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Nutritional and health perspectives of mango peel

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Abstract
Worldwide Mango is a common traded tropical fruits, but its peel, similar to other agricultural by-products, is often discarded. The weight of the mango peel accounts for 15% to 20% of the fruit's total weight. Prime by-products of mango juice and food processing industry is Mango peels and seed. However, mango peels, as nutrition-rich materials, have new gateways for nutrition production in the food industry and low costs for the pharmaceutical industry. Mango peels transformed into functional foods due to their historical consumption as food and medicine in certain parts of the world. The mango peel contains nutrients and natural bioactive compounds that could be utilized to create economic profit in the food industry. A significant agro-industrial waste, mango peel is rich in dietary fibre and polyphenols. The extraction of dietary fibre and polyphenols from mango peels and its correlation with improved gut health are highly relevant. In mango peel, ascorbate, fructose, and soluble (starch and rhamnogalacturonans) and insoluble (lignin and hemicellulose) dietary fibres can be found in good amounts. The aim of this article is to discuss the nutritional, functional, and essential nutraceutical properties of mango peel. The paper also discusses the future research needs in the area of mango peels for application in the food and pharmaceutical industry and wastewater treatment. Additionally, This review aims to raise awareness of the value of mango peels as a source of different nutrition.

Keywords: Mango peels, food industry, nutrition-rich, Waste Water

1. Introduction
One of the most significant tropical fruits is the mango (Family*:* Anacardiaceae), which was produced in excess of 26 million tons worldwide in 2004 (FAOSTAT, 2005). The mango belongs to the Anacardiaceae family. In terms of global production of all fruit crops, mangos came in sixth place in 2018, according to previously released data. In India, the world's largest producer of mangos, the export of mango pulp as a raw material for these goods was projected to account for almost 62% of all fruit and vegetable exports [1, 2]. Mango, magoteen, and guava are all classified as fruits by the Food and Agriculture Organization of the United Nations (FAO), which compiles information on their production. 55.38 million tonnes of these three fruits were produced worldwide in 2018 (FAO, 2019). India, Thailand, Indonesia, China, and Mexico are the top mango-producing country [2].

The majority of research on the utilization of mango peels has focused on their potential as a source of pectin, a high-quality dietary fiber. Peels are generally excluded from processed mango products because of their technological and sensory qualities [1, 2]. About 15 to 25 million tonnes of mango peels are generated each year, and they make about 15 to 20% of the fruit's weight [2]. Mango byproducts (peels) that are deposited in landfills result in financial losses as well as serious environmental issues like bacterial contamination, greenhouse gas emissions and create health hazard. Despite the fact that eastern nations have long used mango peels to season food [2, 4].

Mango peels have the potential to produce useful compounds and natural preservatives [2]. Their high levels of fiber, pectin, Carotenoids, polyphenols lignin, cellulose polyphenols, ascorbic acid, essential oils, pigments and proteinshave been well-documented. Mango peel and seed have strong antioxidant qualities and a high phenolic component concentration, which makes them potentially very beneficial. Phenolic substance can be found in food, medicine, cosmetics, and nutraceuticals. Reusing mango peels to make new delicacies reduces the amount of biowaste that is thrown away and gives mango processing enterprises a new source of revenue [2, 5-7].

Not only is mango peels a source of nutritional value, but have the functional property of heavy metal removal from wastewater. Heavy metal pollution has emerged as one of the most significant environmental issues due to the quick development of industrialization and urbanization. Due to urbanization and industrialization, heavy metal pollution is one of the most serious environmental issues today. The removal of Cd from wastewater has been achieved using a variety of methods, including chemical precipitation, adsorption, ion exchange, membrane filtration, and coagulation-occulation. Sludge disposal, non-recyclability limit, and high cost are some of these methods' intrinsic drawbacks. However, mango peels have additional benefits, including low cost, high performance, ease of operation, and environmental friendliness [8]. Therefore, Assessing the nutritional, functional, and nutraceutical qualities of mango peel was the aim of this study. This article also demonstrates wastewater treatment and ways to enhance the mango peels.

Geographical Distribution

In time, the mango spread throughout all of the nations that grow it, leaving its birthplace in the Indo-Burma (Myanmar) region [9]. The mango arrived in the Philippines from India via Spanish explorers during the end of the 15th and the start of the 16th centuries.In the 16th century, mangoes were transported to Africa, and in the 1700s, they made their way to Brazil via Portuguese ships.The Portuguese introduced mangoes to East and West African coasts in the 17th century, but Africans took a while to adopt them, and their spread into the interior was uneven [9]. Nowadays, most mangoes, which are tropical fruits, are grown in subtropical climates. It is regarded as a pan-tropical fruit, to put it another way. Mangos are currently planted in 89 countries globally, either commercially, in backyards, or as part of mixed plantations. India, Cambodia, Pakistan, Mexico, Myanmar, Egypt, Bangladesh, Sri Lanka, Tanzania, Florida and Hawaii in the United States, Australia, and Brazil are the main mango growing country [9]. In India and Myanmar Most cultivated species are *Mangifera indica* L [10].

Local Name of Mango [10]

- **Hindi:** am, aam
- **English:** Mango
- **Thailand:** mamung
- **Indochina:** ma muang
- **Spanish:** manga, mango
- **Malaysia:** manga, ampelam
- **German:** Mangobaum
- **Philippines:** paho
- **Indonesia:** mempelam
- **Malaysia:** ampelam
- **Myanmar:** tharyetthi
- **New Guinea:** Mango

2. Morphological feature of Mango

2.1 Canopy: Mango trees are long living that can reach heights of 15-30m. The mature height of most mango trees ranges between 3 and 10 meters depending on variety and pruning practice. In suitable temperatures, wild non-cultivated seedling trees can grow up to 15 meters, and in forest settings, they can reach up to 30 meters. The trees can reach trunk girths of more than 4 meters and survive for more than 100 years [11].

2.2 Bark: Trunk of a young tree is more than 20 cm thick, the bark is always smooth and stays that way. Later, straight longitudinal furrows that are shallow or even deep form. Bark of mature mango trees consist hard and glossy (Figure 1). In other situations, the bark separates into a big chunk. Resins, gums and latex exudates when bark is cut, there are milky colour [12].

2.3 Roots: There are usually two to four large anchoring taproots in the mango tree, each reaching deep into the ground.In most cases, feeder roots are found near the surface and reach just beyond the canopy's diameter. Feeder roots are finer, more fibrous, and reach down to about 1 m below surface. Seasonally, the finer roots' distribution varies according to the soil's moisture content [11].

2.4 Leaves: The simple, stipule-free leaves alternate with petioles. Although the size and shape of the leaves varies, they are typically oblong with rounded or accuminate tips. While leaf morphologies vary from variety to variety, they are more uniform within a variety. Initially green, leaves gradually turn tan brown to purple as they enlarge, and as they develop, they finally turn dark green (Figure 2) [11].

2.5 Twigs: The twigs of most species are smooth, dark green, drying black, and cylindrical, but they tend to be angular with short, pointed ribs depending on the species. The colour is different (reddish or reddish gray) in the Rawa region. The twigs is a characteristic that can be used to identify species [12].

2.6 Flowers: Some mango varieties have 60 cm long terminal inflorescences with wide conical blooms. Inflorescences consist of primary, secondary, and tertiary pubescent cymose branches that range in color from pale green to pink or red. The male and hermaphrodite flower types of the mango both appear on the same inflorescence. Petite, hermaphrodite flower petals are oblong lanceolate and thinly pubescent with four to five pubescent sepals [11].

2.7 Fruit: Fruits that have a single seed and are fleshy with a leathery endocarp are called drupes. Fruits of different varieties can range greatly in terms of fleshy texture, colour, shape, and flavour. Fruits have different lateral compression and might be spherical, ovate, oblong, or long. Mango fruit have three major part: Peel (epicarp), Seed kernel (endocarp) and Pulp (mesocarp), (Figure 3). Fruits range in weight from under 50 g to more than 2 kg. When the fruit is growing on the tree, its background colour is dark green (Figure 4); as it ripens, it becomes lighter green and eventually yellow. The fruit's fleshy edible portion, known as the mesocarp, typically has a sweet, somewhat oily flavour. Its texture changes from smooth to fibrous and its colour changes from yellow to orange when it is mature [11, 15].

2.8 Seed: Depending on the mango variety, one can either classify the seed embryos as monoembryonic or polyembryonic. Monoembryonic varieties produce only one zygotic (sexual) embryo. A cross between the paternal and maternal parents results in monoembryonic seeds A sexual (nucellar) embryos constitute the majority of polyembryonic seeds, and their genetic makeup is similar to that of their mothers. As well as the polyembryonic seed, cross-pollinated zygotic embryos are present in polyembryonic seeds [11].

Fig 1: Bark

Fig 2: Leaf

Fig 3: Fruit

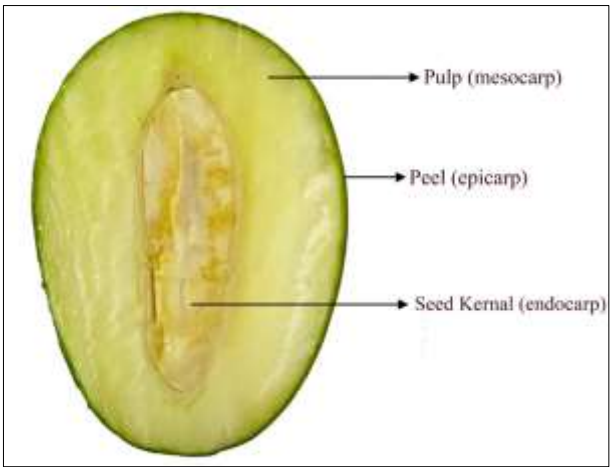

Fig 4: Part of Mango

3. Nutritional Constituents of Mango Peels

One important nutritional sources in the diversity of Earth is Plant. According to the WHO, sources of 80% of the nutrition comes from plants for daily life [13-14]. Fruit peels are typically thrown away and make up between 15% and 60% of the waste materials produced during fruit processing (Figure 5). However, mango peels contain dietary fibre and bioactive substances as well as essential macro- and micronutrients [4].

Fig 5: Mango Peels

3.1 Macronutrients

Manganese peels contain both soluble and insoluble dietary fibers. The total dietary fiber of mango peel have 28% to 78%. Due to its useful qualities, dietary fiber is a significant food addition [4]. Mango peel great sourceof carbohydrates, Proteins [15, 16]. Nutritionally, peel contains 2.62% ash, 2.05% protein, 26.5% carbohydrates and 5.40% fibre [17].

3.2 Micronutrients

Peels are rich in minerals (calcium, magnesium, iron, manganese, copper, potassium, zinc, phosphorus, chromium, sodium, chlorine) and Vitamin (vitamin A, vitamin B-Complex, vitamin C and vitamin E) [15, 16]. Mango peels containstrace ranges vitamin C from 188–2570 µg/g. Generally, vitamin C promotes wound healing and functions as a natural antioxidant. The vitamin A content ranged 5–15 mg/100 g [15, 17]. Burns *et al* reported that mango peels contains 153 – 167 mg/100g calcium, 31 - 41 mg/100g magnesium and 194 - 217 mg/100g iron. While mangopeel contains 205–509 µg/g of vitamin E, it is used to make skin care products. The riboflavin (B2) content ranged from 0.2 to 0.3 mg/100g, which boost the cellsgrowth [15, 17, 18]. Mango peels contain higher levels micronutrient (mineral) than pulp: Ca > K > mg > Na> Fe > Mn > Zn > Cu [15].

3.3 Bioactive Compound

Compared to the fruit's edible portion, mango peels contain even more particular bioactive chemicals. Mango peels contain high amount polyphenol. The peel's polyphenol content varies from 55 to 110 mg/gm dry weight, with ripe peels having higher levels than unripe peels. The main polyphenol compounds are ferulic acid, ellagic acid, caffeic acid, gallic acid, and catechin. The peel also contains two additional significant phytochemicals: mangiferin and quercetin 3-O-galactoside. Vitamin A is provided by β-carotene, one of the carotenoids found in high concentrations in mango peel [15, 16]. Additionally, phenolic compounds have anticancer and antioxidant properties. Approximately 15–20% of mangoes are fresh, and the peel contains more polyphenols than the pulp [4].

Mango peels have water-soluble Anthocyanins pigments. Anthocyanins found in red and purple mango varieties. A

number of anthocyanins are found in the peels of mangos, including peonidin, delphinidin, malvidin, cyanidin and pelargonidin [15]. Berardini *et al* reported that some reddishmangoes contain very low amount anthocyanins [20, 21]. Anthocyanins, which are well known for their beneficial effects in avoiding a variety of ailments, including cancer, neurological, diabetic, and cardiovascular problems, boost human health [22, 23]. Furthermore, peels contain some enzymes including catalase, amylase, peroxidase and and superoxide dismutase (SOD) [16]. The levels for the tannin and alkaloid contains from 15.91 to 24.27 g/100 g and 0.25 to 0.29 g/100 g, respectively. Mango peels content 29.04 to 37.18 g/100g flavonoid [17].

4. Functional foods and diet Supplements

Mango peels, a significant by-product of food processing, are thrown away as garbage and contribute to pollution. Carotenoids, Polyphenols, vitamins E and C, and the B-complex have all been discovered to be abundant in mango peel and it exhibited good Wound healing, Gastrointestinal disorders, Antibacterial, antioxidant, Anti-inflammatory properties (Figure 6) [19].

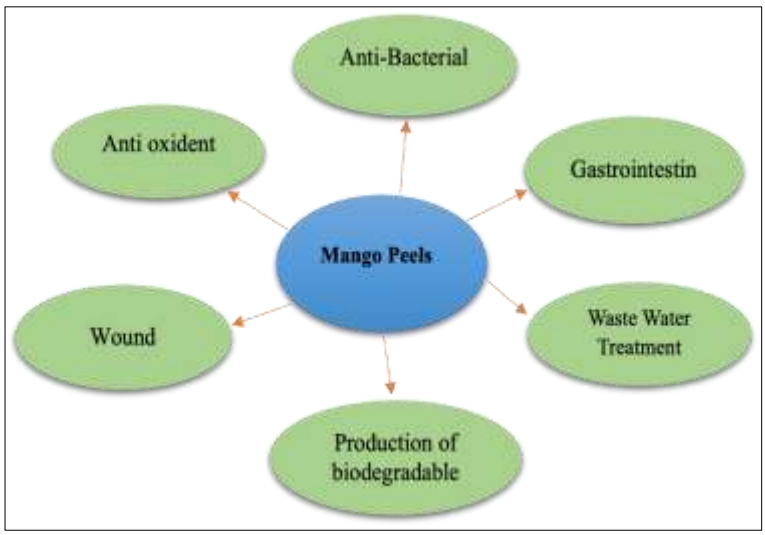

Fig 6: Application of Mango Peels

4.1 Anti-oxidant property

Many antioxidant components, such as phenolic compounds, anthocyanins, carotenoids and tocopherols, are found in fruits and vegetables. Fruit peels are huge source of ascorbic acid, flavonoids, polyphenolic compounds, and numerous other physiologically active substances that are beneficial to health [19-21]. It is well recognised that dietary phytonutrients offer defence against a range of metabolic disorders, hence enhancing people's general health. However, as a possible source of bioactive chemicals, mango peels can help treat a number of illnesses linked to a certain lifestyle **[24]**. Carotenoids and polyphenols, two types of antioxidant chemicals, are abundant in mango peels. While polar polyphenolic chemicals were removed using pressurised ethanol, carotenoids and flavonoids found in by-product of peel were extracted using supercritical CO_2 [4]. The mango peel was high in polyphenols and flavonoids, and it efficiently scavenged hydroxyl radicals, DPPH radicals, and alkyl radicals. Furthermore, the mango peel has been shown to have antiproliferative properties. The combined effects of the bioactive chemicals in mango peel may be the cause of its antiproliferative and antioxidant properties. Mango peel, a by-product of the mango processing industry, therefore exhibits promise as a value-added ingredient or functional food [19].

4.2 Anti-inflammatory:

When the human body responds quickly to injuries brought on by trauma from chemical or microbiological sources, inflammation serves as a defence mechanism. Non-steroidal medications, which have a number of drawbacks, are used to treat inflammatory diseases. The plants may yield more recent chemicals with noteworthy properties [25]. A healthy volunteer's blood sample was obtained, and the human red blood cell (HRBC) stabilisation method was used to determine the anti-inflammatory activity. Assuming 100% haemolysis in the presence of distilled water, the haemolysis percentage was calculated. The mango peels showed great anti inflammatory activity in these samples [25].

4.3Antibacterial

Since infectious diseases are becoming a bigger worldwide issue, it is becoming more and more crucial to find novel, promising antimicrobial medicines. Many pathogenic bacteria that cause significant diseases have become resistant to synthetic antimicrobials as a result of their inappropriate and excessive use. For instance, *E. coli* can result in a variety of ailments, such as bloodstream infections, respiratory disorders, diarrhoea, and urinary tract infections. *In vivo* transmission of antibiotic resistance and serious infections are linked to *P. aeruginosa*. Emetic (vomiting) syndrome and diarrhoeal syndrome are two gastrointestinal disorders that can be brought on by the foodborne bacterium *B. cereus*. From minor skin infections to serious invasive infections of the heart or lungs, *S. aureus* is the cause. Whereas Candida albicans is the principal cause of candidiasis and primary fungal infections, *A. brasiliensis* is mostly responsible for allergic responses and lung infections. As a result, natural materials and extracts are gaining more and more attention since they offer a fresh supply of significant biologically active substances that may have antibacterial qualities. For instance, extracts from fruit wastes, such mango peels, that have high concentrations of bioactive chemicals with antibacterial qualities could be utilised as safe, effective, and alternative natural therapies [16, 26-27].

The exceptional antibacterial properties of mango peel extract derived from different techniques align with the idea that different phytochemicals and bioactive substances cause microbial cell membrane breakdown. Mango peel shows an inhibitory effect of Gram-negative bacteria *E. coli.*With the exception of the HAE (H_2O) extract from fresh peels, all mango peel extracts shown high efficacy in inhibiting the growth of the Gram-negative bacterium E. coli at the maximum tested concentration (5 mg/mL) following 12 and 24 hours of incubation [16].

4.4 In Gastrointestinal disorders: It was found that moisture content, volume, color, and texture were the most important bread quality attributes to assess *in vitro*. Starch digestion rate and extent were also evaluated. The findings demonstrated that the addition of mango peel powder could considerably lower the rate and degree of starch digestion in bread, and that the degree of reduction was strongly correlated with the quantity of powder added. Mango peel powder increased the bread's moisture content while decreasing its volume. Furthermore, adding powdered mango peel changed the bread's texture, making it harder, chewier, and less cohesive. An increase in effects was typically correlated with greater amounts of powdered mango peel. Mango peel powder added at less than 5% did not significantly alter bread quality, but drastically affected starch digestibility. The quality of the bread may suffer, but adding more powdered mango peel could further slow down the digestion of starch. These findings would be helpful in enabling the full use of mango peel and would offer recommendations for the creation of dishes with a low glycaemic index. hence aiding in the treatment of gastrointestinal diseases. It has been reported that dietary fibre reduces the digestion rate of starchy foods because it absorbs water and increases their viscosity, thereby reducing blood sugar response after eating [21, 28-29].

4.5 Urinary tract infections: Our respiratory, digestive, urinary, and reproductive systems are getting infected that can range in intensity from mild to severe and, in some cases, deadly if left untreated. Due to the widespread spread of harmful microorganisms, the occurrence of recurrent infections caused by the same germ, and its resistance to treatment, we have recently observed a rise in UTI cases and the acceleration of the disease's spread. Encouragement to keep looking for antibiotics to stop the spread of these microbes and the current global trend towards natural treatments made from natural components that are readily available to us and have good antimicrobial properties. A serious risk to health is the quick emergence of antibiotic resistance in people. Treating an infection is crucial to saving the life of the infected person. In addition, recurrence of the condition in the same infected person necessitates finding a solution to this bothersome issue without endangering the patient's psychological well-being. As one of the tropical fruits that is highly advantageous to both people and animals due to the minerals, vitamins, and enzymes it contains in both its peel and pulp, mango extract (ME) is being studied today for its potential to treat UTIs. Its therapeutic efficacy, availability, and natural nature make MPE a recommended treatment for UTIs as it acts against both Gram negative and Gram positive pathogenic bacteria [30-31].

4.6 Wound healing: Since these wounds have grown to be a significant public health issue, the clinical community has recently started to concentrate on their care and treatment. Limiting the wound with patches and asepsis to reduce the bacterial load and bandages, changing the bandage at least three times a day, and supplementing with ointments that contain a single chemical compound that acts on one or a maximum of two phases of the healing process are the conventional therapies used for superficial wounds. Over time, these treatments become costly and painful. As a result, research is required to identify new treatment alternatives. Phytochemicals are being produced from natural products through secondary manufacturing processes, which extract bioactive compounds from natural products. Therefore mango peels are being used for treating wound because of its high content of bioactive compounds [32].

5. Other application in Industry

5.1 For Waste water Treatment

The rapid growth of industrialization and urbanization has made heavy metal pollution one of the most important environmental problems. Numerous human-caused processes, including those in the mining, manufacturing, battery, metal plating, paper, and plastic industries, release cadmium (Cd), one of the most dangerous heavy metals, into the aquatic environment. Thus, it is crucial to remove cadmium from water in an environmentally responsible and sustainable manner. To remove Cd from wastewater, several methods have been developed, including ion exchange, adsorption, membrane filtration, chemical precipitation, and coagulation-flocculation. Sludge disposal, non-recyclability limit, and high cost are some of these methods' intrinsic drawbacks. Adsorption has been shown to be a very effective technique for removing Cd(II) from wastewater because of its many benefits, including its low cost, ease of use, high efficiency, and environmental friendliness **[8, 33-36]**.

According to Iqbal *et al.*, leftover mango peel can be utilised to adsorb Pb(II) and Cd(II) from solutions. He *et al.* discovered that Cd(II) in synthetic wastewater may be eliminated by dry biofilms from biotrickling filters. A variety of industrial and agricultural organic wastes, including animal manure, sewage sludge, crop straw, and other plant and animal wastes, can be used to produce biochar. Pectin, cellulose, hemicellulose, polyphenols, carotenoids, and other substances are abundant in mango peel. As a result, making biochar from leftover mango peels is not only an eco-friendly way to deal with garbage, but it also has the potential to be used as an adsorbent to remove harmful metals from wastewater. Mango peel wastes are also inexpensive and simple to get as agricultural residues. However, until today, there was no literature on the effectiveness of biochars made from mango peels for Cd(II) adsorption in particular [8, 37-41].

Mango peels are wasted mango fruit that is thrown away after being used. An extract containing several phytochemicals and phenolic components, including polyphenols, flavonoids, carotenoids, and vitamins, can be made from these peels. These substances are used as an inexpensive stabilising and reducing agent in the production of various metal nanoparticles. These compounds' hydroxyl groups, which are a component of various functional groups, either reduce the metal ions or create metal nanoparticles of various sizes and shapes. Researchers have used mango peel

extract (MPE), which contains bioactive chemicals that reduce metal ions into metal atoms and cage them, to make metal nanoparticles [37, 42-45].

5.2 Production of biodegradable film

A significant amount of waste peel is produced by the essential agro-industrial sector of mango juice. Because fruit peels have higher biological activity and a significant amount of pectin, scientists are becoming more interested in using them. The important components, including pectin, lignin, cellulose polyphenols, essential oils, pigments, proteins, flavouring compounds, enzymes, and many more, can be separated from these waste peels to value them. Citric acid and monosodium citrate buffer were used to extract mango pectin (MP) from mango peels while adjusting for temperature, extraction duration, and pH. Biodegradable film can then be made with this pectin [5, 35, 46-47].

6. Conclusion

Mango peels contain a wealth of components that are nutritionally beneficial, bioactive, and of economic significance. The number of nutritionally, bioactively, and commercially significant components are abundant in mango peels. The composition of mango peel offers a rich combination of protein, carbohydrate, iron flavonoids, tannin, alkaloid, ferulic acid, caffeic acid, ellagic acid, dietary fiber vitamin C, vitamin E.Low-income individuals can benefit from low-cost nutritional supplements offered by peels. Mango peels, for example, contain bioactive compounds which are anti-inflammatory, antibacterial and antioxidant and cosmetic products benefit from their stabilization. They can also provide better treatment for gastrointestinal diseases due to presence of Dietary fiber. The peel of mangoes can be effective in removing Cd(II) from wastewater. Agriculture waste could also be used to prevent environmental pollution. Additionally, Utilizing mango peels also helps to lower garbage generation, environmental pollution, and waste disposal costs in addition to promoting value addition.

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Conflict of Interest

The author declares no conflict of interest.

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