A DISSERTATION ON

"Study on Physiochemical, Functional and Structural Characteristics of Watermelon Rind Powder"

SUBMITTED TO THE

DEPARTMENT OF BIOENGINEERING
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IN PARTIAL FULFILMENT
FOR THE
DEGREE OF MASTER OF TECHNOLOGY
IN FOOD TECHNOLOGY

BY
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M. TECH FOOD TECHNOLOGY (IV SEMESTER)
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UNDER THE SUPERVISION OF

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DECLARATION FORM

I, **Kalim Ahmed**, a student of **M.Tech. Food Technology** (IIYear/ IVSemester), Integral University have completed my six months dissertation work entitled **"Study on physiochemical, functional and structural characteristics of watermelon rind powder"** successfully from **Integral University,** Lucknow under the able guidance of **Ms Gazia Nasir.**

I, hereby, affirm that the work has been done by me in all aspects. I have sincerely prepared this project report and the results reported in this study are genuine and authentic.

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CERTIFICATE

Certificate that Mr. Kalim Ahmed (Enrollment Number 1700103345) has carried out the research work presented in this thesis entitled **"Study on Physiochemical functional and structural characteristics of watermelon rind powder"** for the award of **M.Tech. Food Technology** from Integral University, Lucknow under my supervision. The thesis embodies results of original work and studies carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution. The dissertation was a compulsory part of his **M.Tech. Food Technology** degree.

I wish him good luck and bright future.

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TO WHOM IT MAY CONCERN

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Dr. Alvina Farooqui
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Kalim Ahmed +

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LIST OF ABBREVATION

NAMES	ABBREVATIONS
Watermelon Rind Powder	WRP
Milligram	mg
Kilogram	kg
Millilitre	ml
Microgram	mcg
Gram	g
Association official analytical collaboration	AOAC
Normality	N
Gram Per Centimeter	gcm^{-3}
X- ray Diffraction	XRD
Fourier transform infrared spectroscopy	FTIR

1. INTRODUCTION

The watermelon, or *Citrullus lanatus,* is a blooming plant that originated in the Kalahari Desert of South Africa and is also found across Bangladesh to India. C. *lanatus* grows once a year in the summers that climbs up to 5 to 6 feet in diameter. It has huge, pinnately lobed leaves that are green in color and light yellow blooms with a sweet aroma. The flower was accompanied by a luscious fruit that is a unique variety of Peppo called berry. Fruits come in a variety of sizes and shapes, but they are often round or oval-shaped. Red is the shade of the fleshy, juicy, and edible portion (Theurkar *et al.,* 2023). Black or brown in color with a smooth texture, the watermelon body has a deep green rind or occasionally translucent green lines that transform into yellowish green when mature. It is a plant of tropical behavior, so to flourish properly, it ought to be nurtured at a temperature minimum of 25 degrees Celsius as well as exposed to a lot of sunlight. Watermelon blooms the finest in the ground which has acidic pH, and fertile and well-drained soil (Gupta *et al.,*2014.). 91% of a watermelon's weight is water, while only 6% is sugar. It is rich in vitamin C, among numerous other kinds of fruit. Citrulline, an amino acid, is present in large amounts in watermelons. It is a profound source of vitamins and an excellent option for phytochemicals (Perkins-Veazie *et al*., 2004). West Bengal and Andhra Pradesh are India's top two watermelon-growing states. The top two states for producing watermelons are Andhra Pradesh and Tamil Nadu (685.91T, 557.67T, and 381.55T, respectively). The state, of Maharashtra is also a national leader in watermelon production and cultivation (Theurkar *et al.,* 2023).

Watermelon is abundant in Lycopene, an antioxidant compound that helps prevent cell damage and lowers the risk of heart disease. It is also a great source of minerals like potassium, a cellular component that regulates blood pressure to maintain heart health (Jian *et al.,* 2005). More than 90% of a watermelon's weight is water, which upholds the hydration level in the body and a healthy level of electrolytes in bodily fluids. In the summer, watermelon is a great means to satisfy your thirst. A substantial amount of fiber aids in controlling bowel movement and improves digestion. Given that it contains carotenoids and lycopene, watermelon is an excellent supply of antioxidants. Fruit's anti-inflammatory characteristics are connected to the inclusion of the compound lycopene, which also serves as an antioxidant by scavenging free radicals. Additionally, watermelon also supports antioxidant activity due to the presence of a significant quantity of vitamin A. Lycopene gives its effectiveness as a cancer preventative. According to data released by the National Cancer Institute, Lycopene lowers the multiplication of prostate cancer cells. Citrulline found in watermelon was synthesized into arginine, which aids in lowering body fat. Additionally, it decreases fat, which inhibits the action of TNAP (tissue non-specific alkaline phosphatase), preventing the development of fat (Abdelwahab *et al.,* 2011).

During industrial processing, large quantities of vegetable and fruit wastes and leftovers are produced, which poses a severe threat to the environment. They must therefore be controlled or prepared for utilization. Although watermelon rind is a typical agricultural by-product, most people refuse to consume it because of its unpleasant flavor despite the fact that it contains numerous hiding minerals. They are occasionally consumed as vegetables. The rind of a watermelon is used to make powders, fruit cocktails, nectars, and similar items. Watermelon rind is used as preserves, pickles, pectin, and numerous other items in many countries. Chinese used to stew or stir-fried the watermelon rind. In the Southern US, pickled watermelon rind is frequently consumed (Rattray, 2012). In Bangladesh, watermelon is a common fruit during the period of cultivation. People consume the pink mushy part of the watermelon and discard the rind in the trash. The watermelon rind, however, is beneficial (Koocheki *et al.*, 2007). The flesh, rind, and seeds are the three major components of a watermelon that make up its biomass. Approximately 68% of the overall weight is made up of the flesh, 30% by the peel, and 2% by the seeds. It contains ash, crude fiber, protein, fat, and carbs. It competes fairly. (Hoque *et al.*, 2015). As large amounts of moisture (10.61%), ash (13.9%), fat (2.44%), protein (11.17%), and carbs (56.0%) are present in watermelon rind powder, its rind makes up nearly the total weight of 30% (Al-Sayed *et al.*, 2013). The current findings demonstrated that more than 38% of the total weight of watermelon fruit is waste and could be used as a good source of ash, dietary fiber, essential amino acids, flavonoids, and phenolic compounds. Powdered watermelon rind is also incorporated to improve product stability and preservation. phenolics are present in watermelon in a moderate yet considerable amount (El-Badry *et al.,* 2014). Among phenolics, flavonoids reduce low density lipoprotein (LDL) oxidation and quench reactive oxygen radicals, decreasing thereby the risk of cardiovascular diseases and cancers. Although the biological effect of flavonoids is, in general, attributed to their antioxidant activity, recent investigations indicate that they might affect signaling pathways in animal cells (Maoto *et al.,* 2019). Finding out how to include watermelon rinds, or so-called "wastes," in the manufacturing of various food products is essential. It is also a naturally abounding resource for citrulline, a non-essential amino acid that has a remarkable capacity for binding heavy metals from aqueous solutions. Citrulline contains numerous carboxyl and amino groups. The other half of a watermelon fruit, which is made up of roughly 35% rind and 15% peel, is wasted, according to research by the US Department of Agriculture's Agricultural Research Service. Thus, watermelon rind is utilized as a novel biosorbent to study the biosorption and desorption of Cu, Zn, and Pb in water to decrease agro-waste from watermelons and to find a new biosorbent (Liu *et al.,* 2012). Watermelon rinds have antioxidant properties that shield you from free radical damage thanks to the citrulline they contain. Additionally, arginine, an amino acid essential to the heart, circulatory system, and immune system, is produced from citrulline. According to the theories, blood arteries may dilate when cancer and cardiovascular disease spread (Rimando *et al.*, 2005). Active packaging is also created using watermelon rind, chitosan, and guar gum, which also enhances the physiochemical characteristics of the film. The watermelon rind extract extends the product's shelf life by making the film antibacterial, and antioxidant, and providing a barrier against UV and oxygen (Wang *et al.*, 2023). For producing fruit butter, watermelon rind is also included and its composition is juxtaposed with that of apple fruit butter. When compared to control apple butter, fruit butter made from 100% watermelon rind had a much higher acceptance. Due to the citrulline-containing amino acid found in watermelon rind, using it to make fruit butter can be beneficial for heart patients. As a result, it was also discovered that up to 100% of watermelon rind could be used to make fruit butter that was both healthy and acceptableOne of the most popular foods consumed worldwide is baked goods. By drying, water melon rind may readily be transformed into a value-added product that can then be mixed to rind powder and utilized to make baked goods. Muffins are a favorite among them and are thought of by consumers as a delightful sponge product with required organoleptic properties. Bakery products are frequently used as a source for the incorporation of various nutrient-rich components to increase their variety. The quantity and quality of the ingredients, particularly the flour used in production, affect the muffin's quality. In order to better understand how adding white watermelon rind to muffin recipes affects their physicochemical properties, sensory qualities, and shelf life (Hassan *et al.,* 2017).

Although diverse researches have worked on the characteristics of watermelon rind powder, the data of its functional and structural characteristics is limited and further reaserches are needed in this area which could be beneficial for upcoming food reaserches and industrialists. Therefore, current researches aimed to characterize the watermelon rind powder for the said parameters.

2. AIMS AND OBJECTIVES

- To dry watermelon rinds and preparation of its powder.
- To study the physicochemical and functional characteristics of watermelon rind powder.
- To study the structural characteristics (FTIR and XRD) of watermelon rind powder.

3. REVIEW OF LITERATURE

The thirst-quenching fruit, formally known as *Citrullus lanatus,* is a member of the Cucurbitaceae family and has been grown for more than 4,000 years in the Kalahari Desert of Africa. There are more than 1,000 different types of watermelon available globally (Edwards *et al.*, 2003). Watermelons can be cultivated in warm weather when there is a lot of moisture. It needs a lot of sunshine and a temperature of at least 25 °C for best growth. *Citrullus lanatus* is referred to as a "water" melon since it contains almost 93% water. Furthermore, the term "melon" designates a large, spherical fruit with delicious, pulpy flesh. Smooth with occasional light green streaks that turn yellowish green when mature, the skin is covered in a dark green rind. Watermelon is particularly nutrient-dense and is suitable for breakfast, an appetizer, or a snack (Kerje *et al.,* 2003). One of the most underutilized fruits is watermelon; the skin and seeds are among the largest solid wastes produced by the fruit industry, while the powder or pulp is used for human consumption. (Benmeziane *et al.,* 2023). The Middle East, the USA, Africa, India, Japan, and Europe are the major watermelon-producing regions. Watermelon is grown in Rajasthan, Uttar Pradesh, Orissa, Punjab, Haryana, Assam, West Bengal, Karnataka, Orissa, Gujarat, Andhra Pradesh, Maharashtra, Himachal Pradesh, and Tamil Nadu, according to the National Institute of Industrial Research. Tarbooz, Tarbuj, Kaduvrindavana, Eriputccha, Kallangadiballi, Tormuj, and Indrak are some of the frequent names for watermelon in Hindi, Urdu, and other Asian languages. About 25 commercial cultivars are grown in India, some of which have delightfully intriguing names like New Hampshire Midget, Madhuri 64, Black Magic, Sugar Baby, Asahi Yamato, Arka Jyoti, Arka Manik, Improved Shipper, Durgapura Meetha, and Durgapura Kesar. Sandaloam soil with a pH range of 6.5 to 7.5 and good drainage is used to grow watermelons (Ossai *et al.,* 2021). Watermelons are sown in the North Indian plains in February and March, whereas the optimal period to sow in Northeast and Western India is from November to January. These can be grown practically year-round in South and Central India (Dubey *et al.*, 2021).

BOTANICAL CLASSIFICATION (Alka *et al.,* 2018)

Botanical Name: *Citrullus lanatu*

Kingdom: Plantae

Order: Cucurbitales

Family: Cucurbitaceae

Genus: *Citrullus*

Species: *C. lanatus*

3.1 NUTRITIONAL VALUE OF FRESH WATERMELON

One of the fruits that is frequently consumed worldwide is the watermelon. A watermelon's water content is around 91%, and its carbohydrate content can reach 7%. Citrulline and lycopene are abundant in it. Citrulline concentrations in watermelon rind are higher than in flesh. In addition, watermelon contains several vital vitamins and minerals. Citrulline amino acids had previously been taken from watermelon and examined. The nutritional value of watermelon reveals that it is quite high in vitamin A, various vitamins from the vitamin B complex, such as Pantothenic acid, Riboflavin, Niacin,Folate, and Vitamin C. Along with highly unsaturated fatty acids and oils, the mineral composition includes calcium, iron, magnesium, phosphorus, potassium, and zinc. It is also abundant in essential amino acids including arginine, glutamine, and aspartic acid (Olamide *et al.,* 2011). Alkaloids, glycosides, flavonoids, saponins, phenols, and tannins are also abundant in the plant. Its nutritional qualities are beneficial to human health as well. (Deshmukh, *et al.,* 2015).

Table: 1 Nutritional Value (Ref: Masudul Hoque *et al.*, 2015)

Nutrition	**CONTENT**
WATER	91%
PROTEIN	6 gm
CARBOHYDRATES	7.6 gm
SUGAR	6.2 gm
FIBER	0.4 gm
FAT	0.2 gm

3.2 PHYTOCHEMICAL PROFILE OF WATERMELON

Carotenoids

In watermelon, carotenoids play a key role as functional elements and micronutrients. When evaluating the quality of watermelons, the carotenoid content, and concentration have both gained significant attention (Lv *et al.*, 2013). The red-fleshed watermelons contained the most lycopene and β-carotene. The majority of the total carotenoids (84%–97%) were made up of lycopene. Watermelons with different flesh hues have different carotenoid compositions, which are related to cultivars and growth conditions (Tadmor *et al.*, 2005). Lycopene, a carotenoid, is thought to be the most potent and effective antioxidant and singlet oxygen quencher, and as a result, the risk of malignancies and cardiovascular disorders is decreased. Carotenoids' primary purpose is to counteract substances created during photosynthesis (Perkins-Veazie *et al.*, 2001)

Amino acids

Citrulline, an amino acid that is used to create arginine, is a fantastic source of citrulline and is found in watermelon. Previous research has emphasized the benefits of citrulline and arginine for sickle cell anemia, immunological function, wound healing, and cardiovascular health.

Citrulline has a higher bioavailability than arginine, with 80% of the ingested aggregate being promptly absorbed into the blood (Tong *et al.*, 2004)

Phenolic compounds

Anthraquinones, a type of phenolic compound found in C. *lanatus* in modest concentrations, are useful for treating constipation and stomachaches. Anthranols and anthrone derivatives are particularly specialized substances that are produced by anthracene. Other molecules, including chrysophanol, luteolin, emodin, and rhein derivatives, exhibit a mutual double hydroxylation at the C-8 and C-1 positions. A violet or pink hue in the plant sample indicates the presence of anthraquinones in the base stratum (Nahar *et al.,* 2019).

Triterpenoid

Cucurbitacin E, also known as a triterpenoid, is a characteristic anti-inflammatory compound that is present in watermelon seeds. Cucurbitacin E has been effective in neutralizing reactive nitrogen-containing compounds and blocking the activity of cyclo-oxygenase enzymes. This substance is used to neutralize reactive nitrogen species (RNS) through an anti-inflammatory substance, but it does not affect neutralizing reactive oxygen species (ROS) in cells (Arel-Dubeau *et al*., 2014)

Saponins

Watermelon seeds contain saponins, which are pharmaceutically used to treat several conditions including inflammation, pre- and postmenopausal symptoms, cardiovascular disease, and hypertension. Steroid and triterpenoid saponins are the two primary varieties (Bombardelli *et al.*, 2001). The two main classes of saponins include saponins, triterpene, and saponins steroids. Saponins are soluble in water but insoluble in organic solvents like ether, and upon hydrolysis, they release glycosides linked to aglycones. They are recognized as the responsible parties for blood hemolysis and cattle poisoning. In general, saponins are thought to be quite toxic. They are soluble in alcohol but insoluble in non-polar organic solvents like hexane and benzene (Nadeem *et al.,* 2022).

Alkaloids

Alkaloids are believed to be present in watermelon seeds in the highest concentrations compared to the other parts, and they exhibit potent therapeutically significant bioactivities as plant secondary metabolites and as primary agents for antispasmodic, analgesic, and bacterial effects. They are widely used throughout the world (Akshaya *et al.,* 2018). As the main group of secondary chemical components in the amino acid building blocks that essentially create nitrogen bases and enclose them in a peptide ring, these are primarily composed of ammonia compounds. These are the fundamental substances that, according to their fundamental qualities, aid in turning red litmus paper blue. For alkaloids, the inclusion of one or more nitrogen atoms often increases the alkalinity of an alkaloid by 1°, 2°, or 3°. The degree of basicity is known to vary greatly due to the characteristics of elements, such as molecular structure, functional groups, position, and existence (Nadeem *et al.,* 2022)

3.3 NUTRACEUTICAL POTENTIAL OF WATERMELON

It is believed that wild melon, also known as Citrullus lanatus var. citroide, had a considerable impact on the use of traditional herbal thera py. The seed contains pectoral, tonic, and demulcent effects. The fruit has a diuretic effect and has been demonstrated to be helpful in the treatment of dropsy and kidney stones (Saiwal *et al.,* 2019). It is sometimes used to treat bedwetting and urinary tract infections. You can find both of these therapies at Moerman. Preliminary research suggests that consuming watermelon may help reduce blood pressure (Alka *et al.,* 2018). In Northern Sudan, *Citrullus lanatus* is used as a laxative, to cure rheumatism, gout, and swellings as well as burns. Consuming fruits acts as a severe laxative. Diarrhea, gonorrhea, and other gastrointestinal conditions are treated with them (Ijaz *et al.,* 2022).

3.3.1 Cardiovascular safety

To avail the nutrition you need, it's important to eat fruits like watermelon that are high in l-citrulline, a precursor to l-arginine, an essential amino acid for protein synthesis. The antioxidant status, anti-inflammatory characteristics, and lipid profiles were all improved by adding whole watermelon as a powder supplement. Additionally, consuming watermelon influenced the expression of genes linked to lipid metabolism (Manivannan *et al.,* 2020). Lycopene, an antioxidant that helps prevent cell damage and lowers the risk of heart disease, is abundant in watermelon. It is also a great source of minerals that promote heart health, one of which is potassium, which is a cellular component and regulates blood pressure in addition to maintaining heart health (Jian *et al.,* 2005). Overall, it has become clear that regularly eating watermelon lowers the risk factors linked to chronic illnesses including cardiovascular diseases (Manivannan *et al.,* 2020).

3.3.2 Obesity Controlling and Anti-diabetic

Plasma levels of l-arginine were dramatically raised by watermelon consumption. In Zucker diabetic fatty rats—a commonly used animal model for non-insulin dependent diabetes—watermelon juice administration increased the levels of l-arginine and reduces the levels of glucose, free fatty acids, homocysteine, and methylarginines. On the other hand, it increased tetrahydrobiopterin levels in the heart and acetylcholine-mediated vascular relaxation as well as GTP cyclohydroxylase-1 activity. When given orally to people, watermelon juice can serve as a useful substitute for arginine supplements. Juice from a watermelon effectively helped to control the body's overall metabolism and improved both the cardiovascular system and the immune system in people. It was found that eating watermelon enhanced vascular function and decreased ankle blood pressure, brachial blood pressure, and carotid wave reflection in obese middle-aged adults with pre-hypertension (Wu *et al.,* 2007).

3.3.3 Anti-Ulcerative Colitis

One type of inflammatory bowel disease that affects many people and results in mucosal inflammation throughout the entire gastrointestinal system is ulcerative colitis (Manivannan *et al.,* 2020). The watermelon's abundance of l-citrulline, a precursor to l-arginine, can help in ulcerative colitis treatment. According to a recent study, watermelon supplementation improved cellular kinetics, the micro-architecture of colon crypts, and the quantities of nitric oxide produced by the body. According to the hypothesis put forth by (Hong et al., 2014) watermelon's augmentation of NO levels would synergistically increase the expression of PPAR-, which would then reduce inflammation and oxidative stress. Previous research revealed that PPAR- is directly influenced by NO and l-arginine, whereas ulcerative colitis causes PPAR- levels to decrease (Cai *et al.*, 2018).

3.3.4 Antioxidant

Extracts of Citrullus lanatus in methanol, ethyl acetate, and chloroform shown antioxidant activity. Using DPPH, the antioxidant capacity of each chloroform, ethyl acetate, and methanol extract was evaluated. Citrullus lantus (MECL) seed methanolic extract has the best antioxidant potential (Gupta *et al*., 2014.).

3.3.5 Anti-inflammatory

The oil's anti-inflammatory effectiveness was tested in vivo and in vitro using carrageenan-induced paw edema in rats and the in vitro stabilization of human red blood cell membranes. Diclofenac (10 mg/kg) was used to compare oil potency. The oil protected HRBC in hypotonic solution at 100, 250, and 500 mcg/ml and significantly reduced edoema in the carrageenan-induced rat paw edoema model at maximum at 3 hours (percentage reduction in paw volume: 44.44%, 55.56%, and 63.11% for CLSO (50 mg/kg), CLSO (100 mg/kg), and diclofenec (10 mg/kg), respectively) (Aderiye *et al.*, 2020), (Bazabang *et al*., 2023).

3.3.6 Antimicrobial Effects

Citrullus lanatus var. Citroides (CL) leaves, fruits, stems, and seeds have been shown to have antimicrobial activity against bacteria like *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aureginosa*, *Bacillus subtilis*, and *Proteus vulgaris* as well as fungi like *Aspergillus nigar and Candida albican*. Diffusion studies using a cup-plate and a disc evaluated antimicrobial CL. The strongest antibacterial activity is present in fruit chloroform extract. S. aureus, B. subtilis, E. coli, and P. valgaris were all inhibited by it. The best anti-fungal action is found in an ethanol extract of the fruit and stem of *C. albica* (41 m). Especially vulnerable to nigars were the chloroform and ethanolic extracts of seed and foliage. The antibacterial activity of *Citrullus lanatus* seed extract was also studied. The results of seed extract tests against the chosen bacteria revealed that chloroform, cold maceration, and Soxhlet extraction (Aderiye *et al.*, 2020)

3.3.7 Antisecretory Effects

In Indomethacin-induced ulceration in male albino rats, the stomach acid output and pH of *Citrullus lanatus* juice were measured. The experiment consisted of two investigations. For 30 days, four groups of rats in each research were pretreated with distilled water (control), 25%, 50%, or 100% watermelon juice. Rats' gastrointestinal ulcers were lessened by *Citrullus lanatus* juice (P 0.05). Ulcerogenesis was decreased before treatment (P 0.05). *Citrullus lanatus* (watermelon) juice appears to be gastroprotective against Staphylococcus sp. and *P. aeruginosa* in stomach ulcers brought on by indomethacin (Benmeziane *et al.*, 2023)

3.3.8 Hepatoprotective Effects

By assessing blood hepatic enzyme levels and the histology of liver tissue, *Citrullus lanatus* seeds were found to protect rats from hepatotoxicity brought on by carbon tetrachloride. Rats were administered oral doses of normal silymarin (100 mg/kg) and citrullus lanatus seed oil (125 and 250 mg) daily for ten days. Blood ALT, AST, and ALP levels dramatically decreased in treated groups with CCI4-induced liver injury, similar to what is seen with normal treatment. Histopathological investigations show that Citrullus lanatus seed oil shields the liver (Bazabang *et al.*, 2023)

3.3.9 Laxative effect

The laxative effects of aqueous *Citrullus lanatus* fruit pulp extract were examined in albino Wistar rats. Rats were divided into five groups, each with six rats. Groups 3, 4, and 5 were given doses of 250, 500, and 1000 mg of an aqueous fruit pulp extract from Citrullus lanatus, while group 1 served as the control. Group 2 served as the standard (sodium picosulfate) (Alka *et al.*, 2018)

3.3.10 Hydration and digestion

As previously noted, watermelons have a water content of more than 90%, which keeps the body hydrated and balances the levels of electrolytes in bodily fluids. It is the ideal way to quench your thirst throughout the summer. Watermelon has a sizable amount of fiber that aids in digestion and maintains regular bowel movements. Support for anti-inflammation and antioxidants: Watermelon is a high source of antioxidants due to the presence of carotenoids and lycopene. Fruit's ability to reduce inflammation is linked to the presence of lycopene, which also functions as an antioxidant by scavenging free radicals. The considerable amount of Vitamin A found in watermelon also supports antioxidant activity. cancer-preventing action Lycopene is present, making it an effective anti-cancer agent. According to a National Cancer Institute analysis, lycopene aids in lowering (Dubey *et al.,* 2021).

3.4 UTILIZATION OF WATERMELON RIND IN FOOD PRODUCTS PREPARAT4ION

Watermelon rind with Fruit Butter added based on a 2013 study. Fruit butter made from watermelon has been developed, and watermelon rind can be used in place of other ingredients. The ratios of 100:0, 75:25, 50:50, 25:75, and 0:100 (apple: watermelon rind) were used to create various fruit butter compositions. A spice mixture (nutmeg, cinnamon, and clove) was cooked with 400 grams of watermelon rind pulp and 300 grams of sugar as part of the preparation. The manufactured product was evaluated organoleptically, and Sample 4 (0:100), out of 4 ratios, was approved when compared to apple butter. Therefore, 100% watermelon rind can be used to make a healthy and palatable fruit butter.

3.4.1 Watermelon rind flour-based Cookies

Based on the nutritional and health benefits of watermelon rind, cookies were made using 10%, 20%, and 30% watermelon rind flour, and they were compared to 100% refined wheat flour. In order to make cookies, dry components must be combined with refined wheat flour and watermelon rind flour before being kneaded into dough. It goes through rolling and cutting before being baked for 20 minutes at 160 °C. Based on a nine-point hedonic scale, 30% of watermelon rind-incorporated cookies received an 8.04 rating, making them the most popular. As a result, watermelon rind flour can somewhat alter refined wheat flour, making it a better innovative product and improving the nutritional value of the product's crude fiber, calcium, iron, and phosphorus (Naknaen *et al.*, 2016).

3.4.2 Watermelon rind Dehydrated Candy

Osmotic dehydration was used by (Muhamad *et al.*,2011) to develop a technique for dehydrating candy made from watermelon rind. Pieces of watermelon rind that were 3 cm long and 1 cm wide were blanched for 1 minute before being dipped in 40 °C Brix sugar syrup, which was raised by 5 °C Brix every day, up to 55 °C Brix. For 8, 14, and 20 hours, respectively, crystallized rinds were dried in cabinets at 50 °C before being dusted with icing sugar and corn flour (1:1). Results showed that candies stored in a dehydrated state for 14 hours were the most popular (Dubey, *et al.*, 2021).

3.4.3 Reduced Fat Mayonnaise

Due to satisfactory level of pectin, watermelon rind can act as a stabilizing agent in preparation of food products (Dubey, Rajput, and Batta 2021). When making mayonnaise, watermelon rind can be used with wheat to serve as a stabilizer. Four treatments will be prepared for the study: one with no watermelon rind, one with 2%, one with 4%, and one with 6% oil. According to the findings of the organoleptic test, 2% watermelon rind can be used to make mayonnaise (Evanuarini *et al.*, 2020)

3.4.4 Watermelon rind Cake

Al Sayed and Ahmad, 2013 used the wheat flour substituted with 5, 10, and 15% watermelon rind powder and 100% of wheat flour to develop cake. The study was conducted to explore the use of watermelon rind as a useful ingredient in cake processing. After mixing all the ingredients, the dish was baked for 30 minutes at 180 °C. 5% and 10% formulations were found to be the most acceptable after organoleptic analysis (Al-Sayed *et al.*, 2013).

3.4.5 Watermelon rind incorporated Dietary chips

Sen, 2004 developed dietary watermelon rind chips. Before manufacturing dough with different ratios to make chips, watermelon rind was first manufactured and mixed with composite flour (masoor dal, moong dal, channa dal, and soybean dal), salt, and pepper. The desired shapes were cut out of the chips before baking them for 5 minutes at 270°C. The watermelon rind to composite flour ratio of 32:68 was shown to be the most effective across all experiments due to its higher dietary fiber and lower fat content. Consequently, you can use watermelon to partially substitute the fat or flour needed to make chips (Sen *et al.*, 2004).

3.4.6 Watermelon rind flour-based Bread

A study was carried out to discover if bread could be produced using a watermelon rind flour mixture mixed with composite flour in different proportions, such as 0%, 10%, 20%, 30%, and 40%. Straight dough was used to make the bread. The dough was prepared by blending all the components, and it was baked for one hour and a half at 100° C. It was found that increasing the amount of watermelon rind flour in the bread from 10% to 30%, increased its nutritional value, reduced fruit waste, and produced a high-quality end product (Imoisi *et al.*, 2020).

3.4.7 Addition of watermelon rind powder in Sorghum based Mumu

In Nigeria, a traditional ready-to-eat food called mumu is cooked with maize, millet, and sorghum. Three separate samples—roasted sorghum flour, partly roasted defatted groundnut flour, and watermelon rind powder—were first made using diverse methods. In the following proportions 85:15:0, 75:15:10,70:15:15, 65:15:20%, four distinct mixes with roasted sorghum flour, roasted partially defatted groundnut flour, and watermelon rind powder were prepared. The following powdered form mixture was used to make mumu, along with the requisite amount of cold water and flavoring sugar. The result is that the use of watermelon rind powder significantly enhances the product's functional, pasting, and microbiological properties (Dubey *et al.*, 2021).

3.4.8 Watermelon rind incorporated noodle

In this study, wheat flour was replaced with watermelon rind powder at the following rates 50, 100, and 150 g/kg of mixtures to make noodles. The correct amounts of additional ingredients, including water, sodium chloride, and kansui reagent, were used to create a smooth dough. As a result, noodles of the right thickness might be produced. Watermelon rind-based noodles at a level of 100g/kg obtained the highest score, 6.33, after each combination's final product underwent sensory evolution (Ho *et al.*, 2016).

3.5 OTHER USES OF WATER MELON RIND

3.5.1 Pectin Extraction

Pectin is a complex water-soluble polymer, found in the plant cell wall. Pectin's primary constituent, D-galacturonic acid, is connected by K-(1-4) glycosidic linkages. The pectin from the watermelon rind was extracted using the (Canteri-Schemin *et al.*, 2020) method. Yogurt can be stabilized using extracted pectin, and it can also be utilized as a component of jams, jellies, and other food products. It aids with digestion and lowers cholesterol, but it is also used in the pharmaceutical industry (Chandel *et al.*, 2022).

3.5.2 ZnO Nanoparticles Biosynthesis

One of the remarkable achievements is the extraction of ZnO nanoparticles from watermelon rind. The watermelon rind aqueous extract was prepared by combining watermelon rind powder with distilled water, which was then heated and filtered. An extract of watermelon rind is thought to be the Supernatant solution. This extract is evaluated by HPLC and helps with the chemical production of ZnO nanoparticles. Due to citrulline's high content in the rind, ZnO nanoparticles are stabilized. Later, these ZnO nanoparticles were used as a nano-sorbent and an antibacterial agent. The results of this study suggest that the biogenesis of nanoparticles aids in wastewater rehabilitation and decreases agro-waste (Perera *et al.*, 2022).

3.5.3 Bulk forming laxative

Watermelon is also very helpful in upset stomach and constipation by producing bulk-forming laxatives. The novel method for producing laxatives with less adverse effects and bulk-forming abilities was created using watermelon skin in conjunction with pectin and isabgol. Ten distinct combinations were made using the wet granulation technique, and the dough was made using the required amount of water. After pressing the dough, the granules were dried for 12 hours at 60 °C. The bulk-forming laxative derived from WRP and isabgol was finally found to provide several advantages over the market sample. As a result, this revolutionary drug derived from natural elements will lessen the side effects of other laxatives (Waghmare *et al.*, 2015).

Thus, watermelon rind powder could be used as a functional ingredient due to their nutritional health benefits in food industry but also in another sector. According to the United Nations Food and Agriculture Organization (FAO), fruits and vegetable processing industry estimated that losses and waste is the highest among all types of foods, and may reach up to 60%. About 25% - 30% of by-products wastes among whole commodity group produces by the processing of fruits and vegetables industry. Out of the total annual production, one third of it is simply discarded in the form of rind and peel. Therefore, this review gathers attention towards more and more utilization of fruits and vegetables (Sagar *et al.*, 2018).

4. MATERIALS AND METHODS

The research has been conducted in the Department of Bioengineering, Integral University, Kursi Road, Lucknow. Fresh watermelon free from physical disorder was procured from the local market and the rinds were collected after the flesh has been consumed. Other necessary materials and chemicals were used from the laboratory stock.

4.1 Drying of watermelon rinds and preparation of powder

Watermelon rinds were dried using mechanical dryer. Cabinet Tray dryer (Model OV-165, Gallen Kamp Company) was used for drying of watermelon rinds. The dryer consists of a chamber in which trays of product were placed. Air was blown by a fan past a heater and then across the trays of product being dried. The velocity of air was recorded (0.6m/sec) by an anemometer. For determining the effect of temperature and loading density on the rate of drying, rinds were sliced by stainless steel knives and slices were taken for determination of initial moisture content. Fresh watermelon rinds of 8 mm thickness were placed in trays and drying commenced in the drier at a constant air velocity (0.6m/sec) and at a specific air dry bulb temperature (°C). Weight loss was used as a measure of the extent of drying. Again, to determine the effect of temperature on the rate of drying the rinds were dried at temperature , 60C for 24hrs. The dried rinds were then converted into powsder by grinding in a grinder. The obtained powder was subsequently passed through a 150-mesh sieve to obtain a fine powder. The sieved powder was stored in aluminium pouches at 0 °C for further analysis.

PROCESS CHART

Collection of Watermelon

↓

Seperation of watermelon rind

↓

Washing of watermelon rind

↓

Drying(Tray drying at 60°C for 24 hrs)

↓

Milling(Using grinder)

↓

Seiving

Fig 1: Processing of watermelon rind into powder.

4.2 Proximate analysis of watermelon rind powder

The moisture content, protein, crude fat, ash and dietary fibre content of watermelon rind powder was determined according to AOAC protocols (AOAC, 2000).

4.2.1 Moisture content

5g sample was prepared and kept in a previously dried and weighed petri dish. The petri dish was placed in the hot air oven maintained at 105 ± 2°C for 4 hrs for determining the moisture content of the sample **(BIS, 2003)** shown in **Fig 2.** The formula **(3.12)** used to calculate moisture content wet basis of the sample is given below.

$$\textbf{Moisture content (\%wb)} = \frac{M_2 - M_1}{M_1 - M} \times 100$$

Where,

M_1 = mass of the dish with the material before drying (g)

M_2 = mass of the dish with the material after drying to constant mass (g)

M= mass of the empty dish (g)

Fig 2: Determination of Moisture Content in try drayer.

4.2.2 Protein content

Protein content was determind following AOAC, (2000) standerds using kjeldahl appartus. Kjeldahal method is done three steps namley digestion, distillation and titration. For degestion 2 grams watermelon rind powder sample was taken into a digestion flask with 10 parts of K_2SO_4 (potassium sulfate) with 1 part of $CuSO_4$(copper sulfate) and 20 ml of H_2SO_4 (sulfuric acid). The digestion flask was kept on heating mantle at 100℃ till the solution become crystal clear green clour and then kept for cooling. Upon cooling the clour of the solution changed to blue. 200 ml of distilled water was added to the blue solution with 4-5 drops of phenolphthalein indicator and approximately 50 ml of 40% NaOH (sodium hydroxide) solution. The digested solution was transferred into digestion bulb of kjeldhal unit with 50ml of 2% boric acid beaker on the other side of the unit called as condenser. Digestion bulb was boiled at 80℃ till the volume of the boric acid atteched to the condenser increases up to 200ml in volume. This procedure called as distillation. After distillation the boric acid solution was titrated. 4-5 drops of methyl red indicator were added and 0.1٪ HCL (hydrochloric acid) was added into it drop by drop until it reaches its end point and color changes to pink. Protein content was calculated using the eqution given below:

$$\text{Protein content}(\%) = \frac{(A-B) \times N \times 14.007 \times 6.25}{W}$$

Where,

A= volume of HCL used for sample titration,

B= volume of HCL used for blank titration,

N= normality of HCL,

W= weight of sample,

14.007= atomic weight of nitrogen sample, and

6.25=coversion factor for food product

Fig 3: Process of Distillation

Fig 4: Process of Digestion

Fig 5: Process of Titration

4.2.3 Crude fat content

Crude fat is the term used to refer to the crude mixture of fat-soluble material present in a sample. Crude fat also known as the ether extract or the free lipid content, is the traditional measure of fat in food products. The lipid materials may include triglycerides, diglycerides, monoglycerides, phospholipids, steroids, free fatty acids, fat soluble vitamins, carotene pigments, chlorophylls, etc. Fat content in food was determined using Soxhlet extraction method. 5g oven dried sample was taken in thimble and plugged with fat free cotton. Then, the sample was attached to the soxhlet apparatus. Thimbles were dipped in petroleum ether. Soxhlet apparatus was then set for 1h 45 min. The flask containing crude fat was removed after set time is over. After cooling, the flask containing crude (g/100g) fat was weighed **(AOAC, 1984).** The formula for measuring crude fat is given below.

Crude Fat (%) = $\frac{\textbf{weight of fat (g)}}{\textbf{weight of sample}} \times \mathbf{100}$

Crude fiber

Crude fiber is a measure of the quantity of indigestible cellulose, pentosans, lignin, and other components of this type present in foods. The weighed residue (2g) from crude fat determination was taken and transformed in 200 ml of 1.25 percent H_2SO_4 in spoutless beaker. It was boiled for 30 minutes. After that the flask was removed, and the solution was filtered through Whatman No. 54 filter paper. The residue was washed with hot distilled water. The residue was then boiled in 1.25 per cent sodium hydroxide solution for exactly 30 min. After 30 min of boiling, the contents were filtered through Whatman No. 54 filter paper and washed with hot distilled water using Buchner funnel to apply gentle suction. The filter paper with the residue was dried in oven at 105°C for 3 to 4 hours till constant weight was obtained. It was cooled in a desiccator and weighed. The loss in weight represented the crude fiber content **(AOAC, 1995)**. It was calculated using the formula.

Crude fiber (%) = $\frac{W_2 - W_1}{W} \times 100$

Where,

W_1 = weight of filter paper (g)

W_2 = weight of residue + filter paper (g)

W = weight of sample (g)

4.2.4 Ash Content

Ash or mineral content is the portion of the food or any organic material that remains after it is burned at very high temperatures. The ash constituents include potassium, sodium, calcium and magnesium, which are present in larger amounts as well as smaller quantities of aluminum, iron, copper, manganese or zinc, arsenic, iodine, fluorine and other elements present in traces. 5g sample was weighed in a pre dried porcelain dish and ignited on flame till the fuming ceased and it was then cooled in desiccator, and weighed soon after reaching room temperature. The dish was then transferred to a muffle furnace at 550°C until grey ash resulted. Thereafter it was cooled in a desiccator. The weight of the residue was noted **(AOAC, 1995)** and the ash % was calculated by formula **.** The ash content measurement in muffle furnace is shown in **Figure 6.**

Ash content (%) = $\frac{W_2 - W_1}{W} \times 100$

where,

W_1 = weight of crucible (before incineration)

W_2 = weight of crucible + weight of sample (after incineration)

Fig 6: Determination of Ash content By Furnace

4.2.5 Titratable acidity

Titratable acidity of product (as per lactic acidity) was determined according to the method specified in part-I of IS: 1479 (ISI, 1960) using 10 g sample. Ten- Watermelon sample was taken in a conical flask, it was mixed with 10 ml of distilled water. Then few drops of phenolphthalein indicator were added and titrated again 0.1 N NaoH solutions. The acidity as per cent lactic acid was determined by using following formula

$$\text{Titrable Acidity} = \frac{\text{Titer x Normality x Equivalent-weight x Volume x 100}}{\text{Volume made up x estimated value x 1000}}$$

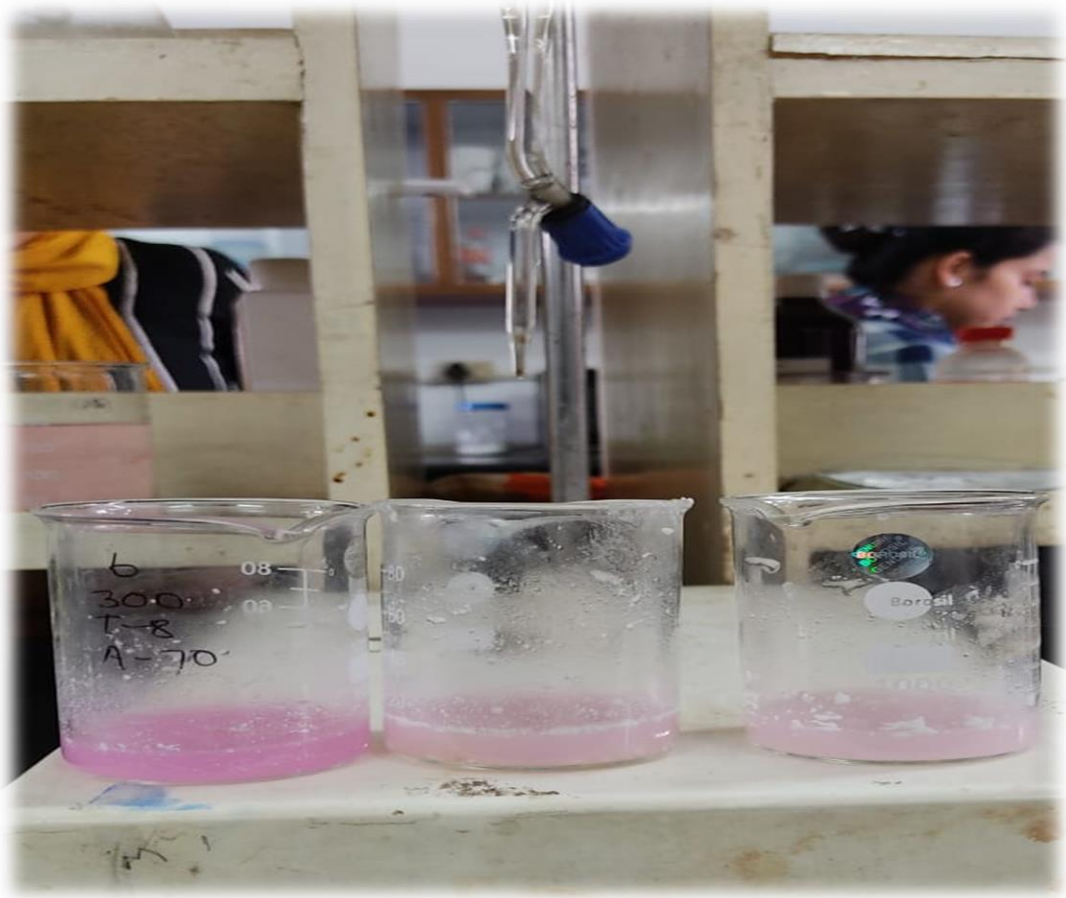

Fig 7: Reading process of titrable acidity of diluted watermelon rind powder

4.2.6 Determination of Total Soluble Solids (*BRIX)

Principle-

Refractometer measures total soluble solids (TSS) concentration based on the principle of refraction of light. When a ray of light travels obliquely from one medium to another, it is bent or refracted. The refraction occurs because light travels at slightly different velocities in different media, the extent being proportional to the density of the solution or the soluble solids concentration. The refractive index of a medium is defined as the ratio of, the sine of the angle of incidence to the sine of the angle of refraction when a ray of monochromatic light is refracted from a vacuum (or, to a very close approximation, from air) into the medium. In a Brix refractometer, the refractive index is calibrated into *Brix readings. As refractive index is dependent on the density of the solution, the measurements have to be made at a specific temperature (20 "C) or suitable corrections have to be applied.

Requirements

Equipment's -

Hand refractometer.

Thermostatically controlled water bath.

METHOD-

Place few drops of the sample in between the prisms of hand refractometer and note the reading at the demarcation line. Apply temperature correction for readings taken temperatures other than 20 OC using the following table.

In the case of Abbe's refractometer, circulate 20 C water in the chamber enclosing the prism from a thermostatically controlled water bath. Place a few drops of the sample in between the prisms and allow the temperature to equilibrate and note the Brix reading, which gives per cent of sucrose sugar or TSS

Fig 8: Hand Refractometer 58-90* brix

4.3 Physical characteristics of watermelon rind powder

4.3.1 Bulk density

Bulk density was calculated by the technique used by (Jan *et al*., 2017). Briefly, a 100 ml graduated cylinder was filled with the flour sample. The bottom of the cylinder was then gently tapped several times on a foam-covered lab bench.

The volume of flour mix was measured and the bulk density was expressed in g/ml as shown in Eq.(1).

$$\textit{Bulk density } g/cm^3 = \frac{\textit{weight of the flour } (g)}{\textit{Volume after tapping } cm^2}$$

4.3.2 Aerated bulk density

The aerated bulk density of watermelon rind powder was measured by the method described by (Jan *et al*., 2017). Sample was carefully poured into a 100 ml standard graduated cylin-der of Vankle's design obtained from the Standard Instru-ment Corporation in Patiala, India. The sample was initially poured into the cylinder to the 100 ml mark. The graduated cylinder with the sample was then weighed in order to deter-mine the aerated bulk density. The aerated bulk density was calculated using Eq.(2)

$${}_{l} = \frac{w_{l}}{V_{l}} \quad (2)$$

where, ρ_{l} is the aerated bulk density ($g.cm^{-3}$), w_l and v-_{l} are the mass and the volume ($cm\text{-}^{3}$) of watermelon rind powder in aerated condition, respectively.

4.3.3 Tapped bulk density

After measuring the bulk density for the watermelon rind powder (WRP), the cylinders filled with the powder, were tapped on a hard wooden surface to determine the materials' settling behaviour under shaking or vibration during transit. The watermelon rind powder was stabilised and settled after ten taps at a tap height of about 20 mm using tap density tester. WRP was added again to the cylinder in order to get the capacity up to 100 ml (Jan *et al*., 2017). The material was weighed again, and the tapped density was determined using Eq. (3).

$$T = \frac{w_t}{v_t} \quad (3)$$

where, ρ_t is the tapped bulk density (gcm^{-3}), w_t and v_{-t} are the mass and the volume -(cm^3) of pea pod powder in tapped condition.

4.3.4 Carr's Index

The compressibility index (CI), commonly referred to as Carr's index or Carr's Compressibility Index, is a meas-ure of a powder's hand compressibility. A compressibility index higher than 25 is seen as a sign of poor flowability and a value less than 15 as a sign of good flowability. The compressibility index (CI) was determined using the aer-ated and tapped bulk densities (Jan *et al*. 2015) as.

$$CI = (t - l) / t \times 100 \quad (4)$$

where, ρ and ρt are the aerated and tapped bulk densities (gcm^{-3}), respectively, and CI is the compressibility index (%).

4.3.5 Hausner's ratio

Hausner's ratio (HR) signifies how easily a granular material or a powder flows. A sign of poor flowability is a Hausner ratio larger than 1.25. It is defined as the propor-tion of tapped to aerated bulk density (Jan *et al*., 2017).

$$HR = \rho_t/\rho_l$$

4.4 Functional characteristics of watermelon rind powder

4.4.1 Water absorption index and water solubility index

WRP The water absorption index (WAI) and water solubility index (WSI) was measured by the method proposed by (Padma *et al*., 2022) with minor modifications. Briefly, the WRP (5g) was suspended in water and gently swirled for 30 min. The mixture was then centrifuged at 3000 rpm for 15 min. The WAI was expressed as the weight of the wet/hydrated residue produced after the supernatant was drained off (Eq. 6). The drained supernatant was collected and dried in a hot air oven at 103 °C overnight. The weight of the dissolved solids in supernatant was then used to calculate the WSI as shown in Eq. (7).

$$\text{WAI (g/g)} = \frac{weight\ of\ absorption\ in\ hydrated\ residue}{weight\ of\ sample}$$

$$\text{WSI (g/100g)} = \frac{\text{weight of dissolved solids in suparnatant}}{\text{weight of sample}} \times 100$$

Swelling power

The swelling power of the WRP was measured by the method given by (Jan *et al*., 2017) and was calculated as:

$$\text{Swelling power (\%)} = \frac{\text{Wt. of wet residue}}{\text{Wt. of sample }(100 - \text{WSI})} \times 100$$

4.4.2 Oil absorption capacity

In pre-weighed centrifuge tubes, 0.5 g of watermelon rind powder was dissolved in 6 ml of mustard oil. After vortexing the sample in oil, the sample was held in a vertical position for 30 min followed by centrifugation for 15 min at 3000 rpm. The oil was then drained off before being weighed again. The increase in weight was calculated as one gram of oil absorbed for every one gram of powder (Jan *et al.*, 2017).

$$Oil\ binding\ capacity\ (\%) = \frac{wt.of\ residual\ powder}{wt.of\ sample\ taken} \times 100$$

4.4.3 Colour

The samples' colours were assessed using a Hunter Lab Colorimeter (USA, model number 45/0). After standardisation with a white calibration plate, measurements were collected immediately at three distinct sites. Hunter Lab units L*, a*, and b* were used to express the colour wherein L* stands for lightness, a* for hue on a green (−) to red (+) axis, and b* for hue on a blue (−) to yellow (+) axis.

4.5 Structural characterization of watermelon rind powder

4.5.1 X- ray diffraction

Diffraction pattern analysis of WRP was done by XRD (RigakuMiniflex 600 Rigaku corporation, Japan) equipped with Cu radiation at a wavelength of 1.541 A. Observations were made at room temperature with a scanning speed of 10°/min and a scan range of 10–90°. The diffraction patterns were analysed using Miniflex Guidance software.

4.5.2 Fourier transform infrared (FTIR) spectroscopy

The FTIR spectra of the sample was analy zed for the WRP by a Fourier transform infrared spectrophotometer (ALPHA Bruker, USA) operating at 25 °C. The powdered samples were blended with KBr and converted into tablets by a mechanical press. Initially, the blank sample was used as part of the calibration of the instrument and then the different spectra were evaluated in the range of 600–4000 cm−1. An average of 38 scans per sample were gathered at a resolution of 4 cm−1.

5. RESULTS AND DISCUSSION

5.1 Proximate analysis of WATERMELON RIND POWDER

The moisture content of powder was 10.68% while the moisture content of watermelon rind was 94.20%. The moisture content of rind found in this study indicating that the moisture content is higher than (Bawa and Bains *et al.,* 1977) which was 93.8%. The moisture content of rind powder was found higher than (Al-Sayed and Ahmed *et al*., 2013) who reported 10.61%.

The ash contents in watermelon rind and rind powder were 0.41 % and 11.98%, respectively. The rind ash content was lower than found by Bawa and Bains (1977). The rind powder ash was lower than Al-Sayed and Ahmed, (2013), which was 13.09%. The protein contents in watermelon rind and rind powder were o.60% and 11.02%, respectively. The observed rinds protein was similar to found by Bawa and Bains (1977). The rind powder protein was slightly higher than (Al-Sayed and Ahmed *et al*., 2013) which was 73.30%. The total carbohydrate contents in watermelon rind and rind powder were 4.6% and 72.98% respectively. The observed rind total carbohydrate was lower than found by (Olaofe *et al*., 1994). The rind powder total carbohydrate was similar to (Al-Sayed and Ahmed *et al*., 2013) which was 73.30%.

Physical characteristics, Functional characteristics, Proximate analysis and color parameters of the watermelon powder (dry weight). pH, Total Titratable Acidity (TTA) and Total Soluble Solid (TSS)

Total titratable acidity (TTA) and pH are interrelated in terms of acidity, but have different impacts on food quality. However, the impact of acid on food flavour is much more determined by TTA than pH since the pH of food gives an indication of its resistance to microbial attack. Total titratable acids (TTA) and total soluble solids (TSS) of all the watermelon rind and watermelon rind powder samples prepared by different drying treatments are shown in the results obtained, it is clearly seen that all the TSS of the flour samples prepared.

The **Proximate analysis of watermelon rind powder** the fresh rind and its powder was determined and the results are given in Table 2.

Table 2: Chemical composition of fresh watermelon rind and its powder

Chemical composition	**Watermelon rind**	**Watermelon rind powder**
Moisture (%)	94.20	10.68
Protein (%)	0.60	11.02
Ash (%)	0.41	11.98
Crude Fat (%)	0.07	2.11
Carbohydrate (%)	4.6	72.98
Dietary fibre(%)	1.02	12.75
Titratable acidity	0.09	2.0
Total soluble solid	2.43	2.85

5.2 Total Titratable Acidity Analysis: Total titratable acidity of the flour sample was determined according to the method as described by Bainbridge with slight modifications. Watermelon rind powder sample (0.5 g) was weighed into a 100 mL beaker and 10 mL of distilled water was added to obtain slurry. The slurry was then added with 5 drops of phenolphthalein indicator and titrated against 0.1 N sodium hydroxide (NaOH) solution until the mixture turns pink. The titre volume was recorded and the total titratable acidity in the sample was expressed as percentage of malic acid (acid factor used: 0.067).

5.3 Physical characteristics of watermelon rind powder

Table 3: Physical characteristics of watermelon rind powder (dry weight)

Physical characteristics	**Watermelon rind powder**
Bulk density (g/ml)	0.33±0.8
Aerated Bulk density	0.35± 0.2
Tapped bulk density	0.41± 0.6
Carr's Index	18.11± 7.6
Hausner ration	1.20± 0.11

Bulk density is a crucial factor in determining a product's need for packaging. To optimize various operations, such as powder handling, storage, and the creation of various products as a dependent of particle size and other associated qualities, it is crucial to ascertain the bulk (loose and tap) density of the particles. Bulk density is another significant factor that determines whether a powder is suitable for use in food compositions.

Results of this investigation showed that that WRP has a low bulk density of 0.33 g/ml. In the creation of complementary foods and the preparation of infant food, a powder's low bulk density is a desired property (Nelson- Quartey *et al.* 2007). The value obtained for bulk density was greater than those reported by (Dias *et al*., 2020) for pineapple peel, orange peel, yellow passion fruit peel and avocado peel but lower than goldenberry (*Physalis peruviana*) waste powder. Further, WRP's aerated bulk density was found to be 0.35 g/ml. Bulk density (BD) depends on particle size and initial moisture content. Low bulk density is advantageous in the formulation of complementary foods. The tapped bulk density of WRP was found to be 0.41 g/ml which was almost similar to that of potato peel powder. After tapping, the WRP's density increased as the air that had been trapped in the vacuum spaces was released.

Carr's index is used to measure the compressibility of powder particles; higher the compressibility, lower the flowability. The internal friction is measured using Hausner's ratio. The WRP appears to have a decent degree of flowability based on the Carr's index and Hausner's ratio. Smaller particles have more contact sites with their neighbors which makes it more challenging for them to reorganize and create a dense packing. Large gaps develop in an aerated condition as a result of particles arching which further collapse upon tapping. As a result, the Hausner ratio and Carr's index rose due to the significant disparity between the tapped and aerated densities. Additionally, stronger cohesiveness between particles due to higher interparticle interactions or mechanical interlocking, lowered the flowability by raising the HR and CI (Jan *et al.,* 2015). The CI and HR of WRP was found to be 18.11 and 1.20, respectively that indicates its fair flowability. Easy flowability of the watermelon rind powder enables its use in baking operations (kneading, mixing etc.). Particles with lower flowability would require more energy-intensive operations and could be uneconomical.

5.4 Functional characteristics of watermelon rind powder

The water-absorption index (WAI) measures how much water a wet substance can hold when compressed or exposed to external centrifugal gravity stress. It is made up mostly of physically imprisoned water and the sum of hydrodynamic water and bound water (Alfredo *et al.,* 2009). The values of WAI in WRP was determined as 3.40 g/g. This result is similar to the water absorption capacity of goldenberry waste products (Mokhtar *et al.*, 2018). Due to the high concentration of hydrophilic groups that may bind water and the high concentration of soluble fibres that have a high capacity to absorb water, the WAI of WRP is notable. High WAI indicates that the sample tested may become moderately viscous, can form gels and retains freshness which has possible application in baked goods. Moreover, the WAI of the fiber strongly indicates its physiological role in proper functioning of intestines and control of blood sugar level. However, the WAI of WRP was observed to be less than that of potato peel powder (4.18 g/g) and banana peel powder (3.64 g/g).

In terms of biodegradability, uniformity, and shelf stability, the water solubility index (WSI) is crucial in determining the overall quality of the finished product. WSI ascertains whether the powders' macromolecules have exposed hydroxyl groups that can establish hydrogen bonds with water molecules. The WSI of WRP was found to be 7.02% which was lower than potato peel powder (12%) and banana peel powder (11%) reported by (Jan *et al.*, 2017).

One essential characteristic of polysaccharides is their ability to absorb oil which is termed as oil absorption capacity (OAC). It is somewhat influenced by the chemical make- up, but it is more closely correlated with the porosity of the fibre structure as compared with the fibre molecule's affinity for oil (Biswas *et al.*, 2011). The OAC of WRP was observed to be 3.25 g/g which is in line with the studies for golden berry waste powder by (Mokhtar *et* *al*., 2018). The high OAC of WRP may be attributed to its high protein content. Protein conformation, surface polarity, and inherent characteristics such as amino acid composition could affect the oil binding ability of biological materials (Sunil *et al*. 2019). It is evident from the results that WRP had appreciable oil binding ability due to which it can facilitate improved binding with plasticizers during various processing steps.

Table 4: Functional characteristics of watermelon rind powder

Functional characteristics	**Watermelon rind powder**
Water Absorption Index (g/g)	3.40 g/g
Water Solubility Index (%)	7.02%
OAC (g/g)	3.25 g/g

5.5 Color

CIE L*, a*, and b* values for WRP were 40.28, 3.44 and 17.71 in (Table 5). Considering the more positive value of a* for the red variety watermelon rind powder, this indicates that the light greenish colour of the watermelon rind disappeared with drying at 60°C. It is well-known that watermelon rind is light greenish in colour due to the presence of the naturally occurring pigments, chlorophylls (green). Chlorophylls are very sensitive to heat, hence heating at high temperature will cause degradation of these pigments and the effect is more prevalence at higher temperature as shown in present study. The higher a* values also indicates the occurrence of non-enzymatic reaction, e.g. Maillard reaction. The increase in drying temperature led to rise of non-enzymatic browning reactions and thus produced darker coloured powdered samples.

Table 5: Color parameter of water melon rind powder (dry weight)

Parameter (Colour)	Value
L*	40.28±28
a*	3.44±0.05
b*	17.71±0.19

5.6 Structural characterization of watermelon rind powder

5.6.1 *X ray diffraction*

The XRD patterns of the water melon rind powder shown in Fig.9 The water melon rind powder was examined using X-ray diffraction research to determine its structural characteristic. It can be seen from the X-ray diffraction pattern of the water melon rind powder that there were obvious peaks at 2θ of 23° which shows its crystalline nature. The XRD pattern of WRP is shown in Fig.9 The intense peaks at 20°, 40° and 48° can be assigned to Bragg's reflection. XRD analysis of WRP also showed a similar semi-crystalline profile in both cases, with the characteristic peaks. This effect can be interpreted as a more organized structure of WRP molecules, probably due to the additional b association of chains as a consequence of interactions produced by a higher quantity of carboxylic groups in the polygalacturonic structure. XRD pattern of the WRP show a weak characteristic diffraction peak at 2θ of 21.3°.WRP show amorphous nature; however, the crystallinity slightly improved. Moreover, a small peak was observed at 2θ of 12.1° for pectin whereas no peak was observed for WRP at this point. This shows slight increase crystallinity for WRP. So, this observation is in agreement with the IR results that revealed a higher de-esterified (de-methoxylated) fraction of carboxylic groups in the solid WRP.

Measurement Conditions

Table 6: Measurement conditions of watermelon rind powder

X-Ray generator	40 kV, 15 mA	Scan mode	1D(scan)
Incident primary	No unit	Scan speed/Duration time	10.00 °/min
Goniometer	MiniFlex 300/600	Step width	0.01 °
Attachment	Standard sample stage	Scan axis	θ/2θ
Filter	None	Scan range	3 ~ 90 °
Selection slit	None	DS	1.25deg
Diffracted beam mono	None	IHS	10 mm
Detector	D/teX Ultra2	SS	Open
Optics attribute	None	RS	Open

Measured profile view

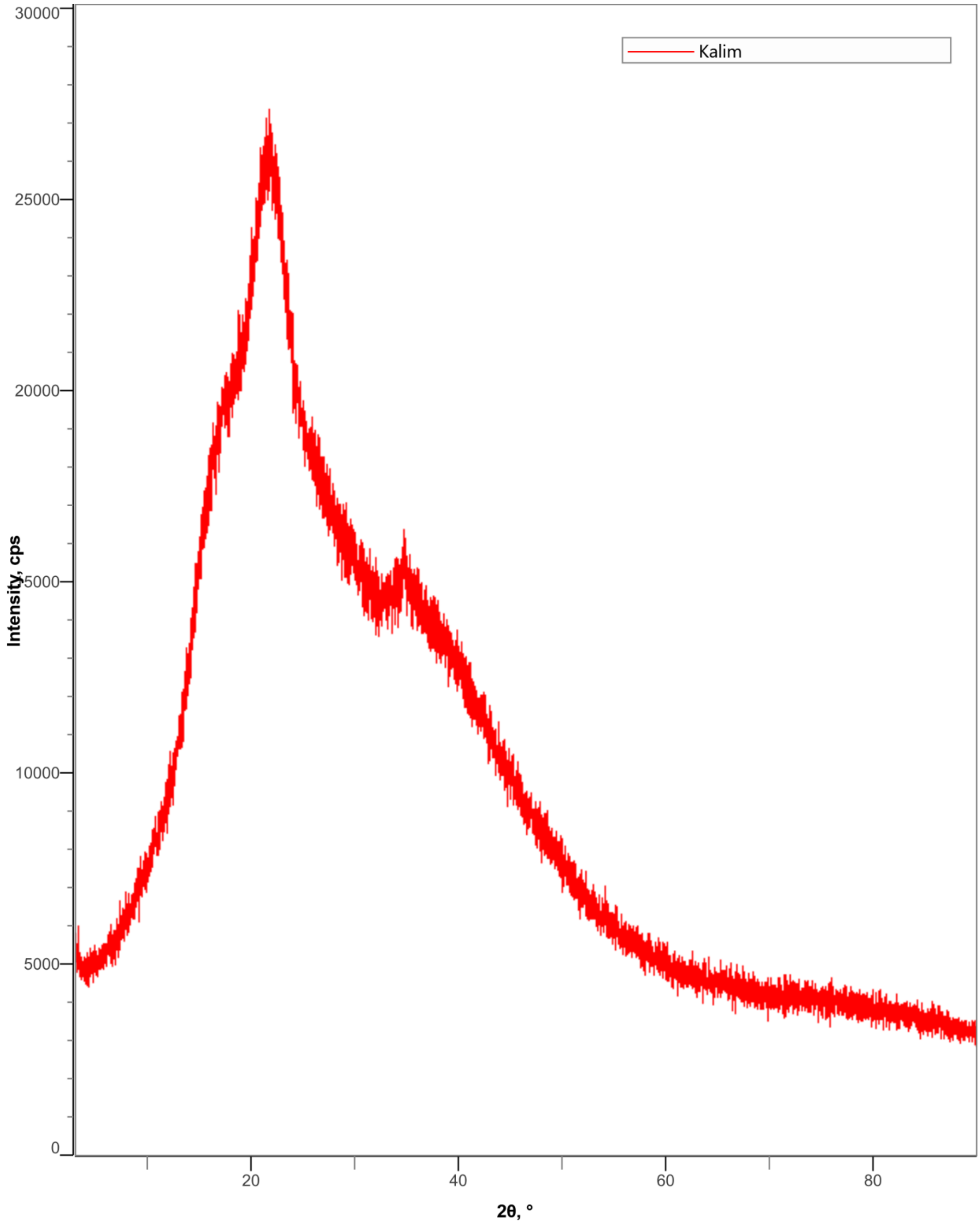

Fig 9: Measured profile view

Table 7: Peak evaluation conditions

Peak search method	Second derivative method	σ cut	3.00		
Profile fitting	Run comp leted	Peak shape	Split pseudo-Voigt	Fitting condition	Auto(Refine background)

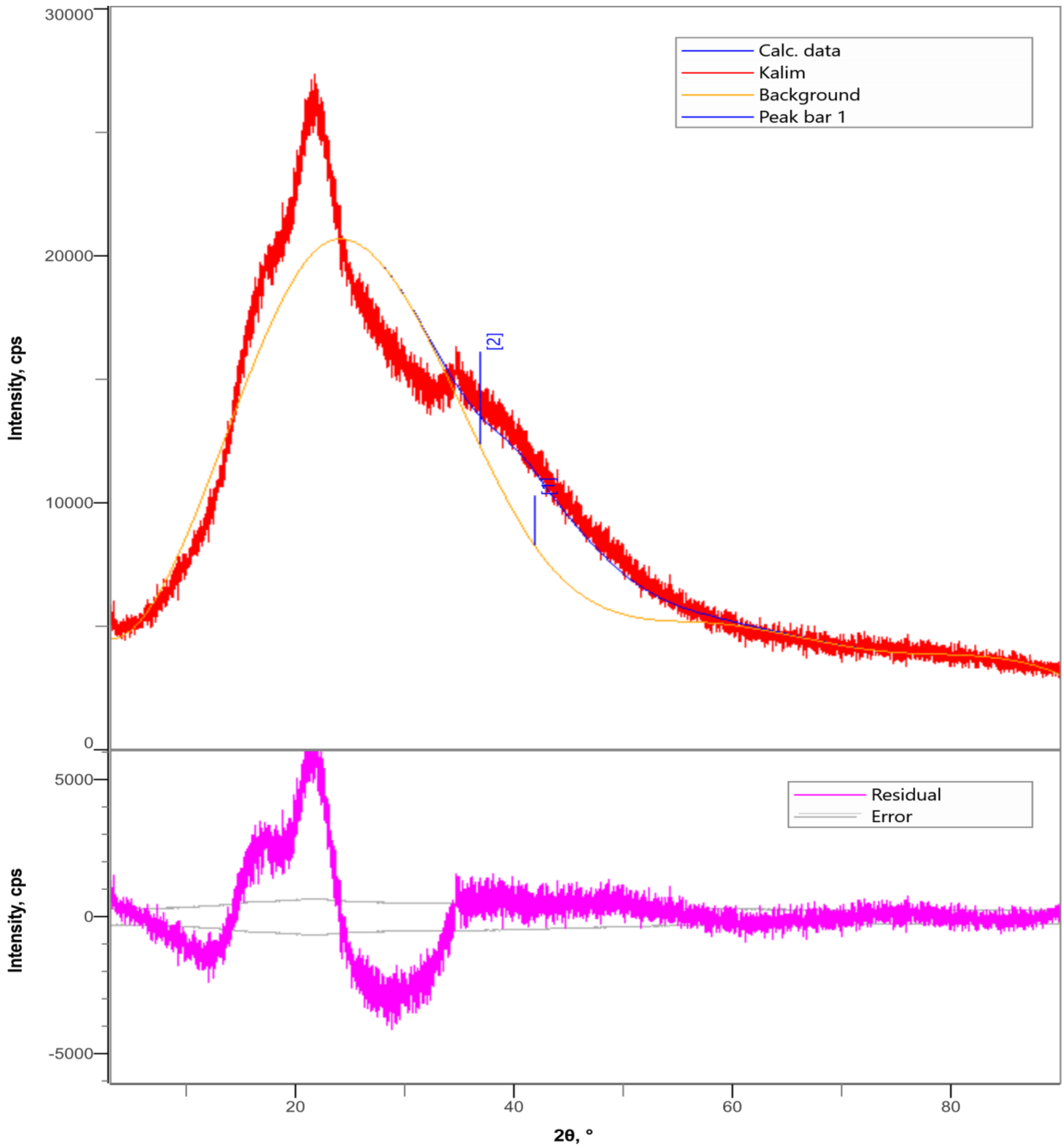

Fig 10 : Peak profile view

Table 8: Peak list

No.	2θ, °	d, Å	Height, cps	FWHM, °	Int. I., cps°	Int. W., °	Asymmetry	Decay(ηL/mL)	Decay(ηH/mH)	Size, Å	Phase Name	Chemical Formula	Card No	Norm. I.	Profile Type	Distribution R.S.D.	Strain, %	Degree of Orientation	Ring Factor	β Cluster	Custom Label
1	41.8(3)	2.158(15)	2004(75)	13.1(3)	27960(13 09)	14.0(12)	0.50(5)	0.0(3)	0.00(15)	6.78(14)	Unknown			56.84	Split Pseudo-Voigt	-	-	-	-	-	
2	36.83(10)	2.439(6)	3813(129)	6.74(16)	49189.74	12.9(4)	1.00(3)	1.16(5)	1.55(3)	13.0(3)	Unknown			100.00	Split Pseudo-Voigt	-	-	-	-	-	

5.7 FTIR spectrum analysis

The spectroscopic properties of water melon rind powder was analyzed by FTIR. The FTIR spectra was obtained in order to know the nature of functional groups. The water melon rind powder FTIR spectra revealed several peaks at 2936.49 cm−1, 1633.13 cm−1, 1384.31 cm−1, 1258.00 cm−1, 1060.57 cm−1 and 866.85 cm−1, frequency, as shown in Table 4 and Fig 11. The spectra of water melon rind powder show a prominent band at 2936.49 cm−1 that is connected to the –OH stretching vibration of either hydrogen bonded hydroxyls or hydroxyl groups in the phenolic (guaiacyl or syringyl monomer unit of lignin) and aliphatic compounds. This association may be brought on by the presence of moisture content in WRP. The (C–H) stretch band of the methyl groups in lignin may be responsible for the vibrational spectra at 1633.13 cm−1. This is likely because the sample contains a large quantity of hydrocarbons, mostly lipids. Alpha-keto carbonyl's C=O stretching vibration of cellulose is principally responsible for the peak in the spectra at around 1633.13 cm−1. The band around 1258 cm−1 may be caused by C–O stretching in the acetyl and phenolic groups, whereas the band near 1384.31 cm−1 may be attributed to phenol's syringyl ring breaking C=O stretching. The Fourier-transform infrared spectroscopy (FTIR) spectrum for WRP, band at 1258 cm^{-1} represents the OH stretch of water molecules in the watermelon rind. The very weak around 1258 cm^{-1} corresponds to C–H stretching vibrations. The peak observed 1060 cm^{-1} strong streatching vibratins (C-O) in C-OH group or strong streatching vibrations (C-C) in the carbohydrate structure, (C-H). The band around 866.85 cm^{-1} anomeric region of carbohydrate or deformation vibrations (C-H) (mainly in the structure of sugar). The peaks observed in the WRP are pronounced. This is because on extraction the pectin is concentrated by improving other WRP components and the FTIR functional group becomes increased.

Table 9: FTIR spectrum analysis of watermelon rind powder

Position of bands [cm−1]	Origin and kind of vibrations
2936.49	–OH stretching vibration of either hydroxyl groups in the phenolic (guaiacyl or syringyl monomer unit of lignin) or hydrogen bonded hydroxyls and aliphatic compounds
1633.13	C=O stretching vibration of alpha-keto carbonyl for cellulose
1384.31	–OH bond
1258.00	C–O stretching in the acetyl and phenolic groups
1060.57	Strong stretching vibrations (C–O) in C–OH group or Strong stretching vibrations (C–C) in the carbohydrate structure, δ (C–H)
866.85	anomeric region of carbohydrates or deformation vibrations (C–H) (mainly in the structure of sugar)

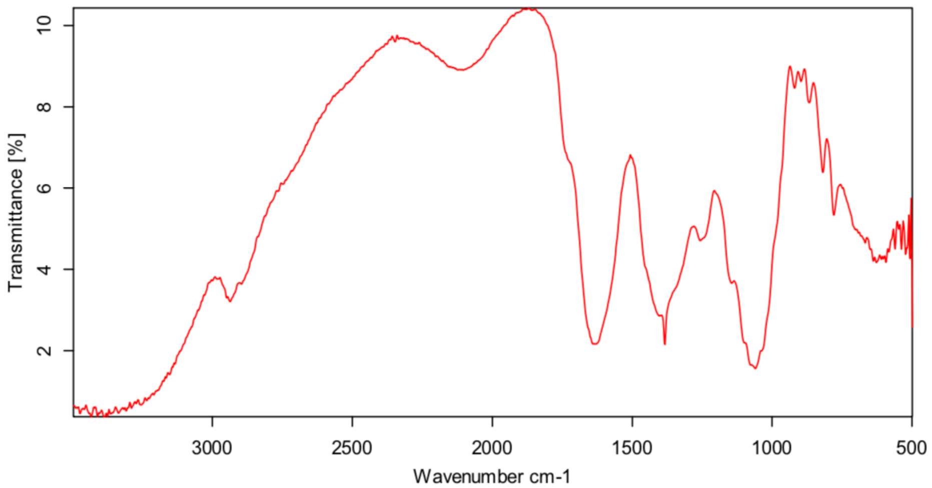

Fig 11: Fourier transform infrared spectroscopy analysis for water melon rind powder (WRP)

6. CONCLUSION

Agro-wastes are the vast amounts of solid waste generated during the growing, preparing, and eating of fruits and vegetables. They can cause disposal issues, contamination, and the loss of important nutrients and biomass. Agro-wastes have the potential to be turned into usable products or even used as raw materials by other businesses. A promising area is the use of processing wastes from fruits and vegetables as a source of useful compounds. Thus, this study comes to the conclusion that the watermelon rind, a significant byproduct of watermelon fruit, has enormous nutritional potential and can be employed successfully in food compositions. The proximate analysis of water melon rind powder revealed notable quantities of ash, fat, and protein. Additionally, water melon rind powder's physical properties—including bulk density, aerated bulk density, tapped density, Hausner's ratio, and Carr's index—showed that it was suitable for use in food preparations and had fair flowability. The extended shelf life of water melon rind powder was demonstrated by the lower values for the water absorption index and water solubility index. Water melon rind powder also shown strong oil absorption properties, indicating the likelihood that it will bond with plasticizers when used as an addition in cereal-based snacks. This research opens up new avenues for possible applications of this ingredient in other food industries.

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