Pomegranate

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Pomegranate (*Punica granatum L.*) is a fruit that is rich in bioactive compounds that has a biowaste (rind and seed) with the potential to be converted into value-added products in a wide variety of applications. Recent studies have demonstrated the potent antioxidant and antimicrobial effects of using pomegranate rind and seed as natural food additives, thus making researchers incorporate them into bioplastics and edible coatings for food packaging. Additionally, these components have shown great plasticizing effects on packaging materials while extending the shelf life of food through active packaging. Even within skin health applications, pomegranate seed oil and its bioactive compounds have been particularly effective in combating UV-induced stresses on animal skin and in-vitro models, where cells and microorganisms are separated from the whole organism. They have also aided in healing wounds and have shown major anti-inflammatory, analgesic, and anti-bacterial properties.

Keywords: pomegranate ; waste ; food packaging ; food additive ; skin health ; cosmetics

1. Introduction

Annually, the United States disposes of roughly 133 billion pounds (31%) of its food supply [1]. Of this, approximately 61.2 billion pounds of food waste end up in landfills [2]. This excessive waste is not only detrimental to the environment, but it also contributes significantly to climate change issues, as food waste produces 18% of the total methane emissions in U.S. landfills. Contributing further to food waste and methane emissions are the 30% to 40% of fruits and vegetables that end up in waste [3]. Among these fruits and vegetables is pomegranate, the majority of which is considered to be waste after extracting juice.

Pomegranate's rind and seeds, which account for roughly 54% of the fruit, are the waste components of pomegranate after juice extraction. California will be used as a model to showcase pomegranate production in the United States, as California produces over 90% of the pomegranates grown domestically, with the majority of the production based in the San Joaquin Valley [4][5]. In 2018 alone, California produced approximately 218,000 tons of pomegranates, making roughly 118,000 tons of pomegranate rind and seed waste [6]. This problem is compounded when the resources and energy that are used in producing the wasted food are taken into consideration [2]. To produce 5.6 tons of pomegranates per acre in San Joaquin Valley, 41 gallons of fuel and over 1.2 million gallons of water are consumed [7]. On a global scale, there are three-million tons of total pomegranate production, resulting in approximately 1.62 million tons of waste [8]. For comparison measures, 68 million tons of oranges are produced globally each year, which is 8.5% of total fruit production, and it results in 15 to 25 million tons of orange biowaste [9]. The sheer amount of waste that is produced for each edible percentage of pomegranate makes it important to look for proper methods of optimizing the nutritional and bioactive components of pomegranate waste and then convert this waste into value-added products to save energy, sustain resources, and protect the environment. Even if the extraction of nutritional and valuable components of pomegranate may not be feasible due to cost, looking into these applications is an important step to take in the future direction for a sustainable way to use this excessive waste.

Properties and Chemical Composition of Pomegranate

Pomegranate's arils are depicted in Figure 1 as the edible red pulp that surrounds the seed that is used by juice manufacturing companies to produce pomegranate juice. The remaining solid waste from pomegranates, after juice extraction, rind, and seed (Figure 1), contains various bioactive and nutritional components, such as flavonoids (e.g., anthocyanins), hydrolyzable tannins (e.g., punicalagin and ellagic acid), and fatty acids (e.g., punicic acid). These components in pomegranate biowaste have various potential value addition applications in food and skin health [10].

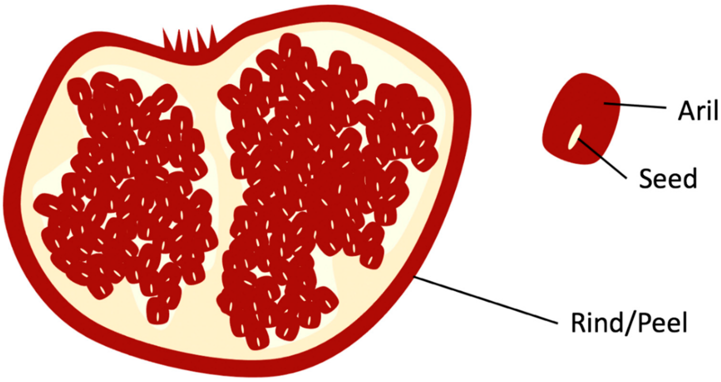

Figure 1. Rind and Seed of Pomegranate.

Figure 2 shows the weight percent composition breakdown of pomegranate parts. The breakdown shows that 46% *w/w* of pomegranate is used as a juice, and the rest of it is considered to be waste. The pomegranate rind is one of the waste components that comprises 43% *w/w* of the fruit. Seeds are another waste component of pomegranate and compose 11% *w/w* of the fruit (Figure 2). The oil content that is extracted from pomegranate seeds varies in weight percentages, depending on their cultivars, and it constitutes approximately 7.6–20% *w/w* of the pomegranate seed [11][12]. The oil content of pomegranate varies depending on the climate of the growing region, the maturity of the fruit, cultivation practices, and storage conditions [12]. To take cultivar variation in weight composition—that is a result of using different cultivars—into account, the average composition from three sources was used in Figure 2. Pomegranate processing factories will benefit from utilizing the waste components because the majority of the pomegranate fruit is disposed of as waste.

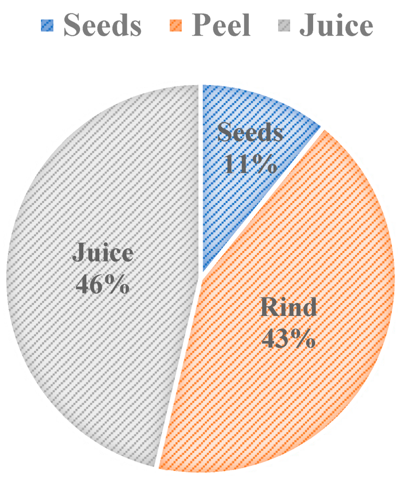

Figure 2. Weight Percent Composition of Pomegranate [10][13][14].

2. Applications

2.1 Food Applications

Sustainability in the food and agriculture industry is compromised as enormous volumes of waste are generated; however, recycling and converting these wastes into value-added products for reuse in the food chain would revitalize sustainability. In this vein, this section will review the applications of pomegranate biowaste, like food additives and bioactive compounds for food packaging, in preventing food oxidation and the growth of pathogenic microorganisms. Pomegranate rind and seed act as sources of antioxidants, antimicrobial agents, and anti-browning agents for both food additives and food packaging material in various studies because of their many bioactive and nutritional components.

2.1.1. Food Additives

Nowadays, there is an increasing demand for natural alternatives to synthetic food ingredients and synthetic antioxidants, in particular, which have carcinogenic effects and have been restricted in use for food applications [15]. Pomegranate rind extract is an alternative natural antioxidant that is comparable to synthetic antioxidants, such as butylated hydroxytoluene (BHT). Pomegranate seed also has antimicrobial and antioxidant properties. In addition to acting as a substitute natural ingredient, pomegranate biowaste can replace commercial nutritional ingredients. For instance, pomegranate rind can serve as an appropriate pectin substitute, and PSP has the potential to be used as a source of nutritional fiber.

2.1.2. Food Packaging/Bioplastics

Several studies show the uses of the pomegranate biowaste's phenolic content as active components in biodegradable and edible films and coatings. The following sections discuss pomegranate extract's antioxidant and antimicrobial properties, coloring effects, plasticizing effects, and strengthening abilities for food packaging films. Pomegranate biowaste has promising impacts on sustainability for bioplastics because the biowaste can be used to fortify materials that can replace plastics in packaging systems.

2.2. Skin Health Applications

Pomegranate rind and bioactive seed compounds can be integrated into skin health products, demonstrating the potential that biowaste can be converted into value-added products. Ellagic acid and punicalagin are both bioactive compounds of pomegranate rind that promote skin health by inhibiting tyrosinase and initiating anti-inflammatory and anti-fungal effects [16][17][18]. PSO is rich in punicic acid, which gives it protective and anti-inflammatory characteristics to act against UV-induced radiation [19]. Furthermore, PSO can act as an inhibitor for aging-induced glycation, a process that negatively affects skin elasticity [20]. The following outlines the pomegranate extract's promising pharmaceutical and cosmetic applications, such as the treatment of UV-induced hyperpigmentation, decreased skin elasticity, and skin wrinkling.

2.2.1. Skin Whitening

Pomegranate has one of the highest levels of ellagic acid (EA) among fruits and vegetables. EA is a phenolic component that is used to protect skin against oxidative stress [21]. EA is currently approved as a lightening ingredient for cosmetic formulations due to its ability to chelate copper ions that are present in tyrosinase enzymes, which are the main enzymes catalyzing the production of melanin [22].

EA that is found in pomegranate has advantageous treatment abilities for UVB-induced hyperpigmentation [19]. In one study, pomegranate rind extract containing 90% *w/w* EA was orally administered to UV irradiated guinea pigs to test its skin whitening effect. The extract taken orally had a comparable whitening effect to L-ascorbic acid (vitamin C), which is a known tyrosinase inhibitor on UV-induced pigmentation, and reduced the number of DOPA-positive melanocytes, whereas L-ascorbic acid did not [16]. Apart from its skin whitening effect, EA in pomegranate has more skin health applications that will be discussed in the next sections.

2.2.2. Skin Wrinkling and Skin Aging

Pomegranate extract also has an anti-aging effect against skin wrinkling and it can increase skin elasticity. PSO can improve the striae distensae skin condition, which is associated with a lack of skin elasticity. It was tested in an oil-in-water cream with Croton lechleri resin, which increased the thickness, hydration, and elasticity values of the dermis [23]. Another topical oil-in-water emulsion was formulated with pomegranate extract, donkey milk, and UV filters. In addition to an overall decrease in brown pigmentation, the emulsion had anti-aging effects on the skin, such as a decreased wrinkle count by 32.9%, decreased wrinkle length by 9.6%, and increased skin firmness and elasticity by 9.6%. This suggests that these effects are due to the synergistic potency of the ingredients of the formulation [24]. Pomegranate EA, in particular, has the ability to prevent UVB-induced thickening of the dermis, a process that can lead to skin wrinkling [25].

2.2.3. Burn and Wound Healing

In addition to its skin whitening and anti-aging effects, EA from pomegranate rind extract has a protective effect on sunburns at low doses (100 mg/day EA) [26]. Pomegranate extract with 40% *w/w* EA also has a healing effect on deep second-degree burn wounds in rats through the induction of collagen formation, which strengthens wounded tissue and speeds up the healing process [27]. The same extract can also enhance the healing process for incision wounds on rats by increasing collagen content and angiogenesis while decreasing polymorphonuclear leukocytes (PMN) infiltration, which causes tissue damage during inflammation [28]. Furthermore, EA and pomegranate rind extract positively contribute to increasing tensile strength in rat incision wounds. Although a high dose of EA alone can inhibit PMN infiltration, it cannot produce significant amounts of collagen. This is an indication of the synergistic effect of pomegranate extract with EA on healing wounds [29].

2.2.4 Anti-Inflammatory and Anti-Pain

Pomegranate rind extract was tested on ex-vivo porcine skin for its anti-inflammatory effects. The punicalagin permeated the skin, thus downregulating COX-2, an inflammatory enzyme [17]. A hydrogel containing pomegranate rind extract and zinc sulfate was formulated by the same research team as a topical treatment for Herpes simplex virus (HSV) infection. The hydrogel exhibited virucidal and anti-inflammatory effects, with punicalagin permeating regions of the skin that are susceptible to infection [30]. This has relevance in the growing need for novel clinical products to combat HSV. Another study using the rind extract's punicalagin with zinc (II) ions established virucidal and therapeutic effects against HSV infections, such as the common cold sore, in order to further emphasize this potential application [31].

2.2.5. Burn and Wound Healing

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3. Summary

Many recent studies in the past year focused on the pomegranate's synergistic effects with different bioplastic materials, particularly in food packaging. Pomegranate rind and seeds have strong antioxidant and antimicrobial properties that make them suitable natural alternatives to synthetic components in bioplastics, food coatings, and food additives. Pomegranate, as a natural source of pectin and fiber, has effects that are comparable to commercial pectin in terms of emulsifying and gelling properties while also providing health benefits from its increased fiber content as a food additive.

There has also been a focus in recent studies on ellagic acid in pomegranate rind, especially in skin health applications for its protective effect against UV irradiation-induced stresses, such as hyperpigmentation, skin aging, sunburns, and skin cancer. Because many of these studies have tested animals, future research should focus on humans to better understand the full potential of pomegranate in food and skin health applications to promote broader commercial uses. It would be valuable to further explore the commercial uses of pomegranate in an economically and environmentally sustainable fashion by adding value to its waste. Moreover, there is a need for cost-effective techniques for the extraction of nutritional and bioactive components of pomegranate biowaste and for studies to be conducted on larger scales. Pomegranate rind and rind extract have an underlying astringency that restrains it from being used as an ingredient in food systems, so more investigation should be done to address this hurdle in food additive applications [32]. Finally, more research must be done on the interaction between food ingredients and the bioactive components of pomegranate. Taking these steps will not only give us a better understanding of pomegranate waste utilization methods, but will also advance research in the fields of skin health and food science.

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