



Understanding traditional usage of bottle gourd (*Lagenaria siceraria*) peel as vegetable in comparison to pulp

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ABSTRACT

The present study was carried out during 2021 and 2022 at ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh to evaluate bioactive compounds, antioxidant and browning enzymes activity in peel of bottle gourd (*Lagenaria siceraria* Stand.) fruit “Kashi Ganga” over pulp. Notably, it was observed that bottle gourd peel showed significantly higher bioactives and antioxidant capacity over fruit pulp, which is generally consumed. Two-fold stronger antioxidant capacity was observed in peel (91%) over pulp (43%). Antioxidant enzyme activities were 2.84 (catalase) and 5.67 (ascorbate peroxidase) fold higher in peel over pulp. The chlorophyll content in peel (48 µg/g FW) was 4-fold higher over pulp (12 µg/g FW). No significant difference in browning enzyme activity polyphenol oxidase and peroxidase were recorded. Higher cellulose content in peel (1.15 g/100 g FW) over pulp (0.5 g/100 g FW) was found. This indicated that health benefits can be enhanced by including peel along with pulp in diet.

Keywords: Antioxidant, Bioactive, Browning, *Lagenaria siceraria*, Peel, Pulp

Cucurbitaceae crops are well liked and widely consumed, particularly in Asia with maximum production share (60%) followed by Europe, America and Africa (16.8%, 12.3% and 9.8%, respectively), based on average production share from 1994–2021 (FAO 2023). In India, cucurbitaceous vegetables contribute 5–6% of the total vegetable production. Bottle gourd (*Lagenaria siceraria* Stand.) also known as calabash, white flowered gourd, and *lauki* or *kaddu* is a popular summer season cucurbitaceous vegetable. Bottle gourd fruit and different parts of vine are commonly used in Indian sub-continent as vegetable and for various ethno-pharmacological uses. Besides, fruit peel is consumed traditionally as vegetable in form of fry, curry or chutney in eastern India, particularly in states of West Bengal and Odisha. The pharmacological properties of fruit and other plant parts have been utilized for anti-diabetic, anti-cancer, anti-inflammatory, anti-hepatotoxic, anti-Alzheimer's, immuno-modulatory, cardioprotective, cooling, diuretic and anti-obesity properties (Mohan *et al.* 2012, Attar and Ghane 2019, Juee and Naqishbandi 2020, Abbas *et al.* 2021).

The need to attain sustainable development goals towards zero hunger, combating abrupt rise in life threatening ailments and lowering agricultural waste is assuming more importance currently than ever (Kennedy *et al.* 2022). Healthy diet and food security is outside the reach of a staggering 3 billion people (Konan *et al.* 2018, FAO 2023). Simultaneously, the burden of diet and nutrition related diseases is witnessing an increase world over, especially in developing countries. Healthy, diverse, affordable and sustainable diet is vital towards strengthening efforts for curbing malnutrition and hunger (FAO 2021). Earlier, studies have been conducted to evaluate bioactives in *Lagenaria* (Ahmed *et al.* 2014, Atique *et al.* 2018, Attar and Ghane 2019, Abbas *et al.* 2021). The objective of this research was to verify the hypothesis whether bottle gourd peel are a better dietary source over pulp. Hence, the study focused on total phenolics, flavonoids and chlorophyll content; fibre content; antioxidant capacity and enzymes, ascorbate peroxidase and catalase activities; enzymes causing brown discoloration, polyphenol oxidase and peroxidase activities in the peel and pulp of popularly cultivated bottle gourd fruit of “Kashi Ganga” genotype.

MATERIALS AND METHODS

The present study was carried out during 2021 and 2022 at ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh. Bottle gourd of genotype “Kashi Ganga” was cultivated following all good agricultural practices. Seeds

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were directly sown in March, 2021–22 and 2022–23. Row to row and plant to plant spacing was kept at 2.5 m and 0.75 m, respectively. First anthesis was observed 35–40 days after sowing (DAS). The fruits (n=30) were harvested 12–14 days after anthesis (DAA) at horticultural maturity stage in April–May. The fruits were light green in colour having tender peel and soft seeds, 22–25 cm length and 4–6 cm width. Uniform quality fruit were immediately brought to postharvest laboratory for analysis. Fruit peel and pulp were stored separately at -80°C temperature until further use.

Total phenolics content (TPC) were determined using methodology of Singleton *et al.* (1999). Total flavonoid (TF) content was estimated following Zhishen *et al.* (1999). Antioxidant capacity (AOX) was measured spectrophotometrically (Brand-Williams *et al.* 1995). Chlorophyll content (CL) was measured by using dimethyl sulphoxide (Lichtenthaler and Wellburn 1983). Cellulose content (CC) was estimated by following the method of Updegraff (1969). Catalase activity (CAT) was estimated as per the method of Shi *et al.* (2016). Ascorbate peroxidase enzyme (APX) was estimated following method of Shi *et al.* (2016). Polyphenol oxidase (PPO) and peroxidase (POD) enzyme activities were measured in fruit pulp and peel (Ikediobi *et al.* 1989). All experiments were carried out in triplicate. Data was expressed as mean±SE. Significant difference between means was analyzed by DMRT test. PCA analysis was done using R software. Python programme was used to draw the heat map.

RESULTS AND DISCUSSION

Bottle gourd peels are commonly considered waste and are usually thrown away. This adds to the landfill problem and greenhouse gas emission in addition to reduced or nil consumption of functionally rich bottle gourd peel. TPC in peel and pulp were 73.4 and 22.4 mg GAE/100 g FW, respectively presenting a significant difference and 3.3 fold higher concentration in peel. Our results correspond with Attar and Ghane (2019) who found higher phenolics in ethanolic extract of wild bottle gourd fruit epicarp compared with mesocarp (88.4 mg TAE/g extract and 65.34 mg TAE/g extract, respectively). Previously, Mohan *et al.* (2012) reported 42.7–402.5 mg GAE/g DW phenolics content in dried bottle gourd fruit extract. In another study, higher phenolics content in ethyl acetate extracts were observed in epicarp (243.5 µg/ml GAE) over mesocarp (109.5 µg/ml GAE) of bottle gourd fruit (Ahmed *et al.* 2014). Mahapatra *et al.* (2023) reported phenol content in the range between 23.75–211.99 mg/100 g FW among 91 bottle gourd genotypes. They recommended IC–0336825, IC–0385814, IC–0418246, IC–0284925 and Pusa Santusthi for possible usage as superior bottle gourd parents in improvement programme for developing nutrient dense varieties.

Significantly higher TF content were observed in peel over pulp (12.6 and 4.3 mg QE/100 g FW, respectively). TF to TPC content ratio in peel and pulp were 0.17 and 0.19, respectively. Our results are in agreement with Attar and Ghane (2019) who noted 6.71 and 3.77 mg CE/g in ethanolic

extracts of epicarp and mesocarp of bottle gourd. Earlier, flavonoid content of 0.49–43.4 mg quercetin equivalents/g extract dw of bottle gourd was reported (Mohan *et al.* 2012). In a recent study by Abbas *et al.* (2021), highest flavonoid content (24.22 mg RE/100 mg) was noted in freeze dried bottle gourd extracts assisted by microwave, which are comparable with our values.

The antioxidant capacity is almost double and statistically significantly different in bottle gourd fruit peel over its pulp (90.7 and 42.6%, respectively). The total antioxidant activity varied between 28.66–203.88 mg GAE/100 g FW (Mahapatra *et al.* 2023). Several studies ranging over a decade have reported antioxidant capacity of bottle gourd varying with species, solvent extracts, extracting methods and fractionated fruit parts (Mohan *et al.* 2012, Ahmed *et al.* 2014, Atique *et al.* 2018, Attar and Ghane 2019, Juee and Naqishbandi 2020). The importance of utilizing varied genetic diversity of bottle gourd for improving availability of genotypes with specific suitable characteristics for value addition and processing preferred by consumer and industry was emphasized by Mashilo *et al.* (2022). They suggested that the selection will prove useful to enhance demand in local market and gain accessibility to global markets. It has been noted that bottle gourd fruit is a potent source for lowering oxidative stress levels by removal of damaging free radicals. Our results are comparable with Ahmed *et al.* (2014) who observed 84.5 and 36.7% DPPH free radical scavenging activity in ethyl acetate extract of epicarp and mesocarp fractions, respectively of bottle gourd. The statistically significant difference was observed in chlorophyll content of bottle gourd peel and pulp 48.3 and 12.4 µg/g FW, respectively, showing 3.9 fold higher value. The chlorophyll content in cucumber peel grown using rockwool and coir as soilless substrate was 0.48 and 0.54 mg/g FW, respectively (He *et al.* 2022). The chlorophyll content in peel of sponge gourd cultivar ‘Tian Xiangrou’ was ~325 mg/kg which was found to reduce with progression in storage (Han *et al.* 2014).

Significantly higher cellulose content was found in the peel in comparison to pulp (1.2 and 0.5%, respectively). Cellulose is the major polysaccharide responsible for maintaining cell structure in plants. Konan *et al.* (2018) observed epidermis with cuticle, followed by lignin rich sclerenchymatous cells and then parenchymatous cells in mesocarp tissue in BG fruit rind. They noted variance in the thickness of sclerified epicarp tissue in fruit rind, with calabash showing thicker lignified tissues over egusi type. The likely health benefits of dietary fibre in all edible parts of winged beans were emphasized by Aulia *et al.* (2024). Sponge gourd fruit fibre is reported to have high cellulose content of 55–90% (Oun *et al.* 2021). The cellulose content in sponge gourd cultivar ‘Tian xiangrou’ fruit was reported to be around 0.6% at harvest which rapidly rose to ~1.3% after 2 days of storage at 25°C (Han *et al.* 2014). The cellulose content in cherry tomato cultivar ‘Zhenzhu1’ at mature green stage was found to be ~1.4 mg/g FW on initial day of storage. He *et al.* (2022) noted 260.3 mg/g DW

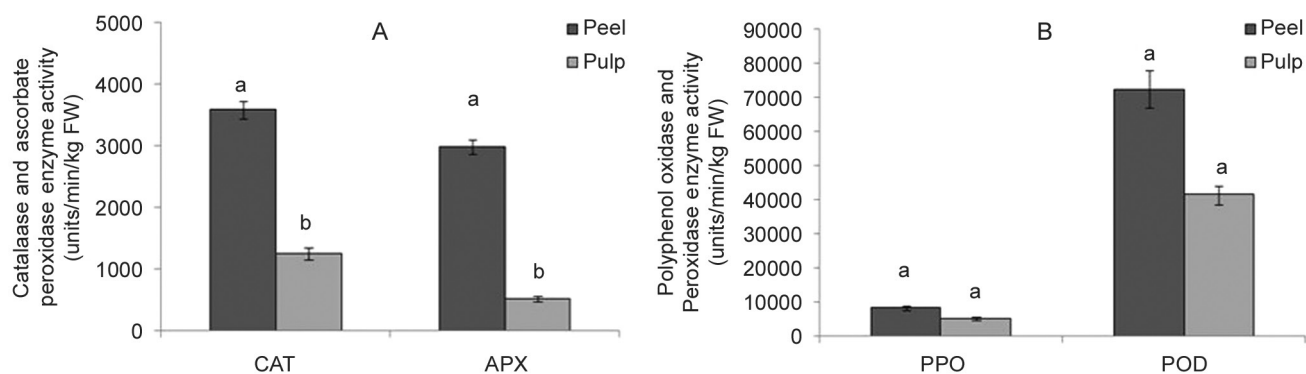


Fig. 1 (A) Catalase and ascorbate peroxidase enzyme activities; (B) Polyphenol oxidase and peroxidase enzyme activities in peel and pulp of bottle gourd cultivar “Kashi Ganga” (n=30). Means with same letters are not significantly different at $p \leq 0.05$, DMRT test.

cellulose content in cucumber fruit grown using coir as a soilless substrate in greenhouse.

Both peel and pulp extracts exhibited significant catalase activity, 3,588 and 1,259.5 units/min/kg FW, respectively (Fig. 1A). The catalase activity in cucumber cultivars “Dahshan”, “Tony-102”, “Beinongjiaxiu” at harvest were observed (~20,000 units/min/kg, ~40,000 units/kg, ~200 units/kg, ~0.015 units/g FW, respectively) (Jia *et al.* 2018, Nasef 2018, Hou *et al.* 2023). The peel and pulp of bottle gourd showed significant difference in the activity of antioxidant enzyme, APX (Fig. 1A). 5.7-fold higher APX activity was observed in peel over pulp (2990.83 and 527.17 units/min/kg FW, respectively). In cucumber, APX activity was reported by Jia *et al.* (2018) (~0.02 units/g FW). APX activity was estimated around 40,000 units/kg and 150 units/kg initially in cucumber cultivar “Tony-102” (Hou *et al.* 2023).

PPO activity showed no significant difference in peel and pulp (Fig. 1B). This enzyme plays a major role in discolouration and browning. Thus, the results are indicative that at harvest the possibilities of development of unwanted brown colour in peel is similar as that of pulp. Previously, 69.2 units/g FW PPO activity has been reported in cucumber fruit (He *et al.* 2022). PPO enzyme activities in different eggplant genotypes ranged between 3–31.02 units/min/g FW (Sharma *et al.* 2022). The peel and pulp extracts exhibited POD enzyme activities of 72,354 and 41,507 units/min/kg FW, respectively (Fig. 1B). Lower POD activity (6 and 9 units/g FW) was observed in sponge gourd and cucumber fruit (Han *et al.* 2014, Jia *et al.* 2018). Different eggplant genotypes

showed significantly higher variation in POD activity in their pulp (Sharma *et al.* 2022). Maximum POD activity (20,500 units/min/kg) was observed in untreated cucumber fruit at the end of storage (Nasef 2018).

Positive correlations were observed between TPC (0.45 and 0.16), TF (0.57 and 0.36), CL (0.15 and 0.43), CAT (0.28 and 0.29) and APX (0.27 and 0.32) with AOX capacity in pulp and peel, respectively (Fig. 2). Similar positive correlations between TPC and AOX capacity have been observed earlier in eggplant, tomato and bottle gourd (Ahmed *et al.* 2014, Sharma *et al.* 2022). AOX capacity showed

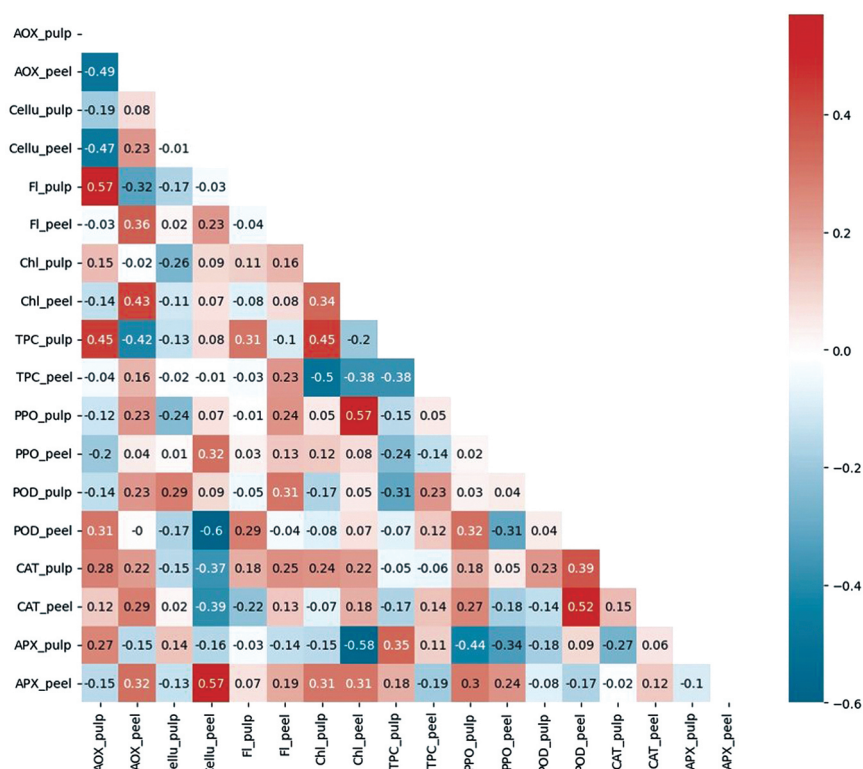


Fig. 2 Heatmap analysis of the correlation between different parameters in bottle gourd fruit peel and pulp.

Note: In a column, correlation level resembles to colour temperature which is indicative of range from negative (blue) to positive (maroon) in individual parameters.

negative to almost nil correlations with PPO (−0.12 and 0.04) and POD (0.04 and 0.0) enzyme activities in pulp and peel, respectively. Unexpectedly, PPO and POD activities in pulp were found to have negative correlations with TPC ($r = -0.15$ and -0.31 , respectively). In the peel, however PPO and POD activities showed positive and negative correlations with TPC ($r = -0.14$ and 0.12), respectively. Strong positive correlations were observed between CAT and POD activities in pulp (0.23) and peel (0.52). It was also observed that CC showed positive correlation with APX activity in both pulp (0.14) and peel (0.57).

Fig. 3 represents the biplot and relative contribution of different parameters in the diversity of quality indicators. The deep orange arrows indicate higher contribution while blue coloured arrows signify lesser variation. Principal component 1 and 2 explained approximately 18.3% and 15.6% of total variation, respectively. The variables nearer to each other are closely associated in the same geometric plane while higher distance is suggestive of negative correlation. TPC, TF, CL and APX were all in the same quadrant with AOX capacity. It was also observed that multiple quality indicators of bottle gourd peel and pulp were clustered separately.

Recently, the significance of proper management of waste generated from fruit and vegetable and its valorization was stressed upon (Devi *et al.* 2023). The extracted dietary fibre and other phytochemicals from peel, seed and pomace may find a plethora of uses in food and nutraceutical industry. Sharma *et al.* (2023) also highlighted the potential of usage of BG peel in different functional products in food industry. Their findings presented that BG peel is a low cost source of dietary fibre and phytochemicals which can be utilized in development of processed foods for additional nutritional security and economic advantage. Banerjee *et al.* (2023) predicted molecular mechanisms of the hyperlipidemic activity of bottle gourd and presented 18 phenolic and phenolic glycosides using tandem liquid chromatography mass spectrometry.

Recommended daily intake of dietary fibre is 25–40 g. The fibre content, expressed as cellulose in bottle gourd peel was 15.0 g/100 g DW which is comparable to the total dietary fibre in cabbage, ~25.0 g/100 g DW (Drozdowska *et al.* 2020). A loss of about 5–10% in dietary fibre on cooking has been reported earlier. High sensorial acceptance by consumers was observed on adding 1% of BG dietary fibre extracted using ultrasound from bottle gourd peel (Sharma *et al.* 2023). Devi *et al.* (2023) extracted dietary fibre from matured bottle gourd seeds as a low cost source, which was used as an ingredient in the preparation of functional cookies. The most optimum cookie composition was found with addition of dietary fibre (3%) and phytochemical (1%) for best quality and acceptance. Abrol *et al.* (2023) utilized dried fresh and pomace of BG fruit for developing ready to cook instant kheer mix rich in energy (400.55 kcal/100 g), total phenols (4.99 mg/100 g), TSS (27°B), strong antioxidant capacity (46%), short cooking time and high sensory acceptance. They underlined the importance of

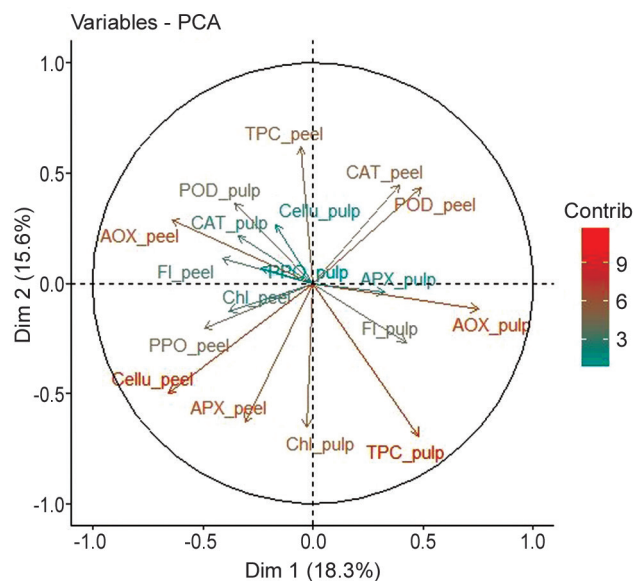


Fig. 3 Score plot of principal component analysis on quality indicators data of bottle gourd fruit peel and pulp.

lowering food waste and utilizing by-products and pomace to meet the food and nutritional demands of burgeoning world population, enhance income while lowering the waste generation and consequent environmental hazards.

In our study, all major bioactive compounds and antioxidant enzymes were significantly higher in peel than pulp. It is opined that consumption of a diet high in antioxidants can help to scavenge free radicals. This indicates that by addition of bottle gourd in diet, particularly with peel, consumers can enrich their diet by increasing intake of health promoting antioxidants. Browning of bottle gourd pulp juice is a significant disadvantage in processing of juice (Bhat and Sharma 2016). Interestingly, it was observed that PPO enzyme was not significantly dissimilar between peel and pulp suggesting that peel is not more susceptible towards discolouration than pulp. This implies that the usage of peel for development of BG based functional food may present enhanced antioxidant capacity, fibre and phenolics content along with lower tendency for browning. Previously, work has been done towards development of fortified bakery product, biscuit, with the addition of de-oiled bottle gourd seed cake (Patel *et al.* 2019). Rational use of bottle gourd peel for development of acceptable processed product can be taken up for its proper utilization and ensuring functional health benefits.

Kennedy *et al.* (2022) also re-affirmed the importance of documentation of indigenous traditional knowledge and food habits of the diverse population for sustainable approach towards achieving dietary diversity and food security. Nutritionally dense, economically viable and sustainable food products with health benefits should be developed. On similar lines, our study presents the possibilities of using BG peel in food and development of other functional foods due to its significantly stronger antioxidant capacity and higher beneficial metabolites content.

In current times, the consumption of vegetables has assumed dimensions greater than only taste and individual choice but rather from perspective of their nutritional content, functional activities and the ensuing health benefits. Our results clearly showed significantly higher bioactives, fibre and antioxidant in the peel of BG “Kashi Ganga” in comparison to pulp. No significant difference in browning enzyme in peel implied similar possible browning with pulp. Bottle gourd peel constitutes about 8–12% of total fruit. Presently, usage of peel in food is restricted to few regions. However, the awareness of higher bioactive and stronger antioxidant capacity and health benefits of peel may enhance its intake. This may also address reduction of agricultural waste generation and give a new direction for development of bottle gourd peel based functional food.

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