potential in their contribution to developing eco-enzymes for sustainable applications.

4 Future Trends Perspective

Tropical fruit peels are a rich source of organic ingredients, phytochemicals, and substances with beneficial nutraceutical qualities and can be used as value-added products [51]. However, due to the lack of adequate infrastructure to process it, everything becomes waste, causing pollution and environmental disasters. Most of these residues are rich in nutrients and enzymes, containing cellulase, amylase, pectinase, protease, etc [52]. These enzymes can be extracted through a fermentation process in the laboratory, but this has yet to be done on a large scale. On the contrary, efforts are being made to utilize these enzymes (eco-enzymes) as an alternative to cleaning and disinfectants so that the waste from these residues can be put to good use. So, to utilize these wasted fruits and vegetables efficiently and prevent further losses, they can be used to make these enzymes [53]. Eco-enzymes can be made using orange peel because of its high acid content. Hence, there is a need to adopt efficient ways to reuse such leather, make eco-friendly enzymes from it, and study its various applications in various sectors and industries to produce it on a large scale.

5 Conclusions

This article discusses and proposes the potential for utilizing the peels of tropical exotic fruits that have the highest annual productivity, including pineapple, banana, orange, papaya, mango, watermelon, and pomegranate, and proposes their potential as additional raw materials in the production of cleaners and disinfectants—the sizeable annual productivity of these fruits results in large amounts of waste, especially from the peel. Scientific studies have revealed the existence of several enzymes contained in fruit peels. Utilization of fruit peels in industry can not only overcome waste problems but also provide additional income for waste management companies. However, many enzymes in fruit peels are still not yet known to be used as eco-enzymes. Therefore, it is necessary to analyse the enzyme content and its use further to provide information on determining the use of fruit peel as raw material for eco-enzymes.

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