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Original Research Article

Development of Gluten-free Baked Nachos Using Watermelon Rind Powder for Assessment of Physicochemical and Sensory Attributes

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Abstract: *Watermelon (Citrullus lanatus) is a widely cultivated fruit, primarily consumed for its sweet, nutrient-rich flesh. However, the rind, which constitutes a significant portion of the fruit, is commonly discarded as agricultural waste despite its emerging potential as a value-added food ingredient. Recent research suggests that watermelon rind is rich in bioactive compounds and dietary fiber, making it a promising candidate for functional food development, especially in gluten-free applications.* ***Objective:*** *This study aimed to develop gluten-free baked nachos incorporating watermelon rind powder (WRP) and to evaluate their physicochemical properties, functional characteristics, sensory acceptability, and storage stability.* ***Methods****: A laboratory-based experimental study was conducted from January to April 2025. Three treatment formulations were prepared: T_0 (100% corn flour), T_1 (85% corn flour + 15% WRP), and T_2 (80% corn flour + 20% WRP). Watermelon rind powder was prepared using a modified method based on Ogo et al. (2021), while nachos were formulated following a modified protocol from Dubey et al. (2021). Functional properties of the powder blends (swelling capacity, water absorption, and oil absorption) were assessed. Physicochemical analyses of nachos were conducted on days 0, 7, and 14, evaluating moisture content, ash, fat, crude fiber, crude protein, and color using a handheld spectrocolorimeter (Lovibond LC-400). Texture analysis was performed using a TA.XT Plus Texture Analyzer. Microbiological assessment for bacterial and mold counts was conducted to determine shelf stability. Sensory evaluation was carried out by a trained panel (n=10) using a 9-point hedonic scale. Data were analyzed using* ***Statistix 8.1*** *software, with statistical significance set at $p < 0.05$.* ***Results****: Incorporation of WRP significantly improved the fiber content in T_1 and T_2 compared to the control (T_0). T_2 showed the highest crude fiber and water absorption capacity but slightly reduced sensory acceptability in terms of taste and texture. T_1 achieved the most favorable balance between nutrition and sensory properties. Over the 14-day storage period, all samples remained microbiologically safe, though T_2 exhibited slightly higher moisture retention and texture changes. Color and texture were moderately affected by increasing WRP levels, while functional properties like oil and water absorption improved.* ***Conclusion****: Watermelon rind powder is a viable functional ingredient for developing gluten-free snacks such as baked nachos. A 15% substitution level (T_1) demonstrated the most promising results in terms of nutritional enhancement, sensory acceptability, and storage stability. This study supports the valorization of fruit by-products in sustainable food systems and contributes to the development of health-oriented gluten-free products.*

Keywords: Endometrial Biopsy, Estradiol, Histological Evaluation, Hormonal Assessment, Hyperprolactinemia, Infertility, Luteal Phase Defect, Menstrual Cycle, Progesterone, Prolactin

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Introduction

Watermelon is a tropical fruit crop that grows best in warm, sunny climates and from seeds. Watermelon, a large, sweet, 93% water fruit with Greek and Latin origins, is used in salads, desserts, snacks, and beverages due to its low-calorie content (1). According to the Instituto Brasileiro de Geografia e Estatística (2017), Brazil produced 2,090,432 tons of watermelon in 2016, with 32% from the Northeast. Water resource constraints in this region, including high salt levels, necessitate irrigation and osmotic effects (2).

In 2012, the worldwide production of watermelon reached 105.37 million tons, according to the Food and Agricultural Organization of the United Nations (FAO). China was the largest producer, yielding 70 million tons annually, which accounts for 66.43% of global production. Turkey and Iran followed, producing 4.04 million tons (3.84% of the total) and 3.80 million tons (3.60%), respectively. Brazil and Egypt ranked fourth and fifth, with production figures of 2.08 million tons (1.97% of the total) and 1.88 million tons (1.78% of the total), respectively. The United States came in sixth place, producing 1.77 million tons, or 1.68% of global production. Following the U.S., Russia produced 1.45 million tons (1.38% of the total) and Algeria produced 1.50 million tons (1.42% of the total) (3).

Snacking popularity surges due to health awareness and nutrient-dense food preferences, with watermelon being a popular choice due to its anti-inflammatory, antihypertensive, and antioxidant properties (4). The tropical fruit watermelon, responsible for 7% of vegetable production, has over 1,200 varieties and hybrid breeding techniques. However, literature reviews are limited, necessitating further scientific studies (5). Watermelon production is influenced by factors like land tenure, pest and disease prevalence, government policies, manual weeding, rainfall, temperature, soil type, storage, transportation, market price, and residence near farmland (6).

For future usage, the watermelon rind (Citrullus lanatus) was cleaned, cut into slices, dried in the oven, pounded into a powder, sieved, and kept in an airtight container (7). Dried by Hot air oven, freeze drying, and Sun drying. Watermelon seeds and skin, rich in phytochemicals, vitamins, minerals, and antioxidants, are often overlooked due to their potential therapeutic benefits in cancer prevention and inflammation reduction (8, 9).

Novel Biscuits were made using a blend of flour, sugar, salt, baking powder, milk, egg, and water, then baked, cooled, and sealed for examination (10). Watermelon rind powder was substituted for wheat flour in noodles, made with wheat flour, egg, salt, CMC, and water. The dough was mixed, seasoned, and dried in a hot-air oven (11). Watermelon rind flour candy offers unique flavors and nutritional value, combining with sugar, gelatin, and flavorings for gummy or chewy sweets, and increasing fiber content in soft confections (12).

Watermelon, rich in lycopene and carotenoids, is an excellent source of antioxidants, known for its anti-inflammatory properties and ability to scavenge free radicals (9). According to the findings, the pulp had the lowest antioxidant activity while the peel had the highest. High water content in watermelon rind poses a challenge for powder production. Drying is a popular method to extend shelf life and reduce storage and packaging requirements. For the watermelon rind to be utilized as flour in a variety of culinary applications, its final humidity must be 15%. Given this, it may be concluded that the watermelon rind's drying kinetics at various temperatures (60°C to 95°C) have not been studied (13).

Research shows watermelon's nutraceutical potential, making it a beneficial functional food for treating various diseases like heart disease, obesity, diabetes, ulcers, and cancer (9, 14). The study explores the nutritional benefits, sustainability, and shelf stability of using powdered watermelon rind in nachos, highlighting its potential for environmental sustainability and cost-effectiveness.

The main aims and objectives of this study are:

1. Development and characterization of nachos by using watermelon rind powder.
2. Evaluation of the shelf stability of baked nachos by analyzing physicochemical properties, antioxidant capacity, and sensory characteristics.

Methodology

Procurement of raw material for nachos production:

Watermelon (Citrullus lanatus), all-purpose flour, ready-to-use corn flour, and spices were purchased from local and supermarkets in Lahore, Pakistan.

Powder preparation of watermelon rind:

After separating the watermelon rind from the flesh, watermelon rind powder was prepared using the method defined by Ogo *et al.,* (2021). The preparation involved grinding and drying fresh watermelon rind. First, the flesh (red fruit part) was completely removed from the rind. Next, the rind was washed with tap water, cut into thin slices, and spread on aluminum foil. These slices were placed in a hot air oven at 50 to 55°C for 24 hours. After drying, the samples were removed and left to cool in a desiccator. Subsequently, the dried rind was ground into a fine powder using a heavy-duty blender and sieved through an 8mm stainless steel mesh. The prepared powder was then properly sealed in polypropylene pouches at a temperature of 27°C.

Flour blend preparation:

To assess the physicochemical and antioxidant properties of gluten-free baked nachos made with watermelon rind flour, corn flour, and all-purpose flour, various formulations of these ingredients were created and compared to the control group across several parameters. The treatment plan is as follows:

Control T_o= 100% Corn flour
Treatment 1 T_1= 15% watermelon rind flour, 85% corn flour
Treatment 2 T_2= 20% watermelon rind flour, 80 % corn flour

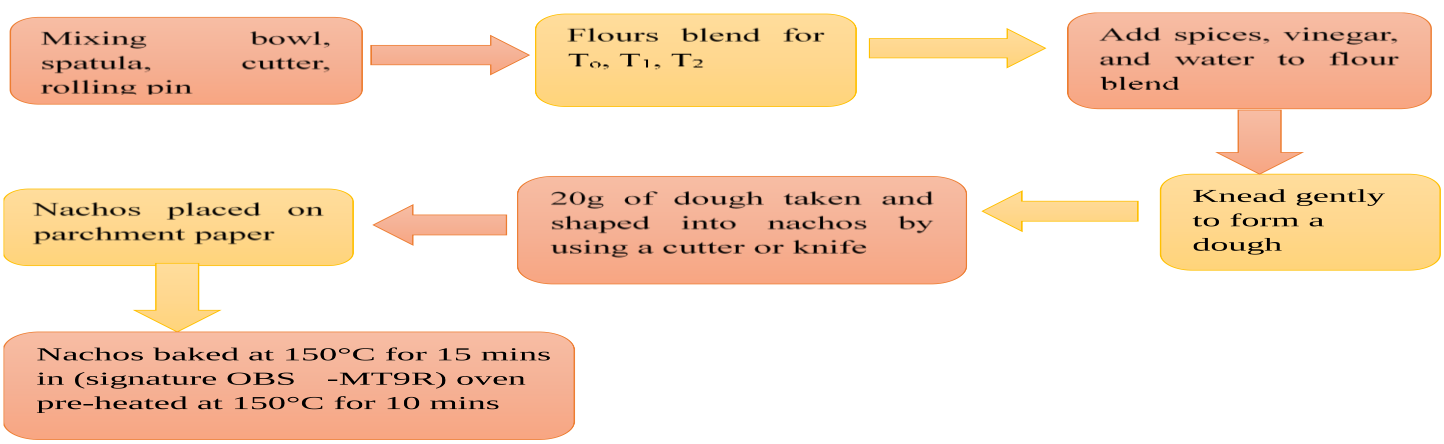
Formulation of watermelon rind powder incorporated gluten-free baked nachos:

The formulation of watermelon rind powder incorporated gluten-free baked nachos was produced according to Dubey *et al.,* (2021) with certain modifications.

Table 1: Watermelon rind flour incorporated in Gluten-free baked nachos

Samples	Flour blend (g) APF: CF: WRF			Salt (g)	Black paper (g)	CH_3COOH (mL)	Water (mL)
	APF	CF	WRF				
T°	44g	44g	0g	1g	1g	5mL	5mL
T1	36.5g	36.5g	15g	1g	1g	5mL	5mL
T2	34.5g	34.5g	20g	1g	1g	5mL	5mL

Figure 1: Flowline of watermelon rind powder incorporated gluten-free baked nachos



Following the above flowchart, nachos were made using each flour blend: corn flour, all-purpose flour, and watermelon rind flour. The proportions of corn flour, all-purpose flour, and watermelon rind flour were altered, but the other ingredients stayed the same.

Determination of functional properties of flour blends:

The functional properties of flour were analyzed by swelling capacity, water absorption capacity (WAC%), oil absorption capacity (OAC%), and foaming capacity (FC%).

Water absorption capacity:

The gluten-forming proteins, glutenin, gliadin, damaged starch, and other components, are hydrated when flour and water are combined. This hydration occurs as protein and starch molecules form hydrogen bonds and hydrophilic interactions with the water molecules. When the particles come into contact with water, they absorb moisture as defined by Awuchi *et al*., (2019). To assess the water absorption capacity of flour blends, 1 gram of each sample (T_o, T_1, and T_2) was mixed with 10 milliliters of distilled water for 5 minutes using a magnetic stirrer. The mixtures were then centrifuged at 2000 rpm for 30 minutes, and the volume of the supernatant was measured with a 10-milliliter measuring cylinder for each sample. The water density was assumed to be 1 g/mL.

WAC (%) = $\frac{\text{Wet sample weight} - \text{Dried sample weight}}{\text{Dried sample weight}} \times 100$

Figure 2: Determination of water absorption capacity of flour of T_o, T_1, and T_2 performed in Lab II at the University of Central Punjab, Lahore

Oil absorption capacity:

To determine nachos' oil absorption capacity as defined by Baljeet *et al.*, (2010). To calculate the oil absorption capacity of nachos, a 1g sample of each flour blend was combined with 10 mL of soybean oil, allowed to sit at room temperature for 30 minutes, and then centrifuged for 10 minutes at 2000 rpm. The volume of the supernatant was measured for each sample using a 10-milliliter measuring cylinder. The oil absorption capacity was expressed as the percentage of oil bound per gram of the sample.

OAC (%) = $\frac{\text{Volume of oil absorbed}}{\text{volume of sample used}} \times 100$

Figure 3: Determination of oil absorption capacity of flour of T_o, T_1, and T_2 performed in Lab II at the University of Central Punjab, Lahore

Swelling Index:

The swelling index method defined by Baljeet *et al.*, (2010) with some modifications, was used. 4g of samples T_0, T_1, and T_2 were filled up to the 10 mL mark in a 100 mL graduated cylinder was added with water to adjust the total volume to 50 mL. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and allowed to stand for a further 30 min. The volume occupied by the sample was taken after 30 min.

Swelling index (%) = $\frac{\text{Volume of water absorbed}}{\text{Volume of sample used}} \times 100$

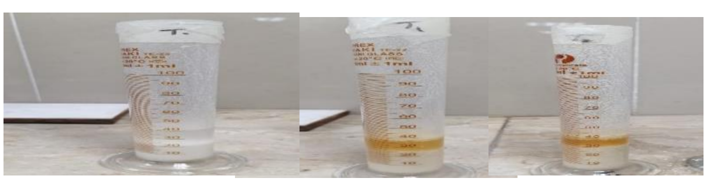


Figure 4: Determination of the swelling index of flour of T_o, T_1, and T_2 was performed in Lab II at the University of Central Punjab, Lahore

Proximate analysis of nachos:

Determination of Moisture Content:

AOAC International has certified several oven methods for determining the moisture content of various food items, which were described by Imoisi *et al.*, (2020). The moisture content was determined by oven drying the 10g of sample at 100°C to 105°C for 12 to 24 hours after it was weighed in a previously weighed petri plate.

Moisture (%) = $\frac{\text{final weight of the sample}}{\text{initial weight of the sample}} \times 100$

Determination of ash content:

Using the AOAC International technique, the amount of ash was ascertained. Before weighing, the crucibles were desiccator-cooled and dried. Weigh 1g of nachos sample into the crucible. At 600°C, the crucible containing the samples was ignited in the muffle furnace for 3h. After the crucibles were removed from the muffle furnace, let them cool in the desicator, and note the readings. Now the ash content is calculated as follows:

Ash (%) = $\frac{\text{WOCAA} - \text{WOCBA}}{\text{WOS}}$ **×100**

Where;

WOCAA= weight of crucible after ashing

WOCBA= weight of crucible before ashing

WOS= weight of sample

Figure 5. Determination of ash content of products T_o, T_1, and T_2 performed in Lab II at the University of Central Punjab, Lahore

Determination of fat content:

The fat content of the nachos samples was determined using solvent extraction with a Soxhlet apparatus, as described by AOAC and Imoisi *et al.*, (2020). One gram of each sample was wrapped in filter paper and placed in a Soxhlet reflux flask, which was connected to a condenser on the upper side and to a weighed oil extraction flask filled with 400 cm³ of hexane. The hexane was heated to its boiling point, causing the vapor to condense into the reflux flask and completely immerse the samples for extraction. This process continued, with the flask filling up and siphoning the extract back into the boiling solvent. The boiling, condensation, and reflux were allowed to proceed for several hours before the defatted samples were removed. The oil extract in the flask was then dried in an oven at 70°C for thirty minutes and subsequently weighed.

Fat% = $\frac{\text{weight of fat in sample}}{\text{weight of dried sample}} \times 100$

Figure 6: Determination of fat content of products T_o, T_1, and T_2 performed in Lab II at the University of Central Punjab, Lahore

Determination of Crude Fiber:

The crude fiber content of the nachos samples was determined using the AOAC and Imoisi *et al.*, (2020). Two grams of each sample were boiled under reflux in a fume cupboard for thirty minutes with 200 ml of 15% H_2SO_4 solution. The resulting mixture was then filtered through filter paper in a Buchner funnel using a vacuum pump and washed with distilled water until neutrality was achieved. The residue was transferred to a round-bottom flask and boiled for another thirty minutes with 100 ml of 5% NaOH solution. Afterward, the final residue was filtered into a crucible, washed with distilled water and ethanol until neutrality was reached. The residue was then dried in an oven and weighed. Finally, the dried residue was incinerated in a muffle furnace, cooled, and weighed again.

Crude fiber (%) = $\frac{W2 - W3}{W1} \times 100$

Where;

W1= weight of sample used
W2= weight of crucible + oven-dried sample
W3= weight of crucible + ash

Determination of protein content:

The crude protein content of the nachos sample was determined using the Kjeldahl method described by Imoisi *et al.,* (2020). 1g of the sample was placed into a digestion flask. 10mL of nitric acid (HNO3) was added, and the mixture was heated and filtered before being made up to a final volume of 100mL. Next, 10mL of the digest was transferred into a 500mL flask and diluted with 40 milliliters of distilled water. A 40% sodium hydroxide (NaOH) solution was then added, and the flask was securely stopped and connected to a 250mL conical flask. In the conical flask, 50mL of 4% boric acid was added. The mixture was heated to collect the distillate. The distillate was then titrated with 0.1N hydrochloric acid (HCl) until a faint pink color was achieved. The initial and final titration results were recorded, and the average titer value was calculated. Finally, the percentage of protein in the samples was determined based on this analysis.

Wet nitrogen % $= \frac{(A-B)\times 1.4007}{\text{Weight o sample}} \times 100$

Where;
A = Vol (ml) Std HCl x Normality of Std HCl
B = Vol (ml) Std NaOH x Normality of Std NaOH

Dry nitrogen % $= \frac{\text{wet moisture \%}}{100-\text{moisture \%}}$

Protein % = dry nitrogen % × 6.25 (protein nitrogen conversion factor)

Textural determination of nachos:

The TPA of nachos was determined using a texture profile analyzer (TA. XT Plus model, Stable Micro System Co. Ltd., Surrey, England) with a modified method described by Kayacier *et al.,* (2014). Three pieces of chips were placed in the Kramer shear attachment (HDP/CFS) and perpendicular to the blades. The parameters for testing are as follows: the probe type was P/0.25S; the pretest speed was 1.00 mm/s; the testing speed was 0.50 mm/s; the post-test speed was 1.00 mm/s, and the compression distance was 5 mm. The crunch value is the number of major peaks when the hardness is larger than 980 N, and crispiness is the number of major peaks when the hardness is between 49 and 980 N when measuring. Each group was repeated at least six times.

Color analysis of Watermelon rind powder incorporated in baked nachos:

Using a handheld spectrocolorimeter (Lovibond, LC-400) and the CIE L a b scale, the color indices of nachos were ascertained using the methodology outlined by Ho and Dahri (2016). Before analysis, the apparatus was calibrated using white reference tiles. After being placed on the petri dish, the nacho samples T_o, T1, and T2 were examined. Color characteristics including brightness (L), redness (a), and yellowness (b) were noted. Lightness is represented by the letter L (0º = black, 100º = white), redness and greenness by the letter a, yellowness and blueness by the letter b, and redness and greenness by the letter a.

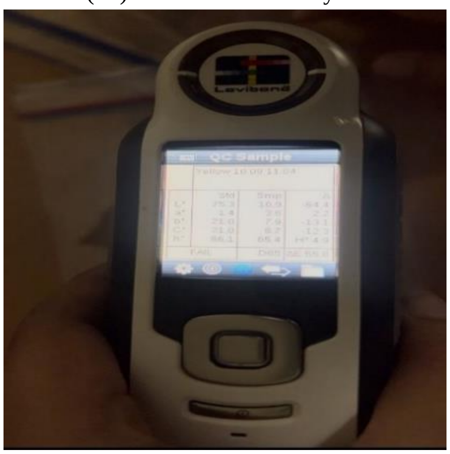


Figure 7: Color analysis of products T_0, T_1, and T_2 performed in Lab II at the University of Central Punjab, Lahore

Microbial Analysis of Watermelon rind powder incorporated in baked nachos:

Total plate count, Mold, and yeast count test:

Following the protocol outlined by Zia *et al.,* (2018) the microbiological analysis (aerobic mesophiles, yeast, and mold) was conducted with modifications. To measure the aerobic mesophiles, the conventional pour plate method was employed. Every treatment sample was serially diluted with a saline solution of 0.85%. A suitable dilution was plated onto plate count agar plates, which were then incubated for 48 hours at 35±1°C. On sample agar plates, the number of yeast and mold was counted after 120 hours of incubation at 25±1°C. Colony-forming units (CFU) were calculated by doubling the dilution factor following incubation.

Sensory evaluation of watermelon rind powder incorporated gluten-free baked nachos:

Sensory evaluation was conducted using a 9-point hedonic scale to determine the sensory acceptability of watermelon rind-incorporated gluten-free baked nachos. A panel of evaluators assessed key sensory factors, including color, aroma, taste, texture, and overall acceptability. The color was judged based on its visual appeal, vibrancy, and uniformity, while the aroma was evaluated for its freshness, intensity, and pleasantness (15, 16).

Shelf life of watermelon rind powder incorporated gluten-free baked nachos:

The shelf life of the developed watermelon rind-incorporated baked nachos was evaluated by performing three treatments over a storage period of 0, 7, and 14 days. The treatments involved varying formulations or storage conditions to assess their impact on product quality. To ensure comprehensive analysis, both proximate and microbial examinations were conducted at each interval. Proximate analysis included determining the moisture, ash, fat, protein, and carbohydrate content to monitor any significant compositional changes during storage. Microbial analysis focused on identifying the growth of bacteria, yeast, and Molds to ensure the safety and stability of the product over time. The findings from these analyses provided valuable insights into the product's nutritional stability, microbial safety, and overall shelf life, highlighting the effectiveness of the treatments applied.

Results & Discussion

Functional properties of Flour blends:

The swelling capacity of flour blends is a critical property influencing texture and viscosity in food products. The study showed that adding watermelon rind powder significantly increased the swelling capacity, with the highest value observed in the T_2 blend (20% watermelon rind powder) at 151.00±1.00%, compared to the control (T_o) with 100% corn flour at 111.47±0.473%, as shown in **Figure 1**. This improvement can be attributed to the fiber and starch in watermelon rind, which enhance water absorption. These findings are consistent with studies highlighting the role of fiber-rich additives in improving hydration and functional properties of flour blends (Kaur *et al*., 2023). This study demonstrated that incorporating watermelon rind powder significantly increased WAC, with the highest value observed in the T_2 blend (20% watermelon rind powder) at 21.413 ± 0.059%, compared to the control (T_o) at 12.463 ± 0.035%, as in **Figure 8**. These findings align with previous studies showing that fiber-rich ingredients improve the WAC of flour blends, contributing to better moisture retention and improved textural properties in food products (17, 18). This study revealed that incorporating watermelon rind powder significantly improved OAC, with the highest value observed in the T_2 blend (20% watermelon rind powder) at -9.950 ± 0.03%, compared to the control T_o (-19.463±0.015%). The improvement in OAC can be attributed to the fiber content and structural properties of watermelon rind powder, which enhance oil retention. Studies have reported similar findings showing that fiber-rich additives improve OAC, resulting in better moisture retention and enhanced product palatability.

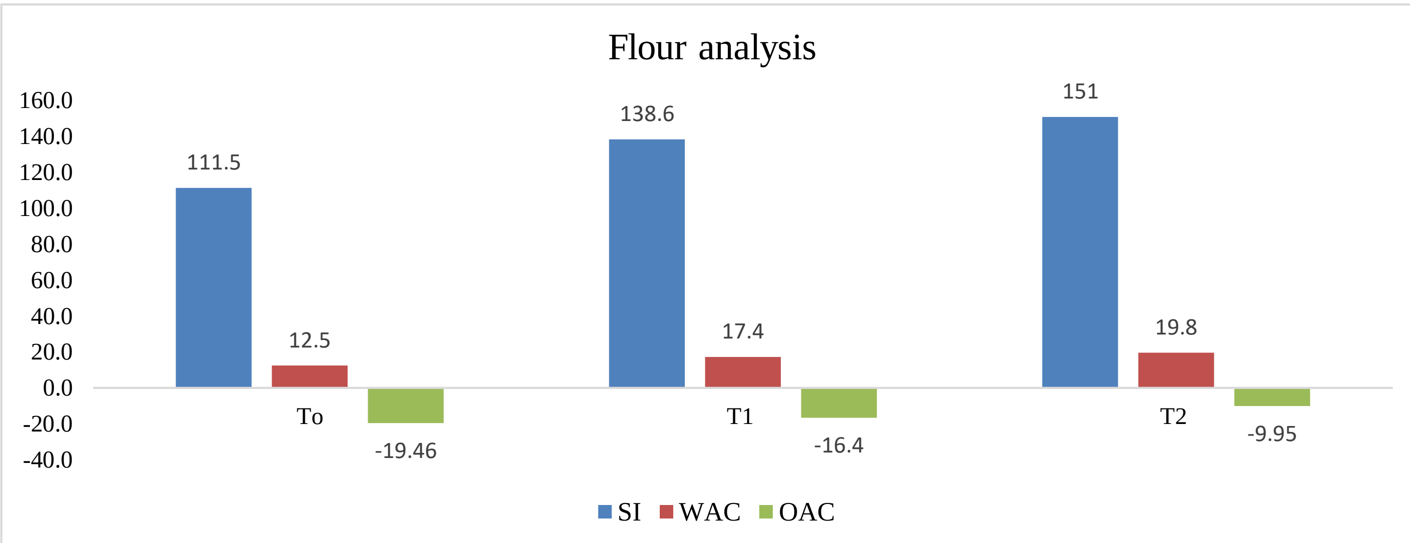


Figure 8: Present the Swelling capacity, Water absorption capacity, and Oil absorption capacity of watermelon rind powder incorporated in nachos T_o (100% corn flour), T_1 (85% corn flour + 15% watermelon rind powder), T_2 (80% corn flour + 20% watermelon rind powder).

Textural analysis of watermelon rind powder incorporated into gluten-free baked nachos: This study demonstrated that incorporating watermelon rind powder significantly affected the chewiness texture of baked nachos as shown in **Figure 9**. Meanwhile chewiness the parameter of texture with the highest value observed in the T_2 sample (20% watermelon rind powder) at 0.1248 ± 0.2%, compared to the T_1 sample (15% watermelon rind powder) at 0.0345 ± 0.2%. The increased chewiness in T_2 could be attributed to the fiber and polysaccharides in watermelon rind powder, which contribute to the firmness and cohesive texture of the product. This study demonstrated that incorporating watermelon rind powder significantly improved the cohesiveness of baked nachos, with the highest value observed in the T_2 sample (20% watermelon rind powder) at 0.8977 ± 0.2%, compared to the T_1 sample (15% watermelon rind powder) at 0.0463±0.2%. The increased cohesiveness in T_2 can be linked to the binding properties and fiber content of watermelon rind powder, which contribute to the product's ability to hold together. This study demonstrated that incorporating watermelon rind powder significantly reduced the hardness of baked nachos. The highest hardness value was observed in the T_o sample (100% corn flour) at 1051.7 ± 0.3%, while the lowest value was recorded in the T_2 sample (20% watermelon rind powder) at 286.6 ± 0.1%. The reduction in hardness with increased watermelon rind powder content can be attributed to its fiber's ability to retain moisture and disrupt the rigid structure of the flour matrix. This study revealed that incorporating watermelon rind powder enhanced the resilience of baked nachos. The highest resilience value was observed in the T_2 sample (20% watermelon rind powder) at 0.9023 ± 0.1%, while the lowest was found in the T_o sample (100% corn flour) at 0.3057 ± 0.03%. This increase in resilience with higher watermelon rind powder content can be attributed to the fiber's structural reinforcement and moisture retention properties, which improve elasticity and shape recovery. In this study, baked nachos incorporated with watermelon rind powder demonstrated improved springiness. The T_2 sample (20% watermelon rind powder and 80% corn flour) exhibited the highest springiness value (0.8413 ± 0.15%), whereas the T_o sample (100% corn flour) showed the lowest (0.3770 ± 0.01%). The increased springiness in T_2 can be attributed to the structural and moisture-retaining properties of watermelon rind powder, which enhance elasticity. These findings are consistent with previous studies highlighting the role of fiber in improving springiness in baked goods (19-21).

Color analysis of watermelon rind powder incorporated into gluten-free baked nachos:

The results show that the L (lightness) values of samples T_o made up of 100% corn flour, T_1 made up of 85% corn flour and 15% watermelon rind powder, and T_2 were made up of 80%corn flour and 20 % watermelon rind powder and their mean values were 64.433±0.058%, 64.367±0.06%, and 59.400±0.15% indicating a significant variation in lightness among the samples. The a (redness) values of samples T_o, T_1 and T_2 mean values were 2.2000±0.1%, 1.5000±0.1%, and 5.8000±0.1% signifying a notable difference in the red-green axis among the samples. Additionally, the b (yellowness) values of samples T_o, T_1 and T_2 values were 65.763±0.06%, 65.767±0.058%, and 60.600±0.1% reflecting a significant difference in the yellow-blue axis among the samples. As it is represented in the graphical form in **Figure 10.** According to these findings, the color of samples changed dramatically over time, becoming more red and less bright. A variety of factors, including variations in chemical composition, moisture content, or exposure to light, may be responsible for the changes in color characteristics. The findings were in accordance with the research conducted on quinoa flour crackers (22, 23).

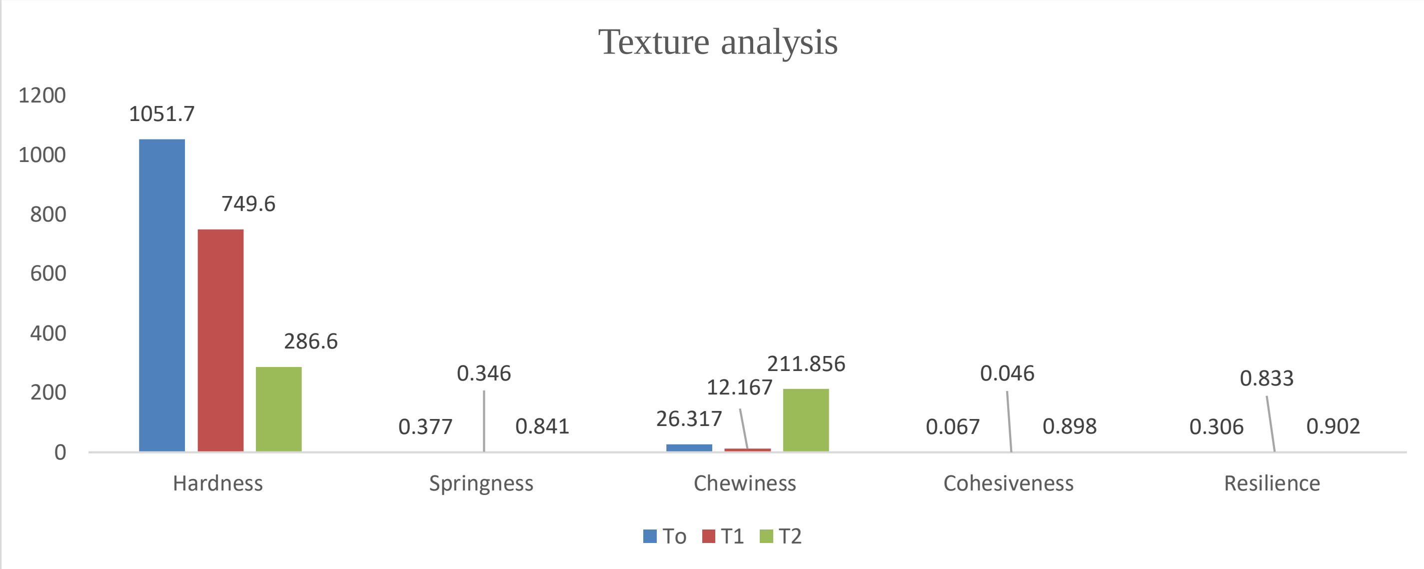


Figure 9: Present the Hardness, Springiness, Chewiness, Cohesiveness, and Resilience of watermelon rind powder incorporated in nachos T_o (100% corn flour), T_1 (85% corn flour + 15% watermelon rind powder), T_2 (80% corn flour + 20% watermelon rind powder).

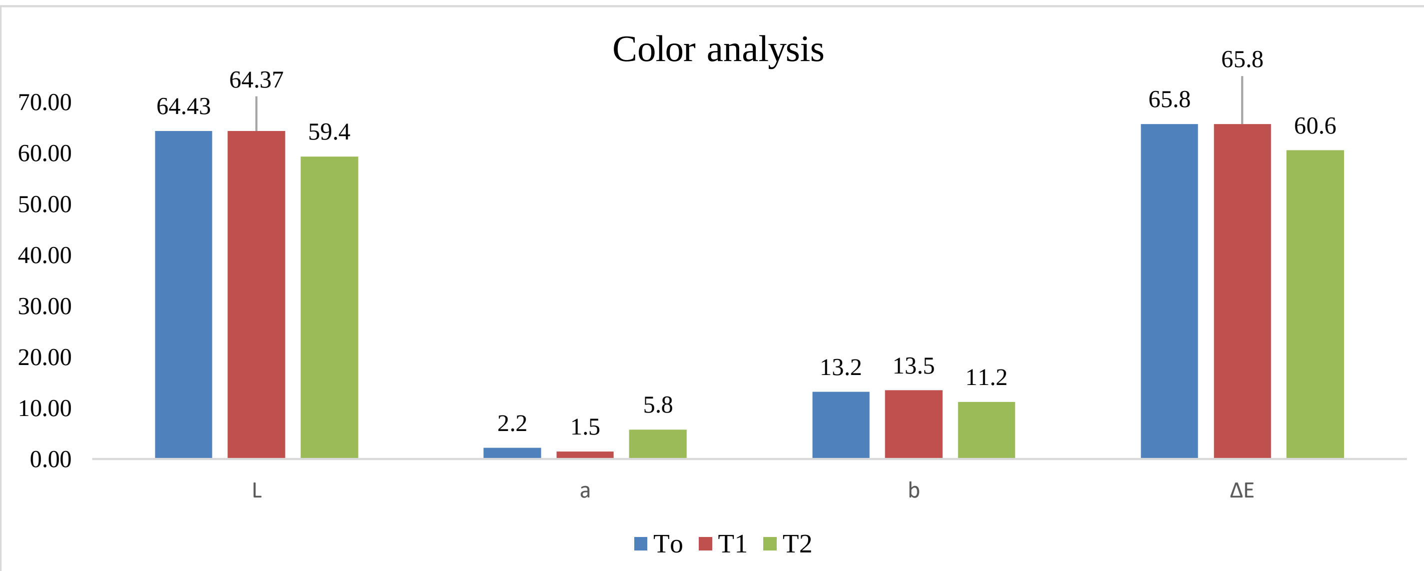


Figure 10: Present the Color Analysis of watermelon rind powder incorporated in nachos T_o (100% corn flour), T_1 (85% corn flour + 15% watermelon rind powder), T_2 (80% corn flour + 20% watermelon rind powder).

Physiochemical analysis of watermelon rind powder incorporated into gluten-free baked nachos:

The moisture content of nachos samples made from watermelon rind powder shows that the minimum mean value (3.37±0.021%) was observed in case of T_2 nachos samples made from 80% corn flour and 20% watermelon rind powder while the maximum mean value (3.43±0.01%) was observed in case of T_o nachos samples made from corn flour values show that moisture content decreases from 3.4700±0.01% to 3.37±0.021% during storage period. The findings were from the research conducted on nachos (24). Their research demonstrated that during storage, the moisture content varies. Moisture content is highest at day zero and gradually decreases to 3.37±0.021% from 3.47±.001% at day 14. The environment's temperature directly affects this decrease in moisture content because, as the temperature rises, the moisture content falls over time. The Ash content of nachos samples made from watermelon rind powder shows that the maximum mean value (1.6700±0.01 %) was observed in the case of T_2 nachos samples made from 80% corn flour and 20% watermelon rind flour while the minimum mean value (1.1700±0.01%) was observed in case of T_o samples made from 100% corn flour. The mean values show that ash content increases from 1.1700±0.01% to 1.6700±0.01 % during the storage period. The results were consistent with the nachos research that was done. Because of its instability, the ash content and mineral composition are guaranteed to increase over time. The consistency of food products' mineral content across storage periods is a well-documented phenomenon in the literature on food science. Fat content of nachos samples made from watermelon rind powder incorporated gluten-free baked nachos show that the minimum mean value (3.5200±0.01%) was observed in case of T_o nachos samples made from 100% corn flour while the maximum mean value (3.9533±0.01%) was observed in case of T_2 nachos samples made from 80% corn flour and 20% watermelon rind nachos. The mean values show that fat content increases from (3.5200±0.01%) to (3.9533±0.01%) during the storage period. Significant increase in fat content during the storage period of 14 days shows that Values for every treatment generally demonstrated a consistent increase in fat content over storage. Over time, the process of lipolysis that occurs during ripening may also lead to an increase in fat content. The results were consistent with the nachos research that was done by Fasolin *et al*., (2017). The fiber content of nachos samples made from watermelon rind powder shows that the maximum mean value (8.4767±0.02%) was observed in the case of T_2 nachos samples made from 80% corn flour and 20% watermelon rind powder while the minimum mean value (6.2833±0.25 %) was observed in case of T_0 nachos samples made from 100% corn flour. The mean values show that fiber content decreases from 8.4767±0.02% to sss6.2833±0.25 during the storage period. The results were not consistent with the nachos research that was done. Because fiber is an unstable component of plant-based components and is resistant to the chemical and physical processes that often occur during food storage, studies have shown that the amount of fiber in nachos varies over 14 days. Protein content nachos samples made from watermelon rind incorporated gluten-free baked nachos shows that the minimum mean value (9.6400±0.02%) was observed in case of T_0 nachos samples made from 100% corn flour while the maximum mean value (9.8733±0.015 %) was observed in case of T_2 nachos samples made from 80% corn flour and 20% watermelon rind powder. The mean values show that protein content increases from (9.6400±0.02%) to (9.8733±0.015 %) during the storage period. Values for every treatment generally demonstrated a consistent increase in protein content over storage. Because ripening involves several metabolic, microbiological, and biochemical processes, the protein content of nacho samples increases. This is a relative increase, not an actual addition of protein (25).

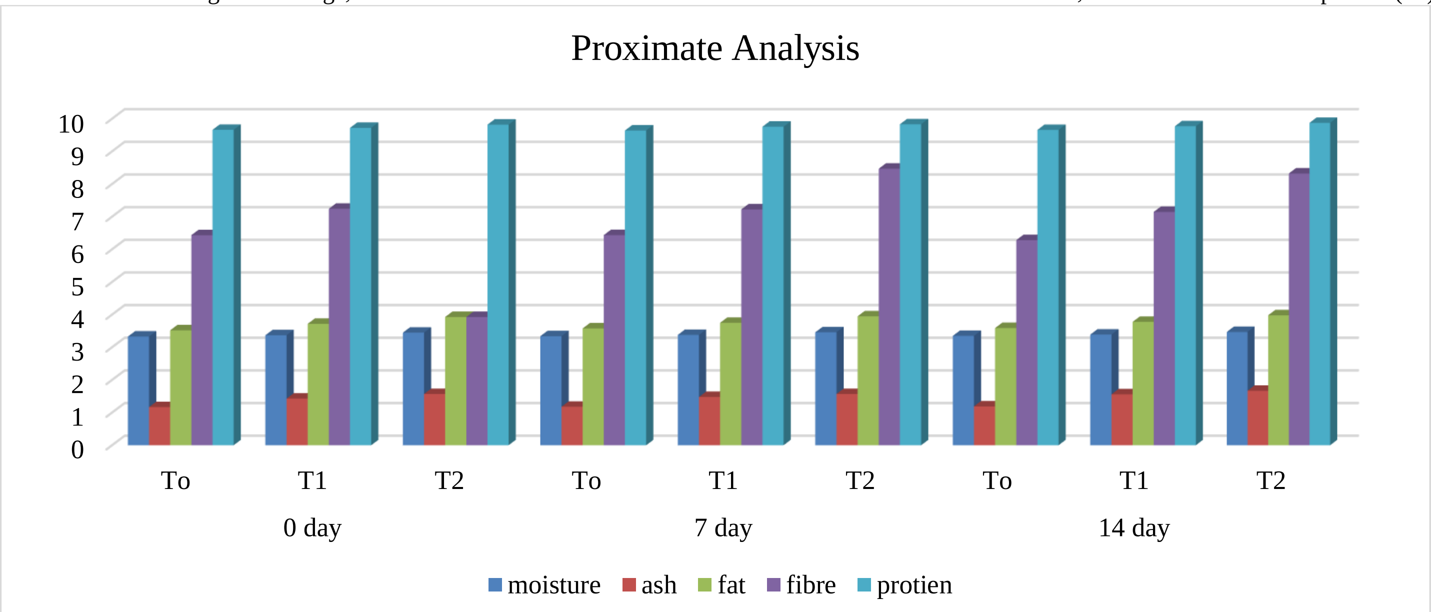


Figure 11: Present the Physicochemical Analysis of watermelon rind powder incorporated in nachos T_o (100% corn flour), T_1 (85% corn flour + 15% watermelon rind powder), T_2 (80% corn flour + 20% watermelon rind powder) with storage of 0,7 and 14 days.

Sensory Analysis of Watermelon Rind powder Incorporated into gluten-free baked nachos:

The appearance score of nachos made with watermelon rind powder shows that maximum mean value (8.3333±0.58%) was observed in case of T_2 nachos sample made from 80% corn flour and 20% watermelon rind powder while the minimum mean value (6.6667±0.58%) was observed in case of T_1 made from 85% corn flour and 15% watermelon rind powder. The mean values show that the appearance score decreases from 8.3333±0.58% to 6.6667±0.58% during the storage period. Moreover, the appearance score of samples may be decreased due to the enzymatic browning, chlorophyll degradation, and decrease in moisture level. The findings were by the research conducted on nachos (24). Mouthfeel score of nachos made by watermelon rind powder shows that maximum mean value (8.6667±0.58%) was observed in case of T_2 nachos sample made from 80% corn flour and 20% watermelon rind powder while the minimum mean value (5.6667±1.53%) was observed in case of T_1 made from 85% corn flour and 15% watermelon rind powder. The mean values show that the mouthfeel score decreases from 8.6667±0.58 % to 5.6667±1.53% during the storage period. Moreover, the mouthfeel score of samples may be decreased due to flavor degradation, moisture loss, or exposure to external odor. The findings were in accordance with the research conducted on nachos (26). The texture score of nachos made with watermelon rind powder shows that maximum mean value (8.3333±1.15%) was observed in case of T_2 nachos sample made from 80% corn flour and 20% watermelon rind powder while the minimum mean value (6.3333±0.58%) was observed in case of T_1 made from 85% corn flour and 15% watermelon rind powder. The mean values show that the texture score decreased 8.3333±1.15% from 6.3333±0.58% during the storage period. Moreover, the texture score of samples may be decreased due to moisture loss, staling, oxidation, and microbial growth. The findings were in accordance with the research conducted on nachos (24). The aroma score of nachos made with watermelon rind powder shows that maximum mean value (8.6667±0.58%) was observed in case of T_2 nachos sample made from 80% corn flour and 20% watermelon rind powder while the minimum mean value (6.0000±1%) was observed in case of T_1 made from 85% corn flour and 15% watermelon rind powder. The mean values show that the aroma score decreases from 8.3333±0.58% to 6.0000±1% during the storage period. Furthermore, flavor deterioration, moisture loss, or exposure to outside odors can all lower a sample's factory score. These results were consistent with the nachos (27). The overall acceptability score of nachos made with watermelon rind powder shows that the maximum mean value (8.3333±1.15%) was observed in case of T_2 nachos sample made from 80% corn flour and 20% watermelon rind powder while the minimum mean value (6.3333±0.58%) was observed in case of T_1 made from 85% corn flour and 15% watermelon rind powder. The mean values show that the overall acceptability score decreased 8.3333±1.15% from 6.3333±0.58% during the storage period. Moreover, the overall acceptability score of samples is changes due to change in taste, texture, and color as they tend to dry out over time, leading to less desirable texture, color might also fade making them appear less appealing and become bland. The findings were under the research conducted on nachos by Zbikowska *et al.*, (2020)

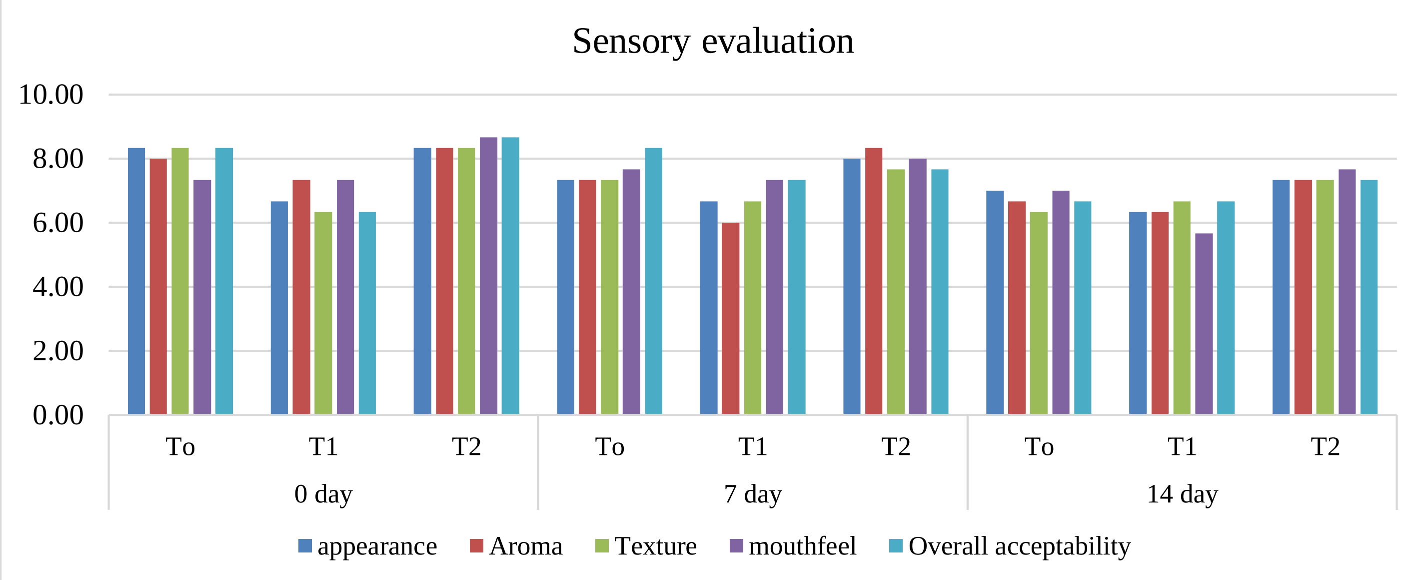


Figure 12: Present the Sensory Evaluation of watermelon rind powder incorporated in nachos T_o (100% corn flour), T_1 (85% corn flour + 15% watermelon rind powder), T_2 (80% corn flour + 20% watermelon rind powder) with storage of 0,7 and 14 days.

Microbial analysis (TPC and Mold count) of watermelon rind powder incorporated into gluten-free baked nachos:

TPC (Total plate count) of nachos samples made from watermelon rind powder shows that the maximum mean value 98.000±1 (Log_{10}cfu/g) was observed in T_1 nachos samples made from 85% corn flour and 15% watermelon rind powder, while the minimum mean value 35.667±0.58 (Log_{10}cfu/g) was observed in T_0 nachos samples made from 100% corn flour. The mean values show that TPC increases from 35.667±0.58 (Log_{10}cfu/g) to 98.000±1 (Log_{10}cfu/g) during the storage period. The increase in the TPC of samples is due to factors such as prolonged storage duration, higher storage temperatures, increased humidity, and the type and effectiveness of the packaging material. The findings were based on the research conducted on nachos (28). The total mold and yeast count of nachos samples made from watermelon rind powder shows that the maximum mean value of 51.333±1.53 (Log_{10}cfu/g) was observed in T_2 nachos samples made from 80% corn flour and 20% watermelon rind powder, while the minimum mean value of 26.000±1 Log_{10}cfu/g) was observed in T_o nachos samples made from 100% corn flour. The findings were in accordance with the research conducted on nachos by Croituru *et al.*, (2018). Studies show that initially, at day 0, the mold and yeast counts were lower, but there was a gradual increase observed over time, ranging from 26.11±0.19% to 49±6.91%. This increase in mold and yeast count is directly linked to environmental conditions, where higher temperatures and prolonged storage periods provide favorable conditions for microbial growth.

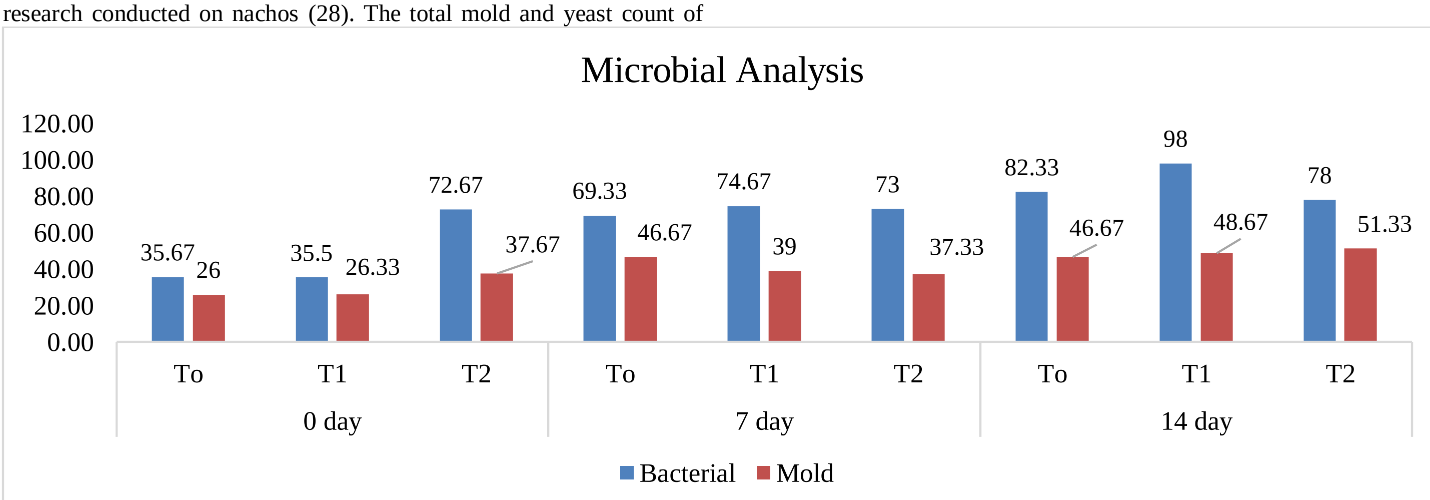


Figure 13: Present the Microbial analysis of watermelon rind powder incorporated in nachos T_o (100% corn flour), T_1 (85% corn flour + 15% watermelon rind powder), T_2 (80% corn flour + 20% watermelon rind powder) with storage of 0,7 and 14 days.

Conclusion

This study successfully developed and characterized nachos made from watermelon rind powder. The results demonstrated that the functional properties, including swelling capacity, water absorption capacity, and oil absorption capacity were high specifically in T_2 blend samples made with 80% corn flour and 20% watermelon rind powder. During the 14-day storage period, all nachos' samples exhibited a decrease in moisture content and fiber content, while fat content, ash content, protein content, and microbial counts increased. Sensory evaluation revealed that nachos made with watermelon rind powder were well-accepted, although the control T_2 nachos sample made with 80% corn flour and 20%watermelon rind powder had the highest overall acceptability. The T_2 sample having 80% corn flour and 20% watermelon rind flour has the best texture and color. Overall, the study highlights the potential of watermelon rind powder as a functional ingredient in ready-to-eat products and bakery products, contributing to enhanced nutritional value and sensory qualities. These findings provide a foundation for further research on the use of watermelon rind by-products in food formulations.

Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-MMNCS-0331d-24)

Consent for publication

Approved

Funding

Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

MB, AS, TF

Review of Literature, Data entry, Data analysis, and drafting article.
Manuscript drafting, Study Design,

SF, MH, FS,

Conception of Study, Development of Research Methodology Design

KS, SK, SJ, FR

Study Design, manuscript review, critical input

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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