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Applications of Valorized Dragon Fruit Waste in the Industrial Sector

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INTRODUCTION

Dragon fruit, also known as pitaya, has high nutritional content and bioactive ingredients, which include potent natural antioxidants, and an exotic tropical plant that offers several advantages to human health. A variety of advantageous biological actions against harmful microorganisms, including bacteria, fungus, and viruses, as well as disorders including diabetes, obesity, hyperlipidemia, and cancer are possessed by extracts from the stems, blossoms, peels, and pulp of dragon fruit. Additionally, dragon fruit extracts have hepatoprotective, cardiovascular, and prebiotic potential. Due to its high flexibility and endurance to a broad range of climatic circumstances, pitaya plantations thrive in Vietnam's tropical climate, which is ideal for their development. A cost-effective product for the Vietnamese economy, particularly in the most impoverished areas of the Mekong Delta region, and a catalyst for Vietnam's sustainable development in the face of climate change challenges like saline intrusion and drought are the dragon fruit's nutritional qualities, biological activities, and commercial value.

Medical applications

2.1 Antibacterial and antiviral properties

Dragon fruit contains phenolic acids, flavonoids, and betacyanins, all of which are effective against various bacteria and yeasts (Joshi and Prabhakar 2020). In a study that was carried out by Nurmahani, antimicrobial properties were extracted from the peels of both red (*H. polyrhizus*) and white (*H. undatus*) dragon fruit. All of the tested fractions of dragon fruit were effective at preventing the spread of the various food-borne bacteria at concentrations between 1.25 and 10 mg/mL (Jiang et al. 2021). The results of this study showed that red dragon fruit peels were significantly more effective at preventing the growth of harmful microbes than their white counterparts.

In addition, a 60% ethanol extract of red dragon fruit (*H. polyrhizus*) peel was recently studied for its antimicrobial properties (Li et al. 2022). The extract was very effective at killing *Bacillus subtilis*, but it was not as effective against the other six bacteria and three fungi that were tested.

Dragon fruit peel extracts with broad antimicrobial spectra can inhibit bacterial and fungal growth, making them promising natural antimicrobial agents. The effectiveness of the extract of dragon fruit peel against gram-positive bacteria may be higher than its effectiveness against gram-negative bacteria (Satpute and Shinde 2022). Dragon fruit peel extract may play a significant role in dragon fruit peel extract's antimicrobial activities. Adnan et al. (2011) found that the antimicrobial effects of the chloroform and n-hexane fractions are stronger than those of the 95% ethanol fraction, and Vijayakumar (2017) found that only the 82% ethanol extract can stop *Bacillus subtilis* from growing.

2.2 Probiotic efficiency

Non-digestible oligosaccharides, known as prebiotics, encourage the growth of beneficial bacteria and provide some protection against gastrointestinal disorders. Both the white-fleshed and the red-fleshed varieties of dragon fruit contain both simple sugars and oligosaccharides (Magalhães et al. 2019). According to research by Putriningtyas and coworkers, consuming dragon fruit oligosaccharides (DFO) can improve gut and gastrointestinal bacteria by increasing the number of beneficial bacteria like *Bifidobacteria* and *Lactobacilli* and reducing the number of harmful bacteria. Furthermore, the study showed that DFO can improve the immune response by elevating levels of immunoglobulin A, C, and G.

Dragon fruit was studied by Wahyuniasim because it could provide a high yield of oligosaccharides, a type of sugar, for use in the commercial production of prebiotics. According to their research (Rohin et al. 2014), dragon fruit oligosaccharides are a promising functional food and nutraceutical ingredient. Prebiotics can stimulate the growth of lactobacilli and bifidobacteria while reducing calorie intake and insulinemia relative to digestible carbohydrates. Dasaesamoh et al. (2016) found that the mixed oligosaccharides in dragon fruit increase feces production and intestinal motility, help form bulk, and reduce harmful microbes.

2.3 Healing Properties for Wounds

In the process of wound healing, which aims to repair damaged tissues, a variety of cell populations, the extracellular matrix, and soluble mediators like growth factors all play important roles (Potekaev et al. 2021). Wound management can fail every day without the right physiological, endocrine, and nutritional support. This makes it one of the most difficult parts of clinical pathology.

Perez et al. (2005) tested the leaf, rind, pulp, and flower aqueous extracts of dragon fruit for their wound healing properties in streptozotocin-diabetic rat wounds. The data demonstrated that only the aqueous extracts of the flowers and leaves showed any significant wound healing activity, with the extracts of the pulp and peel showing even less. The effect on wounds was most pronounced with the dragon fruit flower extract. According to research by Ibrahim et al. (2018), dragon fruit has been shown to aid in wound healing by increasing collagen fiber density. Juliastuti and her colleagues found that when teeth were pulled out of Wistar rats that had been given a 30% dragon fruit peel ethanol extract, the density of collagen fibers was higher than it was in the control group.

Tsai et al. (2019) studied the wound healing properties of dragon fruit peel, stem, and flower extracts *in vitro*. In this study, extracts of dragon fruit stems, peels, and flowers were mixed with 95% aqueous ethanol. The results showed that the DNA was protected, and the researchers came to the conclusion that fibroblasts are necessary for wound healing. Extracts of dragon fruit contain potent antioxidants that can be put to use in the food,

cosmetic, and pharmaceutical industries to protect DNA and heal wounds (Amin et al. 2022). Dragon fruit extracts are also used in traditional Chinese medicine.

2.4 Antioxidant properties (*in vitro* activity)

The antioxidant properties of dragon fruit peels have been the subject of recent laboratory research. In particular, a lot of phenolic compounds and bioactive natural pigments like betacyanins were found in the peels of red dragon fruit (Kunnika and Pranee 2011). The red and white dragon fruit peels have greater radical scavenging capacities than the flesh. This is because the peels contain a higher concentration of betacyanin pigment. *In vitro* research revealed that its extracts possessed a high level of antioxidant activity, which was evaluated based on their capacity to scavenge free radicals (Ramli et al. 2014). Dragon fruit peel extracts have antioxidant properties, mitigating oxidative stress and damage. Rusip and coworkers investigated that 75, 150, and 300 mg/kg of dragon fruit extract have been shown to raise hepatic GSH (glutathione) levels. Overaccumulation of reactive oxygen species (ROS) causes oxidative damage, which is linked to obesity, diabetes, and heart disease. Consumption of red dragon fruit extract improves cell function, prevents oxidative stress-related illnesses, and extends recovery time.

In another study, Ayub and coworkers researched that white dragon fruit peel methanol extracts had a high antioxidant capacity due to their 48.15 mg GAE/100 g phenolic compound content. In a recent study, a water-soluble polysaccharide was extracted from the peels of dragon fruit and analyzed for its chemical composition and antioxidant activity. Extracts of dragon fruit peel that are rich in phenolic compounds, water-soluble polysaccharides, and betacyanins have been shown to have significant antioxidant activity (Zitha et al. 2022).

2.5 Anti-cancer property (*in vitro* activity)

It is common knowledge that cancer is a major factor in the ever-increasing death toll, and this fact is widely acknowledged. Because cancer poses such a significant threat to people's health, researchers have a strong incentive to step up their efforts to find a cure for the disease. The red dragon fruit with 80% acetone extracts has stronger antiproliferative activity than the flesh extracts (Padmavathy et al. 2021). This is possibly due to the different phenolic profiles in the different fractions of the extract. The anticancer properties of the peel and flesh of both red and white dragon fruits were investigated. Both the red and white dragon fruit extracts were able to inhibit the growth of human breast cancer (MCF-7) and human gastric adenocarcinoma (AGS) cells (Kim et al. 2011). Jiang and coworkers found that an inhibitory rate of 67.3% was achieved against human prostate cancer cells (PC3), breast cancer cells (Bcap-37), and gastric cancer cells (MGC-803). The inhibitory effects of the extracts on these cancer cells were found to have a positive correlation with the concentration of the extracts, and amyrin, amyrin, and sitosterol may be the components that are the most effective (Joshi and Prabhakar 2020). The discovery that the bioactive compounds in dragon fruit peels have the potential to inhibit the proliferation of cancer cells hints at the possibility that dragon fruit peels could be developed into products that help reduce the incidence of cancer.

2.6 Antianemia

Riboflavin, iron (Fe), vitamins C, B12, thiamine, and E are just some of the essential nutrients that can be found in abundance in dragon fruit (Hossain et al. 2021). Other essential nutrients found in dragon fruit include those that are required for the erythropoiesis process. Widyaningsih and coworkers researched to investigate the impact that dragon fruit has on postpartum mothers, who are at an increased risk of developing anemia. They found that eating dragon fruit reduced the risk of anemia. Mothers were given dragon fruit juice (obtained from 500 g of dragon fruit) once daily for 14 days beginning immediately after delivery of their

babies. It was discovered that the levels of hemoglobin, hematocrit, and erythrocytes in the treatment group had significantly increased when contrasted with the levels found in the control group. According to Rahmawati et al. (2019), the anti-anemia activity of dragon fruit can be attributed to the high vitamin C content of the fruit, which makes it easier for the body to absorb iron. The production of non-heme iron necessitates the use of non-heme iron.

2.7 Anti-inflammatory properties

Dragon fruit's antioxidant and anti-inflammatory properties come from the presence of compounds like betalains and squalene in their composition (Eldeen et al. 2020). Rodriguez et al. found that both maltodextrin-encapsulated and unencapsulated betalains from dragon fruit peel extract exhibited anti-inflammatory activity. The bioactivity of betalains can be preserved through encapsulation despite their instability and sensitivity to degradation by factors like temperature, pH, oxygen, and light. Betalains were able to alleviate the vascular irritation that was brought on by sodium dodecyl sulfate (SDS) in the duck embryo chorioallantoic membrane (Rodriguez et al., 2015). Maltodextrin-gum Arabic or maltodextrin-pectin matrices encapsulated betalains, which increased their anti-inflammatory activity by a factor of five to six compared to their non-encapsulated counterparts. The high antioxidant activity of betalains found in dragon fruit peels may explain their potent anti-inflammatory effects (Li et al. 2022). Eliminating potential pro-inflammatory mediators like free radicals can reduce the inflammatory response.

2.8 Anti-obesogenic and lipid-lowering properties

The alarming rise in obesity rates across the globe poses serious risks to human health and economic growth. High lipid levels and hyperlipidemia play a significant role in the development of obesity (Hamann et al., 1996). Natural bioactive substances are used a lot in research on obesity and high cholesterol because they work well and have few side effects.

Chandra et al. 2020). Lipase is an enzyme responsible for hydrolyzing dietary fats into usable fatty acids by first binding to the fats and then breaking them down chemically (Chandra et al. 2020). Consequently, reducing lipase activity may reduce dietary lipid absorption, thereby decreasing the risk of obesity and hyperlipidemia. An extract made from dragon fruit peels was found to be able to suppress the activity of the enzyme lipase (Le 2022). Pectin can be found in relatively high quantities in the rinds of dragon fruits. The cholesterol-absorption capacities of high-methoxyl pectin (HMP), which is extracted from the peels of dragon fruit, are quite impressive (Zaid et al., 2019). Betacyanins were isolated and studied for their potential to fight obesity (Song et al., 2016). Mice-fed high-fat diets (HFD) were protected from gaining weight and developing metabolic abnormalities when given 200 mg/kg of betacyanins from the peels of dragon fruit daily for 14 weeks (Holanda et al. 2021). This was accompanied by a decreased accumulation of lipids in adipose tissue and the liver compared to the control group. Recent research suggests dragon fruit peels may reduce hyperlipidemia risk by altering the body's lipid profile (Setiawan et al. 2018). Hyperlipidemia was tested in high-fat-fed mice. Red dragon fruit peels reduce blood LDL and increase HDL in rats.

Together, these findings by Panjaitan and Amelia suggest that dragon fruit peels have a lipid-lowering effect, as their consumption in animal models has been shown to contribute to an improved blood lipid profile by inhibiting the activity of lipases and the interaction of cholesterol with dragon fruit peel-derived HMP. Also, it was found that the betacyanins in the peels of dragon fruit work well to prevent diet-induced obesity by controlling lipid metabolism.

2.9 Antidiabetic properties

Hyperglycemia, caused by a dysfunction in the pancreas insulin production or cells' insensitivity to insulin, is at the root of diabetes mellitus, a common systemic disease (Arora et al. 2021). Many studies have looked

into dragon fruit's potential as an anti-diabetic. Putri and coworkers investigated the effects of red dragon fruit on insulin-resistant rats. The rats were made insulin-resistant by being fed fructose, and then the researchers examined the effects of red dragon fruit on the insulin-resistant rats. According to this study, dragon fruit was able to lower insulin resistance, which may be because of the high levels of antioxidants and soluble dietary fiber found in the red pulp of dragon fruit (Satpute and Shinde 2022). Wu and colleagues investigated whether the consumption of red dragon fruit affected the blood glucose levels and lipid profiles of type 2 diabetics. Patients kept taking their prescribed medicines while also consuming between 400 and 600 grams of dragon fruit daily. It was discovered that consuming 600 grams of fruit led to a decrease in blood glucose, a reduction in LDL cholesterol, and an increase in HDL cholesterol. According to the findings of Panjaitan, the aqueous extract of dragon fruit pulp lowered the levels of fasting blood glucose in diabetic rats that had been treated with streptozotocin. The pulp extract didn't have much of a suppressive effect, and increasing the dose didn't make it stronger.

According to research conducted by Kumar, both the red and white varieties of the fruit were found to reduce the amount of sugar in the blood and the likelihood of developing diabetes. After that, they concluded that there should be more clinical tests that are well-controlled due to the lack of data and evidence in the clinical setting.

Applications in the food product sector

3.1 Bakery products

According to the findings of a study, cookie dough can be prepared using dragon fruit peels in conjunction with regular wheat flour (Tsai and Liu 2022). In this recipe, dragon fruit peels were used as a partial replacement for wheat flour, which resulted in cookies with higher levels of fiber and carbohydrate content when compared to cookies made with wheat flour only. Additionally, in comparison to the unmodified version, the crumb height was lower when dragon fruit peel flour was used in place of some of the wheat flour in the recipe (EL SALOUS et al. 2020). Its flour did not lessen the overall appeal of the products to the senses in any way. As a result, dragon fruit was supposed to be utilized in the production of cookies as a dietary supplement and a wheat flour replacement (Mai et al. 2022). Dragon fruit dough was used to make traditional Chinese steamed bread. The dough and its betacyanin and phenolic compound content are both harmed by steaming. The use of dragon fruit flour has been shown to decrease volume, elasticity, and cohesion. It was hypothesized that adding 3% dandelion fruit peel flour to the dough for steaming bread would enhance both the flavor and the nutritional value of the finished product. The results showed that mantou, which is a type of Chinese steamed bread, that had been mixed with 3% dragon fruit powder, was just as acceptable as the control (Hsu et al. 2019).

Noodle manufacturers have recently begun using dragon fruit peel flour as a partial flour substitute to further improve the quality of their products (Jiang et al. 2022). This is done to further improve the quality of their products. After drying and cooking, the noodles made with dragon fruit peel flour had higher levels of betacyanins and polyphenols, which indicated that they had more powerful antioxidant properties. However, the degree to which dragon fruit peel flour is incorporated into the dough and finished products has a significant impact on their consistency (Huan et al. 2021). As a result, it is crucial to conduct research and make improvements to the formulation of dragon fruit peel flour-enhanced bakery foods.

3.2 Meat products

Both red meat and seafood are excellent sources of the macro and micronutrients that the body needs to function properly. Despite the nutritional benefits dragon fruit extract provides, proteins and lipids are extremely susceptible to oxidation and degradation

during storage, which can result in a reduction in the nutritional value of the substance and an increase in its toxicity (Gao et al., et al 2022). According to the findings of some researchers, the oxidation of proteins and lipids in meat and aquatic products can be slowed down by using dragon fruit peels as a natural antioxidant and antimicrobial agent.

The oxidation of lipids was reduced and the overall quality of the chicken nuggets was improved by the addition of dragon fruit peel extract. Additionally, it lessens the toughness and gumminess of the substance (Madane et al. 2022). In recent studies, it was discovered that adding microencapsulated dragon fruit peel to ground pork at concentrations of 100 and 1000 ppm prevented high-pressure cooking from causing oxidation of lipids and proteins (Cunha et al. 2018). The peel of dragon fruit could be added to beef sausages as an antioxidant and antimicrobial agent to help reduce lipid oxidation and maintain the product's quality while it is being stored (Biswas et al. 2022). The anti-aging properties of an extract made from the peel of dragon fruit were investigated on tilapia. Because treatment of tilapia with 1% dragon fruit peel extract reduces microbial load, it is possible that this substance could be utilized as a natural preservative to delay the process of decay.

3.3 Dairy products

Betacyanins and fiber can be found in the peel of dragon fruit. Its peels can be used in place of some of the fat in ice cream, and the betacyanins they contain can be used to add color (Utpott et al. 2020). To increase the amount of fiber and decrease the number of calories, the ice cream recipe used in the study contained 1% dragon fruit peel extract (Minh et al 2019). The addition of dragon fruit peel extract, which has a high percentage of fiber, makes the frozen treat runnier and improves its rheology. The results of the sensory analysis indicate that the ice cream infused with dragon fruit peel extract is visually appealing, creamy, and has increased nutritional value while simultaneously reducing the amount of fat and calories it contains. As a natural antioxidant and antibacterial agent, 2% of an extract made from dragon fruit peels was added to the pasteurized milk so that the maximum storage time could be increased to 15 seconds at 72 degrees Celsius (Joshi et al. 2021). The bioactive compounds found in dragon fruit peel have the potential to prevent the growth of organisms that cause milk to go bad and to keep the pH level of room-temperature milk normal for up to 12 hours.

3.4 Applications in edible coating and food packaging

Researchers are looking into the possibility of extending the shelf life of perishable foods by using edible films and active packaging. Betacyanins and other phenolic compounds in dragon fruit peels are capable of being extracted for use as an edible coating or in active packaging (Jalgaonkar et al. 2022). The peel of dragon fruit improves the mechanical properties of packaging films, increases their resistance to oxygen, moisture, and ultraviolet light, and imparts antioxidant and antimicrobial properties to the films. In this investigation, a correlation was found between the amount of dragon fruit peel extract and the sensitivity of the film to ammonia. The fact that films containing 1% dragon fruit peel extract changed color noticeably while storing shrimp suggests that in the future, these films could be used to determine the freshness of meat or aquatic products A group of scientists came up with films that you can eat that are made of gelatin and waste from dragon fruit peels. (Gao et al. 2022).

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