

## Prospective values and applications of durian (*Durio spp.*) Shell waste in various industries and its potential in the development of pharmaceutical products: A review

Anh N Nguyen<sup>2</sup>, Phuc N T Le<sup>2</sup>, An D X Nguyen<sup>1</sup>, Uyen P Le<sup>2</sup>, Phu H Le<sup>1\*</sup>

<sup>1</sup> Department of Food Technology, School of Biotechnology, International University–Vietnam National University of Ho Chi Minh City, Ho Chi Minh City, Vietnam

<sup>2</sup> Department of Biotechnology, School of Biotechnology, International University–Vietnam National University of Ho Chi Minh City, Ho Chi Minh City, Vietnam

### Abstract

The objective of this study was to review the potential value and current applications of durian shell waste worldwide. Durian fruit, known for its unique flavor, has been a strategic target for agriculture and export in several countries across the SouthEast Asia, with 600,000 tons of annual production and 1,000,000 tons at its peak in 2021. However, the durian market also produces a significant amount of agricultural waste, particularly from its tough and spiky shell, which constitutes nearly 60-70% of the fruit's weight. Especially in durian-producing countries like Thailand, Vietnam, Malaysia, and Indonesia. Although they are traditionally discarded after the fruit is consumed, durian shells have gained huge attention in recent years for their potential utilization in sustainable development of both value-added products and by-products. The methods used were reviewing, analyzing, and discussing recent publications from the literature during the period of 2014-2024. The results highlighted the awareness and importance, both regarding research and industry, of the high possibility in utilization of durian shell for various industries, e.g. pharmaceuticals, food, agriculture, in commercialization of potential value-added products from its waste, and in solving of environmental issues. In addition, this review also cited the standing state of this field, which only stay at laboratory research without exploring further into pilot and production scales. Their richness in cellulose, hemicellulose, and lignin has been explored as eco-friendly alternatives for various industries. Recent research have uncovered various innovative applications for durian shells, thus transforming them into valuable resources. It has been suggested scientifically as an alternative component for ingredient substitution in the food industry, or as water filtration systems due to its ability to produce high-quality activated carbon with excellent adsorption properties. Additionally, the durian shell's cellulose content allows it to produce bioplastics and eco-friendly packaging. Further applications include its use in soil enhancers, fertilizers, green nanocomposites, and as a raw ingredient in the production of antimicrobial agents. Moreover, durian shell is abundant in bioactive compounds, e.g. polyphenols, flavonoids, and tannins. These compounds exhibit antioxidant properties, which can be harnessed by various extraction methods for creating health supplements, functional food ingredients, or even cosmetics. The contribution of the study is the shedding of light on these innovative uses, researchers are paving the way for a circular economy in durian-producing regions.

**Keywords:** *Durio spp.*, durian shell, extraction, valuable compounds

### Introduction

Durian is a distinctive fleshy tropical fruit that grows primarily in Southeast Asia countries, known for its large, spiky outer shell and strong odor. The fruit is commonly considered as the "king of fruits" due to its popularity and cultural significance in countries like Thailand, Malaysia, and Indonesia. Durian comes in various species, with *Durio zibethinus* being the most widely consumed. Its rich, complex flavor has earned it a dedicated fan base, while its potent odor has led to bans in public places such as hotels and public transport in some regions <sup>[1]</sup>. The fruit is large, with a thorny exterior that protects the soft, custard-like flesh inside. The edible portion of a durian fruit typically makes up only about 15 to 30% of the whole, with the remaining majority classified as durian biomass waste <sup>[2]</sup>. This waste can be divided into two main components: the peel (also referred to as the rind, skin, husk, or shell) and the seed.

The disposal of durian shell waste presents significant environmental challenges due to its slow decomposition. As durian consumption increases, particularly in Southeast Asia where it is most popular, the volume of discarded shells has surged. When improperly disposed of in landfills, durian

shells contribute to methane emissions, a potent greenhouse gas, due to anaerobic decomposition. Methane is a major contributor to climate change, making the accumulation of organic waste like durian shells an environmental concern. Beyond the environmental harm, the decomposition of durian shells produces unpleasant odors, leading to hygiene and sanitation concerns, especially in urban areas <sup>[3]</sup>.

Efforts to mitigate the environmental impact of durian shell waste are underway. Researchers have explored innovative uses of the shells, such as converting them into activated carbon, biofuel, or biodegradable materials, which could reduce reliance on non-renewable resources <sup>[4]</sup>. Moreover, durian shell also contains several bioactive compounds that have garnered interest for their potential health and environmental applications. Among these compounds are flavonoids, phenolics, and carotenoids, which possess antioxidant, antimicrobial, and anti-inflammatory properties <sup>[5]</sup>. These alternative uses not only help in waste reduction but also create economic opportunities. However, widespread adoption of these practices remains limited due to the cost and technical challenges involved in large-scale implementation. This review elucidates the existing situation and applications of durian shells in various

industries, suggesting its potential in pharmaceutical development.

### Current status and potential of durian shell

Globally traded quantities of durian increased more than tenfold between 2003 and 2022, intermittently reaching a peak of 930,000 tons in 2021. Most of the durian imported by China comes from Thailand, though imports from Vietnam have also grown in recent years. China enforces strict regulations on durian imports and currently allows shipments only from Thailand, Vietnam, the Philippines, and Malaysia<sup>[6]</sup>. According to statistics from the Ministry of Agriculture and Rural Development, durian from Vietnam has been exported to 24 markets, with the export value to China accounting for over 99% of the total export turnover<sup>[7]</sup>.

However, the durian industry also threw out a massive amount of shells. In many Asian countries, particularly in Southeast Asia, durian shells are a significant waste issue due to the popularity and large-scale consumption of the fruit. Countries like Thailand, Malaysia, Indonesia, and the Philippines, where durian production is high, face challenges in managing the large volumes of durian shell waste, which is bulky, non-edible, and slow to decompose. In urban areas of countries like Singapore and China, where durians are primarily imported, the disposal of shells adds to municipal waste concerns<sup>[6]</sup>.

Efforts to manage durian waste in Vietnam align with broader national waste management strategies. Vietnam is promoting the development of circular economy models and public-private partnerships to tackle agricultural waste. These efforts include exploring ways to repurpose durian shells, such as converting them into biochar for soil improvement or biofuels. Additionally, there is interest in using the bioactive compounds in durian shells for applications in medicine and cosmetics. Some projects in Vietnam have also looked at converting agricultural waste into energy, which could include durian shells as a potential resource<sup>[8]</sup>.

### The value of bioactive compounds in durian shell

Durian shells are rich in several bioactive compounds, e.g. triterpenes, phenolic acids and glycosides, flavonoids, simple glycosides, cellulose, pectin, etc. In addition, the volatile oils are mainly esters and acid components<sup>[5]</sup>. In recent research, 17 compounds were reported in durian shell extract by using an ultra-high-performance liquid chromatography combined with linear ion trap quadrupole Orbitrap mass spectrometry<sup>[9]</sup>. Bioactive compounds were also isolated from durian peel by methanol extraction and analyzed for chemical structures, which contributed to a comprehensive knowledge of their chemical and pharmacological effects, such as cytotoxicity<sup>[10]</sup>. The finding reveals that the extract from the durian shell was high in polyphenols, exhibiting potent antioxidant activity as well as reducing inflammatory damages. The polyphenols extraction rates were 3.77 mg.g<sup>-1</sup> and 1.86 mg.g<sup>-1</sup> from durian white peel and its outer shell, respectively<sup>[11]</sup>.

Besides, the amount of flavonoid varies in different types of durian shell. Among different local Indonesian durians, Monti durian shell was reported to have higher amount of flavonoid, each  $0.405 \pm 0.002$  mg QE.g<sup>-1</sup>, compared with each other shell type, i.e. Malika and Malon, of  $0.321 \pm 0.003$  mg QE.g<sup>-1</sup> and  $0.324 \pm 0.002$  mg QE.g<sup>-1</sup>, respectively

<sup>[12]</sup>. However, the highest total flavonoid content of durian rinds collected from Tien Giang, Viet Nam was 82.17 mg QE.g<sup>-1</sup> extract, achieved using extraction with 75% ethanol at 60 °C with a maceration time of 24 h<sup>[13]</sup>. Crude water-soluble polysaccharides (PG) extraction yielded approximately 10% w/w of dried durian fruit rinds as creamy white powder. Pharmaceutically potential PG extracted from the peels of *D. zibethinus*, consist of pectin as the main component and starch as a contaminant, which is often found in commercial pectins and referred to as a ballast compound. The crude PG is depicted as a high viscosity and may, as a consequence, be used as an alternative viscosity enhancer instead of commercial pectins<sup>[14]</sup>.

## Applications of durian shell in various industries

### 1. Applications in material sciences

In material science, durian skin fibers can be used as reinforcement in polymer-based composites. When combined with other polymers or biopolymers, these composites can be utilized to produce packaging materials that are not only biodegradable but also exhibit improved mechanical strength, thermal stability, and flexibility. Pectin from durian rind was extracted and synthesized to get pectin-based biopolymer films, which subjected to a weight reduction of up to 62% in 14 days. Utilization of the durian rind for developing biopolymers could be considered as an alternative plastic substitution with proper development in the future<sup>[15]</sup>. Cellulose nanofiber (CNF) prepared by using cellulose extracted from durian shell had positive dispersibility and stability in water and could spontaneously cross-link to form hydrogel at room temperature. It was reported to effectively prevent the volume shrinkage of aerogel and the strongest compression performance was CFN aerogel with 1% CNF<sup>[16]</sup>. The carbon source from durian shell was used as catalyst support for transesterification reaction and was confirmed that activated carbon from durian shell modified with KOH is suitable as a heterogeneous catalyst in the synthesis of biodiesel<sup>[17]</sup>. The mechanical properties of durian shell resemble the value of hemp and cotton fiber, indicating that it can be processed through polymerization in the high temperature and applied in the textile industry<sup>[18]</sup>. Employing durian skin to make bio-briquette has been researched and developed recently. It was usually mixed with other biomass such as coconut shell and palm shell to lengthen the duration of ignition for bio briquettes durian skin quickly burned out<sup>[19]</sup>.

### 2. Applications in agriculture

A number of studies have exploited the potential of using durian rind as a feed ingredient for livestock. Durian rind, which constitutes a significant portion of durian waste, is rich in fiber and other nutrients<sup>[18]</sup>. *Lactobacillus bulgaricus* and *Streptococcus thermophilus* were employed in the fermentation process of durian shell to produce dietary fiber<sup>[20]</sup>. The optimal procedure was determined as: 10% of inoculation concentration, 22h of fermentation time, and 38.3°C of fermentation temperature. Under these conditions, the highest productivity of 29.50% could be obtained. In animal feed, it has been found to enhance dietary fiber content, making it beneficial for ruminants like goats. When fermented with additives such as *Lactobacillus casei* or combined with molasses, durian rind improves nutrient digestibility and reduces methane production, making it a

promising alternative feed component that supports sustainability and methane mitigation in livestock farming. Studies on goats have demonstrated that fermented durian peel can enhance the nutritional efficiency of feed without compromising animal performance, making it suitable for inclusion in total mixed rations for livestock [21].

In addition, the high fiber and mineral content of durian rind make it an excellent choice for use in herbivorous animals. Fish, for instance, benefit from the use of durian rind in their diets, particularly species with longer digestive tracts like herbivorous fish. The rich magnesium, manganese, and copper content in the rind also offers immune-boosting properties, which can help strengthen livestock against infections [22]. Moreover, the utilization of durian shell and seeds in whole feed can improve the digestibility and overall consumption of both dried matters and organic matters in male sheep with the optimal dose of 30% durian peel:20% durian seed: 10% elephant grass [23]. Moreover, durian shell could also be used as a biopolymeric matrix to manufacture a slow-release soil fertilizer added with microalgal (*Scenedesmus* sp.) biomass residue. The growth of the Okra plant expressed a significant improvement in height, number and size of leaves compared to the control group when applying this fertilizer [24].

### 3. Applications in the food industry

Durian shell has potential applications in producing various food products, e.g. pectin, edible films, crackers, flour, and noodles. Research has also emphasized the potential of transforming durian shells into flour, which can be used as an ingredient in baking products, bread, and cakes. It was also used as a dietary fiber to produce gluten free cookies as an alternative choice for consumers who want to avoid gluten products. As the proportion of durian rind flour increased, the cookies tended to become harder in texture. Due to the moisture absorbance of polysaccharide composition in durian rind flour, the dough texture is dry and crumbly. As a result, an optimal formulation of gluten free cookies supplemented with durian rind dietary fiber was suggested as 10% of durian rind flour, 47.5% of wheat flour, and 42.5% of salted butter, respectively [25]. A similar study revealed that brownies made with durian shell powder had significantly higher dietary fiber than the control ones. When 30% of the wheat flour was replaced with durian rind powder, the fiber content increased by 18.2%. There was no significant difference in acceptance scores, including appearance, color, odor, flavor, texture, and overall satisfaction, among the samples. These findings suggest that replacing 30% of wheat flour with durian rind powder is suitable for making brownies. This alternative offers a healthier bakery option, with lower calories (123.73 kcal per serving) and higher dietary fiber (6.37 g per serving) [26]. Durian peel flour was also used in substitution of wheat flour to make biscuits. Biscuits made with 100% durian peel flour exhibited the lowest water activity at 0.24. This full replacement of flour resulted in biscuits with the highest ratings for appearance, color, aroma, taste, flavor, texture, and overall acceptability, with statistically significant differences ( $P < 0.05$ ) [27]. In Vietnam, durian peel powder from Ri6 durian was utilized as a wheat flour substitute to make biscuits and the final products maintained the structural properties, quality and were accepted by consumers [28].

Moreover, the durian shell is also an abundant source of pectin and is likely to become an important raw material for food industries [29]. Durian pectin powders exhibited good thermal stability, suggesting that durian rind could serve as a valuable source of low methoxyl pectin, making it an effective thickening agent for low-calorie foods and beverages [30]. Due to its low amount of  $2.48 \pm 0.31\%$  methoxyl (LM) and the ability to form gels, durian's pectin could be considered as a potential material used in developing edible ink formulations. It can also function as a polymeric crosslinker when used in combination with other materials [31]. Durian skin was also applied in food packaging by using alkaline extraction to obtain cellulose, hemicellulose, and lignin. Corn starch with additional extracted fractions from durian skin were used to generate biodegradable food trays by thermos-pressing [32]. Durian peel and seed extract could be considered as preservatives in the food industry due to its antibacterial and antioxidant compounds. Studies have emphasized the potential of utilizing *D. zibethinus* peels and seeds in prolonging the shelf life of meat as well as fresh-cut fruits and vegetables [33, 34].

### 4. Applications in the pharmaceutical industry

The exploration of durian husk in pharmaceutical applications has garnered increasing attention, particularly due to its diverse chemical constituents and potential pharmacological effects [5]. Various studies conducted across ASEAN countries have highlighted the multifaceted utility of durian shells in combating microbial pathogens and promoting cellular proliferation.

Researchers investigated inhibitory capability of PG extracted from durian husk against various bacterial and yeast strains, e.g. *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans*, and *Saccharomyces cerevisiae*. The results showed that PG extracted appeared to inhibit the growth of these two bacteria while having no inhibitory action against *C. albicans* and *S. cerevisiae* [35]. Another study underscored the inhibitory effects of durian rind PG against *Vibrio harveyi*, a shrimp bacterial pathogen, suggesting its potential applications in aquaculture [36].

Scientists also discovered the efficacy of PG from durian shell in the field of cosmetics. It appeared to have a positive effect on skin capacitance after 28 and 56 days. In addition, the skin firmness improved significantly after 56 days of treatment without allergic effect [37]. Polysaccharides extracted from durian peel was also used as an ingredient in anti-inflammation cream. It was suggested that the combination with the 1:1:1 ratio of 2% of snail seromucoid, 2% of polysaccharide from durian peel extract, and 2% of chitosan would be effective to heal chronic wounds, acute wounds, and diabetic ulcers [38].

Researchers also investigated the antibacterial characteristics of water extracts derived from durian white sacs. The extract exhibited a minor inhibitory effect on *S. aureus* and *Staphylococcus epidermidis*, while demonstrating a robust inhibitory action against *Pseudomonas aeruginosa*. This differential activity emphasizes the complexity of the bioactive compounds present in durian husk and their varying efficacy against different bacterial strains [39]. Durian rinds extract also expressed a moderated antibacterial properties to the *Propionibacterium acnes*, a bacterium causing a skin disease called *Acne vulgaris*. This result revealed the

potential of the rinds of durian as an antibacterial agent [40]. Besides, flavonoids extracted from durian peel at 1.25-10 mg.mL<sup>-1</sup> concentration had different inhibitory effects on different bacteria. Specifically, the flavonoids inhibited the growth of *S. aureus* and *P. aeruginosa* but had no antimicrobial effect on *E. coli* and *Bacillus megaterium* at 1.25-10 mg.mL<sup>-1</sup> concentration [41].

Scientists reported cellulose extracted from durian shell grafted with 2-[acryloyloxy] ethyltrimethylammonium chloride (CIAETA) shows significant activity against *S. aureus*, *S. epidermidis*, and *C. albicans*, indicating the potential for durian husk derivatives in the development of novel antimicrobial agents [42]. In anti-septic assays, hand sanitizer samples containing durian peel extract showed a significant effect on bacterial growth inhibition of *E. coli*, *S. aureus* and *S. typhosa* [43]. Moreover, durian peel extracted by ethanol appeared to have the antimicrobial property of *Streptococcus mutans* and *Enterococcus faecalis*. This concludes that the extract can prevent dental caries due to it being antibacterial against *S. mutans* and *E. faecalis* [44].

In preclinical trials, the ethanolic extract of durian peel helped reduce blood glucose levels of alloxan-induced mice after 11 days of administered orally. The best percentage of reduction in blood's glucose levels was 50.19 ± 3.66% with the dose of 250 mg.kg<sup>-1</sup> b.w. [45]. Pectic polysaccharides isolated from durian peel and could change the flowing status of blood, and also expressed an *in vivo* anticoagulant effect [46]. Durian peel extract had significantly enhanced the negative conditions of morphological damage, i.e. color, texture, weight, and volume, as well as its histology from the degeneration, inflammation, congestion, and necrosis of mice's lung induced by 7,12-Dimethylbenz (α) Anthracene (DMBA) [47]. Cellulose extracted from durian rinds has been applied to fabricate organohydrogels with antibacterial effect. There was no indication of cytotoxicity when employed as a topical wound treatment on pig skin, indicating that durian sheel-extracted cellulose organohydrogels have the potential to be commercialized in medical supplies [48].

The existing studies on the pharmaceutical applications of durian husk has revealed its potential as a source of bioactive compounds with diverse therapeutic applications. As research continues to evolve, the insights garnered from this review pave the way for future studies aimed at harnessing the medicinal properties of durian husk in the pharmaceutical industry.

## Conclusion

The applications of durian shells are increasingly recognized for their potential in various industries, transforming what was once agricultural waste into valuable resources. The shells are rich in bioactive compounds like polyphenols, flavonoids, and tannins, which exhibit antioxidant, antimicrobial, and anti-inflammatory properties. These compounds would likely be explored for possible use in pharmaceuticals, nutraceuticals, and cosmetic products. Additionally, the high fiber content of the shell has led to its suggested utilization in manufacturing of various gluten-free food products and in biodegradable packaging. Besides, microbiological transformation of durian shells into agricultural compost will not only reduce waste but also provide a sustainable solution for soil enrichment, making it an effective way to manage durian waste. These innovations point to a growing trend of valorizing durian husks,

reducing waste while creating value-added products that contribute to environmental conservation. Overall, the potential applications of durian shells showcase a shift towards circular economy models in durian producing regions, paving the way for more sustainable waste management.

## Competing interests

The authors declare no conflicts of interest.

## Author contributions

Phu H. Le conceived the idea, provided support, and critically revised the manuscript. Anh N. Nguyen structured the contents and wrote the manuscript. Phuc N.T. Le, An D.X. Nguyen, and Uyen P. Le contributed to the finding of materials and proofreading. All authors read and approved the final manuscript.

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