Watermelon skin, its nutritional value and therapeutic uses

Behzad Mohammadi[1*], Dorna Abdolkhani[2], Seyedeh Elaheh Jafari Sang cheshmeh[3]

Department of Food Science and Technology, Afagh Higher Education Institute, Urmia, Iran.

Department of Food Sciences and Industries, Biotechnology Orientation, Islamic Azad University, Yasouj Branch, Yasouj, Iran.

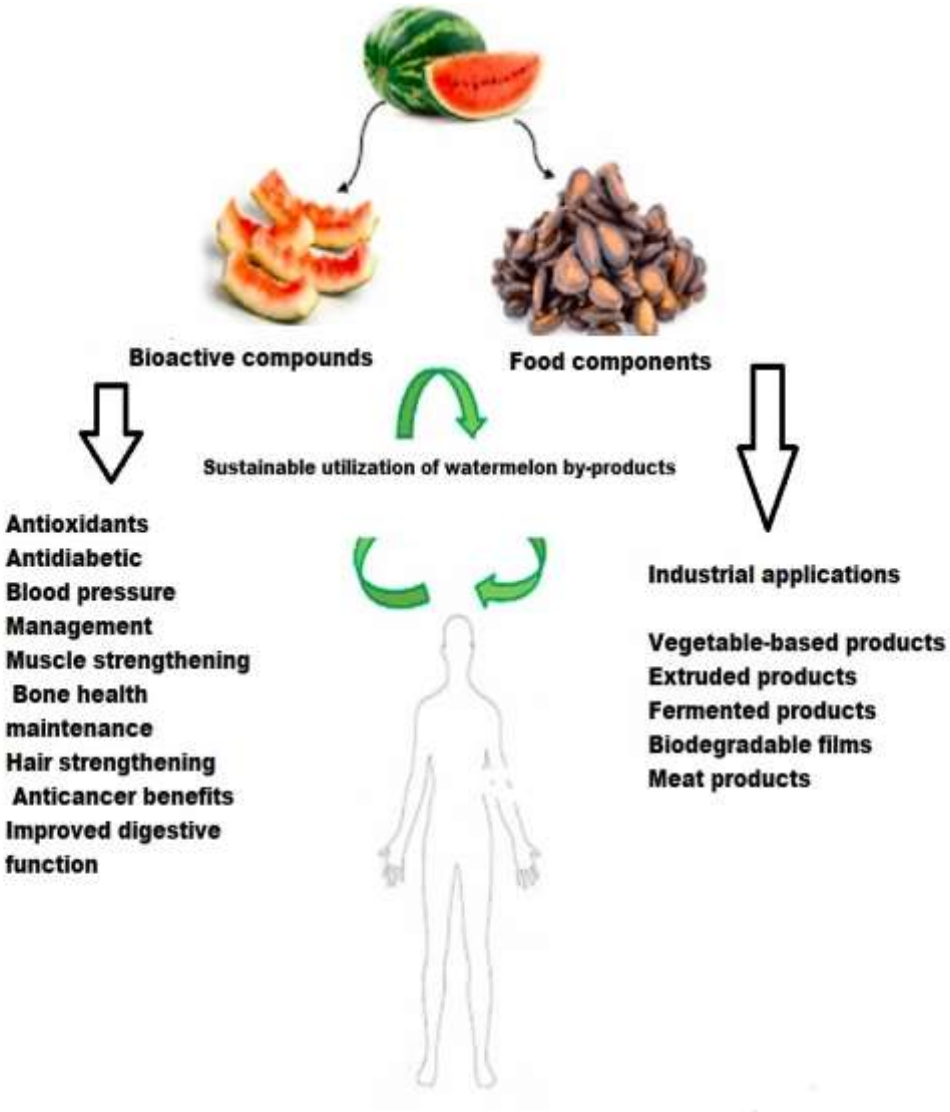
Ph.D. in Food Industry - Education Director of Sima Proto Vista Research Center, Mazandaran, Sari, Iran

Abstract

Due to the growth of the global population, evolving dietary preferences, and recognized health benefits associated with these essential foods, the demand for fruits and vegetables has significantly increased, leading to increased waste and subsequent environmental problems. This requires the management of food waste and its processing into high-nutrient products as a permanent priority to ensure food security worldwide. Watermelon is considered a fruit high in FODMAPs (fermentable oligosaccharides, disaccharides, monosaccharides, and polyols), meaning it contains short-chain carbohydrates, making its firm flesh low in calories. Contrary to misconceptions, the rind and white part of the watermelon can help improve oxygen delivery to hair follicles and prevent hair loss through increased collagen production. Among the most important nutrients found in watermelon rind are vitamin A, vitamin C, vitamin B6, vitamin B12, vitamin B4, vitamin B1, potassium, magnesium, and zinc. Watermelon rind contains citrulline, which helps improve blood circulation and heart health. It also contains arginine, which increases nitric oxide production, leading to vasodilation and potential treatment of angina and cardiovascular diseases. Compounds in watermelon rind improve muscle growth, aid in wound healing, combat fatigue, stimulate the immune system, and fight cancer through possessing cucurbitacins.

Keywords: watermelon, seed, watermelon skin, nutritional value, therapeutic properties.

Graphical Abstract



Introduction

The demand for fruits and vegetables has significantly increased due to the rising global population, changing food preferences, and the perceived health benefits associated with these essential nutrients [1]. By 2022, the worldwide production of various fruits and vegetables is expected to surpass one billion tons, influenced by geographical variations, agricultural practices, and consumption patterns, leading to the generation of a substantial amount of by-products and waste [2]. While fresh fruits and vegetables are typically processed before consumption to extract the desired products, food processing industries, including fruit and vegetable processing, are major contributors to global waste generation alongside domestic sewage. The processing of fruits and vegetables leads to the production of significant amounts of waste materials such as peels, seeds, stones, and unused flesh. Effectively managing by-products from food processing is a critical concern in the agricultural and food industries, reflecting the increasing focus on food waste and its significant social, economic, and environmental consequences globally, making food waste management a priority for ensuring food security permanently[3]. Watermelon, originating from South Africa, is a plant and fruit belonging to the gourd and summer plant family. It grows in Jaleez and has a large, annual plant with long, creeping stems. The plant has hairy pentagonal cross-sections and can grow up to 3 meters high. The young plant is covered in yellowish-brown hairs that disappear as it matures. The leaves are large, coarse, and become rigid and rough with age. The watermelon has broad, hairy leaves with deep cuts and white or yellow flowers. Its skin is thick, smooth, and green with dark green stripes or yellow spots. The flesh is sweet and juicy, ranging from deep magenta to pink in color, and sometimes orange, yellow, or white. It contains many seeds that can be white and soft or black and hard. Efforts have been made to develop disease-resistant and seedless varieties, as well as those with white seeds suitable for digestion. Some cultivars can produce ripe fruit 100 days after planting. The fruit can be eaten raw or pickled, and the skin can also be cooked and consumed [4]. The worldwide watermelon supply in 2023 reached 111 million tons, with China leading as the top provider with 67%. Following behind were Turkey, Iran, Brazil, and Egypt, each contributing less than 4% of the global supply [5].Figure 1 illustrates the structure of a watermelon. This review aims to compile information on the nutritional and phytochemical components, as well as the medicinal and therapeutic properties of both watermelon and its rind. The goal is to facilitate future production, utilization, genetic preservation, research, and development of this product. By highlighting the unique benefits of watermelon rind, this review provides a foundation for further exploration and utilization of this often overlooked resource. In essence, the article underscores the importance of maximizing the use of bioactive compounds from watermelon skin to promote health, especially in regions where its nutritional value is not widely recognized and it is commonly discarded as waste, leading to both nutrient loss and environmental pollution.

Fig 1.Structure of a Watermelon

The origins and development of watermelon throughout history

Watermelon, one of the oldest fruits used by humans, originates from the dry and desert regions of Africa. Historical evidence suggests that watermelon cultivation dates back to around 5000 BC in Egypt. Over time, it spread from Egypt to other parts of the world and is now recognized as one of the most widely consumed and popular fruits globally. The wild ancestor of the watermelon, known as the Abu Jahl watermelon, is native to North and West Africa. Research on the chloroplast DNA of domestic and wild watermelons indicates that they branched independently from a common ancestor, possibly the Citrullus assyrrhosus plant in Namibia. Evidence of watermelon cultivation has been found in the Nile Valley dating back to the second millennium BC. Watermelon seeds have been discovered in ancient Egyptian dynasties and in the tomb of Pharaoh Tutankhamun. By the 7th century, watermelons were being cultivated in India, and by the 10th century, they had reached China, which is now the world's largest producer of watermelons. The Moors introduced watermelon to Europe, where it was first planted in 1158 in Córdoba and Seville before spreading northward. Despite its appearance in the European Botanical Handbook in 1600, watermelon cultivation in Europe was initially limited due to the climate. However, by the 17th century, it became a widely cultivated garden crop [6].

The nutritional content of watermelon flesh

The red-colored flesh of watermelon is not only delicious but also packed with various nutrients. It primarily consists of simple sugars like glucose, fructose, and sucrose, with approximately 7.5 grams of carbohydrates per 100 grams or 12 grams per cup. With a sugar index ranging from 72-80, watermelon can cause a rapid increase in blood sugar levels. While it contains a relatively small amount of carbohydrates per serving, it may trigger digestive discomfort in individuals with irritable bowel syndrome due to its short-chain fermentable carbohydrate content. Additionally, watermelon contains minimal fiber at 0.4 grams per 100 grams.

- **Water:** Watermelon has a high water content, with about 90% of its composition being water. As a result, consuming watermelon can aid in keeping the body hydrated [7].
- **Vitamin C:** Watermelon contains a high amount of vitamin C, which serves as an antioxidant and supports the health of skin, bones, teeth, and body tissues [8]**.**
- **Vitamin A:** Watermelon has vitamin A, which helps maintain the health of the eyes, body immunity and skin health[9].

- **Vitamin B6:** Vitamin B6 is a water-soluble vitamin essential for the proper metabolism of sugars, fats, and proteins. It is also crucial for the growth and functioning of the brain, nerves, skin, and various other body tissues[9].
- **Vitamin B4:** Choline is necessary for fat metabolism and is used to burn fat in the body. This material is very important[9].
- **Vitamin K:** plays an effective role in blood clotting. K stands for coagulation (a German word for coagulation or clotting process). This vitamin activates the protein needed for normal blood clotting; A protein that heals wounds and prevents excessive bleeding [10].
- **Vitamin B9:** Vitamin B9 or folic acid, which is in the category of B vitamins, is not stored in the body and is necessary for food digestion and protein production. This vitamin plays an important role in many important activities of the body, including the health of the nervous system and blood, and protects it against heart diseases, osteoporosis, birth defects, and some cancers[9].
- **Fiber:** Watermelon has soluble fiber that can help improve the function of the digestive system and reduce the risk of digestive diseases such as constipation and intestinal diseases [11].
- **Potassium:** Watermelon is high in potassium, which acts as an important mineral to maintain cardiovascular health [12].
- **Lysopene:** Watermelon is rich in lysopene, a potent antioxidant that aids in combating chronic illnesses like heart disease, cancer, and diabetes[13].
- **Manganese:** Manganese is essential for the utilization of various vitamins including choline, thiamin, vitamin C, and vitamin E. It also supports proper liver function and serves as a cofactor in growth, reproduction, energy production, immune response, and regulation of brain activity.
- **Copper:** Copper is a vital and uncommon mineral necessary for survival. It is present in all body tissues and is involved in the production of red blood cells, as well as the maintenance of nerve cells and the immune system. Copper's properties aid in collagen formation, ion absorption, and energy production. It is predominantly located in the liver, brain, heart, kidneys, and skeletal muscles. Both low and high copper intake can impact brain function. Deficiency in copper has been linked to Alzheimer's, Wilson's, and Menkes' diseases[14].
- **Selenium:** Selenium, also known as Se, is a vital mineral for the body, supporting numerous bodily processes. It plays a crucial role in maintaining thyroid hormone metabolism, DNA synthesis, and protecting the body from oxidative damage and infections[15].
- **Zinc:** Zinc, also known as a mineral, is referred to as an "essential trace element" due to its minimal requirement for human health. Because the human body does not retain surplus zinc, it needs to be regularly included in the diet[16].
- **Sodium:** Sodium plays a beneficial role in the body's natural growth process by aiding in the absorption of calcium and other essential minerals in the bloodstream. It is distributed in the fluids surrounding the cells and regulates the body's water concentration[16].
- **Iron:** It is involved in the formation of hemoglobin, myoglobin, and enzymes that impact cellular respiration (iron center nuclei and cytochrome oxidase). Hemoglobin is crucial for transporting oxygen to the body's cells[16].

The nutritional value of watermelon seeds

Watermelon seeds, often overlooked, have unique properties and benefits that can aid in preventing various diseases and improving the function of body organs. Just 1/8 cup of watermelon seeds provides approximately 10 grams of protein. They are packed with protein, magnesium, vitamin B, and unsaturated and polyunsaturated fatty acids, all of which help lower cholesterol, reduce inflammation, and prevent heart disease and stroke. The protein in watermelon seeds contains several essential amino acids, including arginine, which can regulate blood pressure and aid in the treatment of cardiovascular diseases. Additionally, watermelon seeds are rich in B vitamins, such as niacin, which support the nervous and digestive systems as well as skin health[17]. The therapeutic properties are as follows:

- **Infertility treatment**

Watermelon seeds have various properties, including the ability to treat infertility. Amino acids, such as lysine, glutamic acid, and arginine, found in watermelon seeds, are essential for enhancing sexual desire and activity in men experiencing infertility and impotence. Additionally, the high levels of carotenoids in watermelon seeds play a crucial role in increasing sperm production and fertility in couples trying to conceive. Folate in watermelon seeds helps prevent birth defects and supports the formation of blood cells and bone marrow. Furthermore, watermelon seeds aid in strengthening the immune system of pregnant women, while the iron content helps prevent anemia. As a result, the impact on pregnancy and fertility is among the beneficial properties of red watermelon seeds[18].

- **Hair restoration**

Watermelon seeds have properties that help maintain hair health. They are rich in protein, iron, magnesium, and copper, which contribute to improving the appearance and strength of hair. Protein is essential for hair growth, and watermelon seeds are effective in treating hair loss and thinning. Additionally, the presence of copper aids in the production of melanin, responsible for hair color. The magnesium in watermelon seeds strengthens hair, preventing breakage and split ends. Consuming watermelon seeds can result in healthy, soft, and lustrous hair[19].

- **Enhance the body's immune system**

Watermelon seeds are rich in nutrients like carotenoids, antioxidants, and B vitamins, which can enhance the body's immune system and alleviate stress on the immune system. They also contain antioxidants that combat the damaging effects of free radicals, neutralize them, and decrease oxidative stress, thereby lowering the likelihood of developing chronic conditions such as cancer and heart disease[20].

- **Control of blood pressure**

Watermelon seeds are packed with magnesium, potassium, and essential amino acids that positively impact heart health. The presence of arginine amino acid in watermelon seeds contributes to lowering blood pressure. Additionally, the omega-6 fatty acids found in these seeds play a beneficial role in reducing blood pressure. Moreover, the potassium content in watermelon seeds acts as a vasodilator, helping to regulate blood pressure and alleviate strain on the cardiovascular system[21].

- **Lowering levels of unhealthy cholesterol**

One of the properties of watermelon seeds is to reduce the level of LDL or bad cholesterol. Watermelon seeds contain fiber and fatty acids that reduce bad blood cholesterol or LDL and prevent disorders and problems such as plaque deposition in the blood, atherosclerosis, heart attack and stroke and at the same time increase good blood cholesterol or HDL[22].

Watermelon skin and nutritional value of watermelon skin

Watermelon rind, the thick white layer between the outer green skin and the inner red flesh, constitutes about one-third of the fruit's total mass. Although edible, it is typically discarded due to its unpleasant taste[23]. The nutritional value of watermelon rind is as follows:

- **Protein**

  Watermelon skins are a valuable source of protein (15-50%), including albumin, globulin, prolamin, and glutelin

- **Amino acid citrulline**

Watermelon rind is the richest known source of the amino acid citrulline, primarily found in the white part of the rind. Citrulline has several significant effects on the body, notably promoting vasodilation, which widens blood vessels, lowers blood pressure, and enhances blood flow. Upon consumption, citrulline converts to arginine, which in turn transforms into nitric oxide, relaxing muscle cells and further dilating blood vessels. Notably, citrulline raises arginine levels more effectively than direct arginine intake due to variations in metabolic processing. This increase in nitric oxide and improved blood flow can enhance sports performance. Although citrulline doesn't directly contribute to protein synthesis, it stimulates a key signaling pathway that promotes muscle building and can reduce the liver's absorption of certain amino acids, thereby helping maintain or increase muscle mass. Studies indicate that watermelon juice and its white rind significantly boost citrulline and arginine levels in the bloodstream. To meet daily arginine needs, one would need to consume approximately 2.3 kg of watermelon daily, despite its being the best citrulline food source. Additionally, citrulline plays a vital role in the urea cycle, aiding in the removal of toxic byproducts from protein digestion to produce cellular energy[24,25].

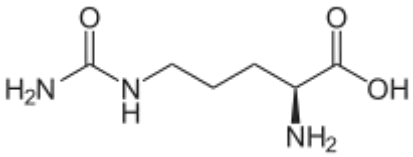


Fig 2. shows the chemical structure of citrulline.

- **Lycopene Antioxidant.**

Lycopene, a member of the carotenoid family, is an organic pigment that can be converted into vitamin A in the body. It possesses antioxidant and anti-inflammatory properties that neutralize free radicals and prevent DNA damage. In terms of antioxidant strength, lycopene is 100 times

more potent than vitamin E. The red color of lycopene-rich fruits, such as tomatoes, watermelons, and grapefruits, is notable. While tomatoes are the best-known source of lycopene, fresh watermelon actually contains more of this antioxidant. Raw tomatoes bind lycopene to insoluble fibers, limiting absorption, but cooking or processing tomatoes increases lycopene availability. Additionally, fresh watermelon juice enhances blood levels of lycopene and beta-carotene. Lycopene also reduces insulin-like growth factors (IGF), hormones that promote cell division, which, if excessive, can lead to cancer. Figure 3 shows the chemical structure and Figure 4 of the functional mechanism of lycopene[26,27].

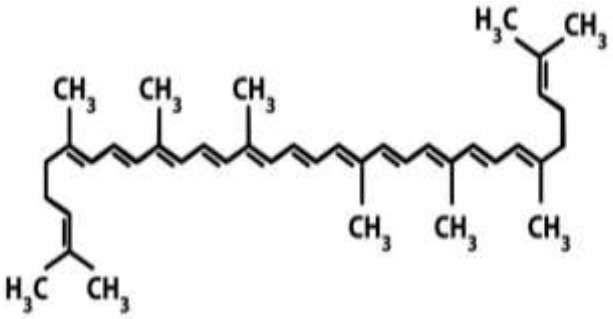


Fig 3. shows the chemical structure lycopene.

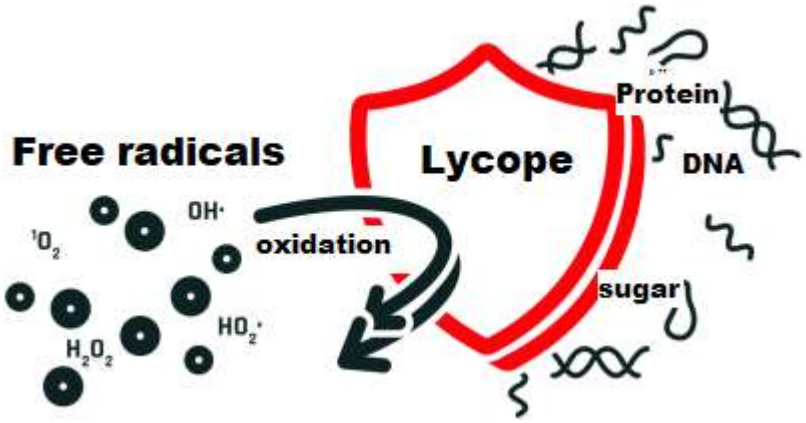


Fig 4. of the functional mechanism of lycopene

❖ **Antioxidant cucurbitacins.**

Cucurbitacins are highly oxidized tetracyclic triterpenoids found in various plants, serving as chemical pheromones that defend against biological threats. The white part of watermelon rind is a significant source of these antioxidants. Cucurbitacins demonstrate a broad spectrum of biological activities, such as cytotoxic and antitumor effects, hepatoprotection, anti-inflammatory and antimicrobial properties, and benefits for cardiovascular and diabetic health. Their unique chemical structure and various functions position them as promising anticancer agents by inhibiting cell proliferation, inducing apoptosis, and disrupting STAT3 signaling. For instance, cucurbitacin B and E glucosides exhibit antioxidant properties and free radical scavenging abilities, highlighting their potential in preventing diseases related to oxidative damage[28,29].

❖ **Chlorophyll**

Watermelon skin is rich in chlorophyll, which aids digestion and alleviates constipation by promoting beneficial intestinal bacteria while eliminating harmful ones. Chlorophyll also maintains a healthy balance of gut flora, thanks to its antibacterial, antifungal, and antiviral properties, supporting body detoxification. Experts suggest that chlorophyll benefits liver and kidney health as its detoxifying effects may reduce the risk of various diseases and help manage high blood fat and cholesterol levels. Figure 5 illustrates the chemical structure ofchlorophyll[30].

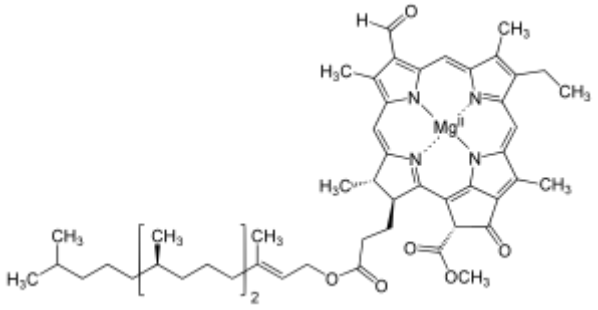


Fig 5. chemical structure of chlorophyll.

Healing benefits of watermelon rind

- **Urea scavenger**

Watermelon skin contains citrulline, which aids the urea cycle by absorbing nitrogen from the blood and converting it into urine. This urea-expelling property supports kidney function and helps eliminate excess toxins from the body[31].

- **Wound treatment and muscle growth improvement**

Watermelon rind contains a substance called arginine that boosts nitric oxide levels. This compound helps relax blood vessels and aids in treating angina and cardiovascular diseases. Additionally, the compounds found in watermelon rind can enhance muscle growth and are effective in wound healing. They also fight fatigue, stimulate the immune system, and may even play a role in cancer prevention[32].

- **Improvement of blood flow**

Watermelon rind has less water and less sugar content, but it has a lot of fiber compared to the fruit part. This white part of the watermelon rind contains a lot of citrulline which is an amino acid, which improves blood flow by dilating the blood vessels of the body. If you blend the rind of the watermelon with the addition of lemon juice and sugar, it provides good and delicious pleasure for a drink.

- **Anti-cancer and anti-aging properties of the skin**

Watermelon skin contains lycopene and citrulline, which play a role in neutralizing free radicals and preventing cell mutation. Regular consumption of watermelon rind can help prevent chronic diseases. These compounds help to maintain the general health of the body and prevent various diseases. Watermelon skin is full of lycopene, flavonoids and antioxidants that reduce the effects of free radicals and oxidative stress. These compounds help reduce the appearance of dark spots, wrinkles, and age spots[33].

- **Lower blood pressure**

Watermelon skin can help to reduce blood pressure as well. It's because watermelon skin is high in potassium, which is a vasodilator, meaning that it reduces the stress and pressure on blood vessels and arteries that can lead to atherosclerosis, heart attacks, strokes, and coronary artery disease. Hence, it strengthens the cardiovascular system and boosts your overall health[34].

- **Hydrate**

Dehydration can lead to various side effects such as tiredness, muscle cramps, and headaches. Watermelon, being 92% water, is a simple way to stay hydrated and support your body. With more than 90% water content, watermelon is effective in keeping you hydrated. Many adults do not consume enough water, and adequate hydration becomes crucial during the summer months when perspiration increases due to higher temperatures. Consuming watermelon with a pinch of salt after exercising or sweating profusely is beneficial. This combination of carbohydrates and salt is optimal for replenishing lost electrolytes and carbohydrate reserves[34].

- **Bone health maintenance**

The fruit's skin naturally contains beta-cryptoxanthin, a pigment that helps reduce joint inflammation and contributes to maintaining healthy bones[35].

- **Watermelon rind in hair restoration**

Despite common misconceptions about watermelon skin consumption and baldness, the white part of watermelon skin can actually enhance the oxygen supply to hair follicles and prevent hair loss by increasing collagen production[35].

Methods for using watermelon rind

- **Pickled watermelon skin**

In several developed countries like China and the United States, watermelon skin is commonly consumed in pickled form. The pickles have a surprisingly pleasant and delicious taste, often enjoyed as a dessert. The natural tartness of the watermelon rind helps to enhance its flavor, turning it into a treat that you'll truly enjoy. To pickle the skin, the tough outer green layer should be removed, revealing the softer white layer beneath the red flesh. The skin is then cut into pieces and marinated overnight in a mixture of rice vinegar, soy sauce, sesame oil, and sugar. Figure 6 displays the pickled watermelon rind[36].

Fig 6.pickled watermelon rind

- **Fermented watermelon rind**

The benefits of fermented foods are well known. Fermented watermelon skin is the best option for those who are sensitive to sauerkraut. Fermentation provides similar results to skin pickling along with the added digestive benefits of fermentation.Fermented watermelon skin not only offers a unique flavor profile, but it also retains valuable nutrients found in the rind. Rich in vitamins A, B, and C, as well as antioxidants, this unconventional food can enhance overall health while being gentle on the digestive system. The process of fermentation introduces beneficial bacteria that can aid in gut health, promoting a balanced microbiome[37].

- **Canned watermelon rind.**

Canned watermelon rind has transformed into a unique delicacy, elevating what was once a simple leftover into a delicious treat. This culinary innovation opens up a world of possibilities, allowing chefs and home cooks to experiment with flavors and textures in their recipes. The process starts with carefully selecting the freshest watermelons. The rinds are then peeled and cut into strips, which can be infused with a variety of spices and seasonings. Whether it's a sweet syrup with a hint of cinnamon or a tangy pickling solution, the options are limitless. Once canned, these colorful pieces provide an unexpected crispness to salads, serve as a delightful topping for desserts, or can be enjoyed on their own as a snack. Canning watermelon rind not only reduces waste but also promotes sustainability in the kitchen. It's a way to honor the entire fruit, minimizing what goes unused in our culinary endeavors. As the trend of "root-to-leaf" cooking gains popularity, canned watermelon rind is finding its rightful place on our pantry shelves, valued for its adaptability and taste[38].

- **Watermelon rind jam**

An alternative method for using watermelon goat skin is to pickle it. This involves removing the thicker green layer and cutting the skin into small pieces. Additionally, you can mix in some red watermelon flesh, then add sugar, a little lemon peel and lemon juice. Let the ingredients sit for about 30 minutes before boiling. Cook for two hours or until the watermelon skin and apple pieces become very soft. Once finished, the jam can be added to sterilized jars and stored for later consumption. To add extra flavor, consider including spices such as a pinch of cinnamon or some cloves. After cooking, allow the jam to cool before sealing the jars tightly. Figure 7 displays watermelon skin jam[39].

Fig 7. watermelon skin jam.

- **Watermelon skin juice**

To create a delicious and revitalizing juice, the rind and red flesh of watermelon are blended together, commonly enjoyed during the warm seasons. The juice is made by mixing the flesh, a portion of the rind, a dash of honey, and lemon juice. The watermelon rind contributes a slightly bitter taste, which is why honey and lemon are added to balance the flavors. Figure 8 illustrates juice based from watermelon skin[40].

Fig 8. juice based from watermelon skin.

Conclusion

Watermelon by-products such as seeds and skins are often discarded as waste around the world, leading to a loss of nutritional value and environmental pollution. However, these by-products have the potential to be utilized as a source of beneficial compounds for creating new food products. The chemical composition of watermelon skin and seeds reveals that they contain important nutrients with health-promoting properties. They can be incorporated as food supplements in dietary programs to support the immune system and treat various diseases, while also addressing environmental issues associated with their disposal through modern recycling methods.

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