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# Comprehensive analysis of nutritional and antioxidant properties of *Cucumis callosus* peel

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## ABSTRACT

*Cucumis callosus* (commonly known as Kacheri) fruit is typically analyzed for its nutritional components, including moisture, ash, protein, fat, fibre, and carbohydrates. However, specific studies on *C. callosus* remain limited. Peel of *C. callosus* is a rich source of nutrients and analyzing the bioactive composition reveals its potential benefits. It constitutes about 20% of the total residue and is often considered an environmental challenge due to disposal issues. In this study, the phytochemical and proximate compositions of *C. callosus* peels were analyzed. The proximate analysis revealed a fat content of 6.89%, protein content of 9.34%, moisture content of 9.59%, ash content of 8.18%, and carbohydrate content of 36.66%. The crude fibre in the peels was found to be 29.34±0.94%. The crude fibre *C. callosus* content of peels was significantly higher compared to other vegetable peels. *C. callosus* has demonstrated remarkable functional properties, exhibiting a water-holding capacity 26 times its own weight and an oil-holding capacity 16 times its own weight. The methanolic extract of *C. callosus* peel exhibited antioxidant activity with an $IC_{50}$ value of 67.76 ± 2.34 $\mu g$/mL in the DPPH assay, indicating its potential as a promising natural antioxidant source. The mineral analysis result shows Iron as a major element followed by zinc and copper, and manganese highlighting their potential nutritional benefits. This study aims to raise awareness about the potential of *C. callosus* peels as a valuable source of phenolic compounds and iron element. The research underscores the importance of utilizing these peels in various food products to enhance their nutritional and technological properties.

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## INTRODUCTION

Food production and processing generate significant waste, with 25-30% of fruit processing output discarded each year, exceeding 100 billion tons of fruit and vegetable waste globally. Among the various types of food waste, fruit and vegetable waste accounts for a substantial portion, making up 42% of the total waste generated (Ganesh *et al*., 2022). The exploration of food waste and by-products as sources of bioactive compounds has gained considerable attention in recent years, owing to their demonstrated antimicrobial and antioxidant properties. Fruits and vegetables are particularly valuable as rich sources of dietary fibre. Peel from fruits and vegetables constitute around 50% of waste. The peels of fruits and vegetables are gaining scientific attention due to their rich content of bioactive compounds, especially phenolic compounds, and their potential therapeutic applications, biological activities and the packaging industry (Bhardwaj *et al*., 2022). Utilizing fruit and vegetable peels enhances oxidative stability and extends the shelf life of products while reducing microbial decomposition. This not only extends the shelf life but also maintains the flavour, colour, and texture, making these products more acceptable and sustainable in the food industry (Gullón *et al*., 2020; Das *et al*., 2021). The recovery of these bioactive compounds from the food industry has become a new trend, contributing to the production of sustainable, high-value food goods (Devi & Geethanjali, 2017; Taglieri *et al*., 2021).

Fruit and vegetable peels are indeed valuable by-products, rich in bioactive compounds such as polyphenols, carotenoids, and other beneficial substances. These compounds have been shown to offer various health benefits, including antioxidant, antimicrobial, and anti-inflammatory properties (Pathak, 2020). Fruit peels possess a unique chemical composition and offer great potential for value addition due to their abundance and low cost (Suhag *et al*., 2022). The peels from various fruits possess significant therapeutic and pharmacological potential, offering prospects for integration into medical nutrition therapy. In recent years, a significant area of research has focused on identifying, quantifying, extracting, and analyzing the beneficial properties of bioactive compounds derived from fruit peels (Coman *et al*., 2020).

The objective of the present study is to explore the under-researched *C. callosus* peel, grown in the semi-arid regions of Rajasthan and Haryana, India, for which no prior research has been reported. This study focuses on conducting a comprehensive proximate analysis, assessing macronutrients, mineral content, and phytochemicals such as flavonoids, phenolics, and antioxidants. Additionally, it aims to evaluate the peel's functional properties, including oil-holding capacity (OHC) and water-holding capacity (WHC), to investigate its potential for applications in the food and pharmaceutical industries.

### Cucumis Callosus

*Cucumis callosus* ("Kachri") is an underutilized member of the Cucurbitaceae family, primarily found in the arid and semi-arid regions of India, especially Haryana, Rajasthan, and Gujarat. This perennial herb, valued for its medicinal and nutritional properties, is commonly intercropped with cotton and pearl millet during the kharif and summer seasons, with fruiting from August to November (Chand *et al.*, 2012; Yadav *et al.*, 2022).

Traditionally, *Kachri* has been used to enhance memory, treat mental disorders, vertigo, bilious conditions, and diabetes (Kirtikar & Basu, 1935; Rahman *et al.*, 2006). Its seeds possess cooling and astringent properties, and in Sri Lanka, are used for stomach issues like pain, vomiting, and constipation (Ediriweera & Ratnasooriya, 2009; Goyal & Sharma, 2009). The fruit pulp has been used to regulate menstruation and induce abortion (Seliya & Patel, 2009). Despite its potential use, the hard-textured peel is often discarded.

*C. callosus* (Kachri) is traditionally processed by local communities and valued for its therapeutic properties, including antioxidant, anti-diabetic, anti-cancer, and cardioprotective effects (Varadharajan *et al.*, 2016). Nutritionally, it is rich in proteins, carbohydrates, essential fatty acids, phenols, and phytochemicals. The nutritional content, shelf-life, and sensory attributes of *C. callosus* syrup were recently investigated and optimized to enhance its value and consumer appeal, highlighting its potential as a food ingredient (Deepika *et al.*, 2023). Due to its high moisture content (88.99%) and perishability (Dahot *et al.*, 1999) the fruit is often sun-dried and stored as powder. Its seeds, extracted post-destoning, are rich in oils, bioactive compounds, and phytochemicals (Meena *et al.*, 2016). The morphology of peel and vegetative part is shown in Figure 1.

## MATERIALS AND METHODS

### Sample Collection & Preparation

The fruits of *Cucumis callosus* (Rottl.) were collected from the field of the Alwar region. The fruit were thoroughly washed with Deionised water, and peeled by a scraper. The peels were then dried in a hot air oven at 60 °C for 12 hours to ensure consistent dehydration. The dried peels were ground into a fine powder using an electrical grinder. This powder was stored in airtight containers at 4 °C for subsequent analysis.

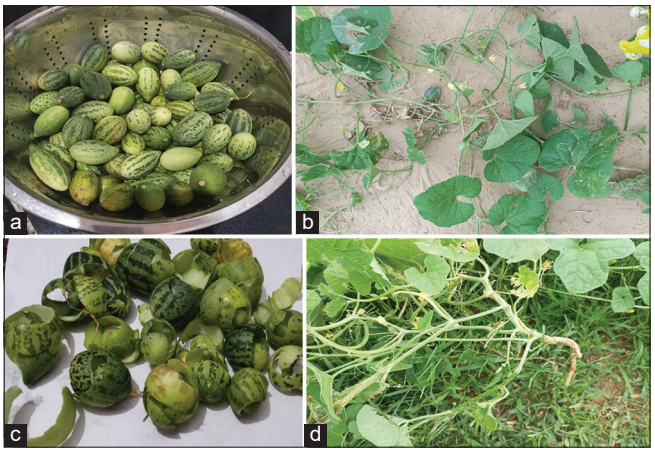


**Figure 1:** Morphology section of *C. callosus* a) whole fruit, b) field view of plant, c) peel part of fruit and d) Leaves and tendrils of a plant

### *Chemicals*

All solvents (ethanol, methanol and acetone), acids and chemicals, including DPPH (2,2-diphenyl-1-picrylhydrazyl), gallic acid (GA), and quercetin, $AlCl_3$, sodium carbonate etc., were of analytical grade and sourced from Qualigen, Hi Media, Merck, and Loba, respectively. All calibrated glassware was used in the experiments. Before use, the glassware was thoroughly washed with detergent, rinsed with tap water, and sterilised in an oven at 110 °C for 1 hour.

### Proximate Analysis Methodology

The sample was analyzed for moisture, ash, crude fibre, total protein, and total fat content. Moisture, ash, fat, crude fibre, and protein content were determined following the AOAC Official Methods of Analysis (AOAC, 2005). Mineral content was carried out from Y.S. Parmar University, Solan (Nauni, Himachal Pradesh), using the Analytikjena Atomic Absorption Spectrometer model Zeenit 700P and Flame photometric analysis by Systronics -128 model. Moisture content was determined gravimetrically by drying the samples in an oven at 135 °C to a constant weight, following AOAC Method No. 930.15. Crude protein content (N × 6.25) was determined using the Kjeldahl method, as per AOAC Method No. 2001.11. Crude fat was determined using the Soxhlet extraction method with petroleum ether (60-80 °C) as the extraction solvent, according to AOAC Method No. 2003.05. Ash content was assayed by incinerating the samples in a muffle furnace at 550 °C, following AOAC Method No. 942.05.

### *Carbohydrate*

Carbohydrate content was determined using the difference method (Onyeike *et al.*, 1995). This method calculates the percentage of carbohydrates using the formula:

Carbohydrate (%) = 100-(% Moisture+% Crude Fiber+ % Ash+% Crude Fat+% Crude Protein)

### *Energy calculation*

The energy content of the samples was calculated using the protein, fat, and carbohydrate values, applying the Atwater formula as outlined by FAO (2003). The energy value is expressed in kilocalories (kcal): Energy value (Kcal/100g) = P x 4.0 + F x 9.0 + C x 4.0

### Functional Properties

The water-holding capacity (WHC) and oil-holding capacity (OHC) of the sample were determined using a modified centrifugation method, as outlined by Larrauri *et al.* (1996) with slight modification. For this, 1.0 g of sample was mixed with 10 mL of water or mustard oil, stirred, and allowed to stand for 40 minutes at 30 °C. The mixture was then centrifuged at 3000 rpm for 20-30 minutes. The residue was weighed, and WHC and OHC were calculated as grams of water or oil per gram of dry sample, respectively.

### Analysis of Antioxidants

The bioactive compounds in the fruit peels were analyzed using a UV-visible spectrophotometer (Thermo Fisher model Orion Aquamate 8000).

### *Extract preparation*

To estimate polyphenols and flavonoids, the samples were extracted using solvents like acetone and methanol. Specifically, 1.0 g of the sample was suspended in 10 mL of the respective solvent for 12 hours. Then, the mixture was extracted for 3 hours at room temperature with continuous agitation. After extraction, the mixture was centrifuged at 3000 rpm and filtered through Whatman filter paper. The solvent was evaporated on rotavapour and the residue was collected. Sample extracts with a concentration of 1mg/ml were prepared and used for analysis.

The total phenolic content was measured following the Folin-Ciocalteu method, using gallic acid as a standard. Fruit peel extracts were mixed with Folin-Ciocalteu reagent, followed by sodium carbonate, and the absorbance was recorded at 765 nm (Sadiyah *et al.*, 2020). For total flavonoid content, the $AlCl_3$ colorimetric method was used, with quercetin as the standard. After mixing the extract with $AlCl_3$, the absorbance was measured at 415 nm (Chang *et al.*, 2002).

To determine the antioxidant content, 1 g of the sample was extracted with 10 mL of methanol by shaking at room temperature for 70 minutes. After extraction, the mixture was centrifuged at 3000 rpm for 15 minutes. The supernatant was collected and used for further analysis of antioxidant activity. Antioxidant activity was assessed via the DPPH radical scavenging assay, with the reduction in absorbance at 517 nm indicating antioxidant potential (Brand-Williams *et al.*, 1995).

Statistical Analysis: Every parameter was analyzed in triplicate, with results expressed as the mean±standard deviation.

## RESULTS AND DISCUSSION

### Macronutrients

The macronutrient composition and the estimated energy values of the fruit peels are presented in Table 1.

The ash content of the sample (8.18%) is comparable to that of bottle gourd (8.5%) and ridge gourd (7.3%) and is higher than the ash content of fruit peels such as apple (2.6%), mango (3.5%), and pomegranate (3.35% to 6.07%) on a dry matter basis (Sadef *et al.*, 2022; Singh *et al.*, 2023). The moisture content is low in the analysed peel powder on dry matter basis (9.59%) whereas high water content is reported in potato peel, pumpkin peel powder (5.96 to 10.31%)) and pomegranate peel and Carrot peel (9.70%) (Jimenez-Champi *et al.*, 2023: Wanderley *et al.*, 2023).

The lipid content in *C. callosus* peel is substantially higher (6.89%) than the reported ranges for other fruit (apple and mango) and vegetable peels (bottle and ridge gourd) (0.15% to 0.34%). This indicates that peel has a much higher fat content compared to the peels of bottle gourd, mango, apple, and bitter gourd. The higher lipid content suggests that *C. callosus* peel could be a richer source of energy and essential fatty acids. This could make it a valuable ingredient in food products aimed at enhancing nutritional value.

Vegetables generally contain higher levels of both fibre and protein compared to fruits, with the peel being a particularly rich source of dietary fibre. In *C. callosus* peel, the fibre content is recorded at 29.34±0.94 %. This crude fibre level is significantly higher compared to other fruits (apple and mango) and vegetables (bottle and ridge gourd), where the fibre content ranges from 4.5±0.22% to 17.6±0.24% on a dry matter basis. The analyzed peel sample exhibited a protein content of 9.34 %, which falls within the range observed in other fruits and vegetables, typically varying from 1.24±0.045% to 16.52±0.18% on a dry matter basis. Similarly, pomegranate peel contains lower levels of ash, fat, and protein content (3.35-6.0%, 0.55-3.36%, and 3.24-3.46%, respectively) compared to *C. callosus* peel, indicating this fruit is relatively richer in these nutritional components. However, crude fibre content is found to be in a similar range, while carbohydrate content is higher in pomegranate (Sadef *et al.*, 2022).

The fruits contain high carbohydrate content, often in the form of sugars, contributes to the distinct nutritional profiles

Table 1: Proximate composition (%) of *C. callosus* peel (dry matter)

| Parameters | Proximate composition |
|---|---|
| Moistures (%) | 9.59±0.99 |
| Ash (%) | 8.18±0.06 |
| Fat (%) | 6.89±0.49 |
| Crude Fiber (%) | 29.34±0.94 |
| Protein | 9.34±-0.39 |
| Carbohydrates | 36.66±- 0.57 |
| Energy | 245.71(Kcal) |

of fruits. The recent study demonstrated that fruit peels from 12 commonly consumed fruits possess significant nutritional value, including high levels of carbohydrates, dietary fibre, minerals, and phenolic compounds with potent antioxidant activity. Notably, black seedless grapes and guava exhibited the highest total phenolic content (Hussain *et al.*, 2023). The review by Olufunso *et al.* (2024) highlights the overlooked potential of edible plant peels as valuable sources of nutrients and therapeutic agents, advocating for their inclusion in health and nutrition strategies while also emphasizing the need for further research in this area.

In our study, the analyzed sample contained 36.77% carbohydrates, which is lower than the reported carbohydrate ranges from 47.3±0.76% to 78.5±0.24% of dry matter in fruit and vegetable peels (Sadef *et al.*, 2022).

## Mineral Analysis

In the mineral analysis of the sample peel, the concentrations of key trace elements were measured. Iron (Fe) content was found to be 809.9 mg/L, indicating a substantial presence of this essential mineral, critical for various biological processes such as oxygen transport. Copper (Cu) was detected at 68.4 mg/L, playing a significant role in enzymatic reactions and iron metabolism. Zinc (Zn) was present at 128.3 mg/L, which is vital for immune function and cellular growth. Manganese element is 59.3 mg/L followed by a small amount of calcium, sulphur and magnesium. These results highlight the nutritional potential of the peel as a source of important micronutrients. The complete data is represented in Table 2.

### Functional Properties

Hydration properties refer to the ability of cell wall material to retain water within its structure, typically measured by water holding capacity (WHC) and swelling capacity (SWC) (Ma & Mu, 2016). The SWC and WHC are primarily associated with insoluble polysaccharides, which bind water through surface tension within the matrix pores or via ionic bonds, hydrogen bonds, and hydrophilic interactions. The data of OHC and WHC of *C. callosus* are shown in Table 3.

Oil and water holding capacity of the *C. callosus* peel exhibited remarkable functional properties, with an oil- holding capacity of 8.62±0.14 and water-holding capacity of 13.35±0.42 g/g. While the potato peel waste showed low oil-holding (fat-binding) and water-holding capacities of 4.398±0.04 g/g and 4.097±0.537 g/g, respectively (Jeddou *et al.*, 2016), the sample peel exhibited much greater capacities. These comparisons highlight the superior functional properties of the sample peel, particularly in terms of moisture and oil retention, suggesting its potential for enhanced applications in food formulations requiring these characteristics.

Swelling capacity, an important hydration property related to the cellulose content in fibre, was measured at 4.06±0.04 mL water/g for *C. callosus* peels sample. In comparison, other fruit fibre concentrates, such as passion fruit, pineapple, and mango, reported swelling capacities of 8.2, 6.6 and 4.60 mL water/g, respectively (Martínez *et al.*, 2012). Among the samples, guava fibre showed the lowest swelling capacity.

Table 2: Mineral composition of *C. Callosus* peel ppm

| Minerals | Method | Result |
|---|---|---|
| Total Ca | Flame photometer | 11.12 |
| Magnesium | AAS | 1.1 |
| Sulphur | Turbidimetric method | 2.01 |
| Iron | AAS | 809.9 |
| Manganese | AAS | 59.3 |
| Copper | AAS | 68.4 |
| Zinc | AAS | 128.3 |

Table 3: Functional properties of *C. callosus* peel

| Functional properties | Values |
|---|---|
| Water Holding (WHC) (gm water/gm dry fiber source) | 13.35±0.42 |
| Oil Holding Capacity (OHC) (gm/oil/g dry fiber source) | 8.62±0.14 |
| Swelling Capacity (SWC) (mL water/g) | 4.06±0.04 |

## Phytonutrients Analysis

Phytochemicals contribute to their notable antioxidant, antimicrobial, and anti-inflammatory properties, making peels valuable for potential applications in nutraceuticals and functional food ingredients. Exploring their composition is essential for promoting sustainable food systems and value-added utilization. Therefore, an in-depth analysis of *C. callosus* phytonutrient profile was undertaken and presented in Table 4.

### *Antioxidants*

The DPPH assay is commonly employed to evaluate free radical scavenging activity, primarily due to the presence of polyphenols. This method is considered a non-specific free radical scavenging assay, as it measures the neutralization of free radicals from both phenolic and non-phenolic compounds, including ascorbic acid. It is based on the reduction of purple DPPH radicals to yellow, in the presence of hydrogen-donating antioxidants, forming diphenyl picryl hydrazine. Due to their hydrogen-donating capacity, the extracts reduce the DPPH colour. The remaining DPPH radicals, which show maximum absorption at 517 nm, are then measured. The antioxidant activity of the methanol extract in our study showed a percentage inhibition of 82.77±2.94%. A graph was plotted for the methanol extract, yielding the standard curve equation y=0.0.0007x+0.0188 with a regression coefficient of $R^2$=0.9802 (Figure 2).

The total antioxidant activity of the fresh *C. callosus* peel (82.77±2.94%) was higher than that reported for potato peels (27.78%) (Biswas *et al.*, 2021). Our results are comparable to carrot peel (80.1%) and bottle gourd peel (72.35%). The antioxidant activity of *Cucumis callosus* peel was assessed by the DPPH assay, yielding an IC50 value of 67.76±2.34 $\mu$g/mL. This places the peel in the category of strong antioxidant potential according to widely accepted classification criteria, extracts with $IC_{50}$ values between 50 and 100 $\mu$g/mL are considered to exhibit strong antioxidant potential. Antioxidant activity values can vary

Table 4: Phytonutrient analysis of *C. callosus* peel

| Parameters | Amount |
|---|---|
| Antioxidant Activity | 82.77±2.94% |
| Total Flavonoid Content in Methanol | 19.87±2.77 mg QE/g |
| Total Flavonoid Content in Acetone | 21.74±4.23 mg QE/g |
| Total Phenolic Content in Methanol | 2.37±0 mg GAE/g |
| Total Phenolic Content in Acetone | 16.08±0.35 mg GAE/g |

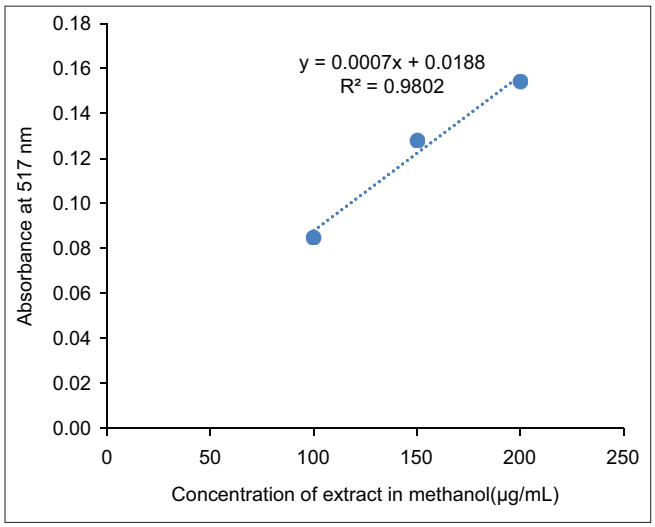


**Figure 2:** Curve of methanol extract for scavenging activity

significantly depending on the extraction solvent and method employed, as solvent polarity and extraction conditions strongly influence the yield and composition of bioactive compounds extracted from by-products (Ghazzawi *et al.*, 2021). When compared specifically to other waste fruit and vegetable peels, *C. callosus* peel demonstrates superior or comparable radical scavenging capacity. For instance, Bello *et al.* (2023) reported that mixed fruit peel waste extracts exhibited $IC_{50}$ values ranging from 76.21 µg/mL to 98.44 µg/mL, while Suleria *et al.* (2020) found that mango peel a well-studied fruit by-product, had an IC50 of 85.10 µg/mL for DPPH radical scavenging. The 80% ethanolic extract of lemon peel exhibited an IC50 of 59.82 µg/mL, while orange peel extract showed an IC50 of 22.2 µg/mL, both indicating strong antioxidant activity (Saleem *et al.*, 2023).

These comparisons highlight the strong radical scavenging capacity of *C. callosus* peel, supporting its potential application as a natural antioxidant in food and nutraceutical products.

### *Phenolic content*

Phenolic compounds have attracted significant attention due to their potential health benefits. They have been reported to exhibit antiviral, anti-allergic, antiplatelet, anti-inflammatory, anticancer, and antioxidant properties. The total phenolic content in fruit and vegetable extracts was quantified using the Folin-Ciocalteu reagent (Chantaro *et al.*, 2008). Total Phenolic Content (TPC) is higher in acetonic extract than methanolic extract in *C. callosus*. The TPC in methanol is 2.37±0.32 mg GAE/g whereas in acetone, TPC is found 16.08±0.35 mg GAE.

The TPC value of our studied sample (16.08 mg GAE/g) is lower than that of mango, grapefruit, and lime peels, which exhibit TPC values of 27.51±0.63, 27.22±1.00, and 23.32±2.07 mg GAE/g, respectively. It is followed by orange and avocado peels (Sultana *et al.*, 2012), which also have higher phenolic content. Similarly, Nurliyana *et al.* (2010) reported high TPC in dragon fruit peel, largely due to the presence of betacyanins (pigments) rather than polyphenols, indicating that factors such as pigments can elevate TPC in certain fruit peels.

In comparison, the phenolic content of avocado (18.79-77.85 GAE/g) and custard apple peel (15.72 GAE/g) closely aligns with our findings. Additionally, higher phenolic values are reported in *Cucurbita maxima* peel, with the native and hybrid varieties exhibiting 74.76±1.7 mg GAE/g and 68.76±0.87 mg GAE/g, respectively, further highlighting the variation in phenolic content across different fruit peels (Susmi *et al.*, 2023).

### *Flavanoids*

Flavonoids, a major class of phenolic compounds, are present in nearly all plants. In this study, flavonoid content was determined using the aluminium chloride colorimetric method. This method is based on the reaction between aluminium chloride and the carbonyl groups in flavonoids, resulting in the formation of a stable complex. Flavonoid content was found in the concentration range of 19.87±2.77 mg/mL in methanol and 21.74±4.23 mg/mL in acetone. The equation of the standard curve: y=0.0189x+0.247, with a regression coefficient ($R^2$) 0.9729.

The flavonoid content in *C. callosus* is found 21.74 mg QE/g, which also falls below the flavonoid levels reported for *C. maxima* peels (Susmi *et al.*, 2023), where the hybrid variety had 36.66±1.29 mg QE/g and the native variety had 34.11±0.13 mg QE/g. Compared to vegetable peels, fruit peels contain a lower amount of flavonoids. Additionally, the peel of fruits has a higher concentration of flavonoids than the pulp.

## CONCLUSION

This investigation highlights the significant nutritional value of vegetable peels, particularly their high carbohydrate and crude fibre content. In particular, *C. callosus* emerged as a rich source of fibre and ash content, making it especially beneficial for patients suffering from constipation and inflammation. The substantial moisture, oil retention, and water-holding capacity (WHC) make them promising candidates for food formulations and functional foods. The ash content signifies an indispensable source of minerals. Mineral analysis indicated high levels of iron, manganese, and copper, further underscoring their nutritional potential. The high fibre content (29.34%) is effective for digestive health, while the substantial total flavonoid (19.87±2.77 mg/L) and phenolic contents support its potential in treating various diseases such as atherosclerosis, diabetes, cancer, irritable bowel syndrome, peptic ulcers, tumors, and osteoporosis. Additionally, the antioxidant activity (82.77±2.94%) contributes to its anti-inflammatory, antibacterial, analgesic, and anti-constipation properties, further

emphasizing its health-promoting effects. These findings highlight the biological activity of Cucumis peels, presenting new opportunities for identifying potent antimicrobial agents from this species in the future. The utilization of vegetable peels, particularly *C. callosus* should be promoted at a commercial scale to reduce agro-waste and contribute to the production of functional foods, nutraceuticals, and pharmaceuticals.

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