



## Comparative Analysis of Nutritional Constituents, Antioxidant and Antimicrobial Activities of Some Common Vegetable Wastes

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### Abstract

Vegetables are intrinsic to a healthy diet. But the peels are discarded as food waste, unknowing of their potential as the source of bioactive compounds. The study aims to find the nutritional constituents, antioxidant and antimicrobial activity of these food wastes. Here we make a comparative investigation among the five underutilized vegetable parts namely, *Solanum tuberosum* (Potato peel), *Cucumis sativus* (Cucumber peel), *Musa acuminata* (Unripe Banana peel), *Brassica oleracea* (Cauliflower stem), *Lagenaria siceraria* (Bottle gourd peel). After the primary screening, including proximate and qualitative analysis, the quantification of primary and secondary metabolites as well as minerals was estimated by different standard methods. The antioxidant potential was evaluated by both DPPH and  $H_2O_2$  radical scavenging assays. Antimicrobial activity was analyzed by Kirby Bauer disc diffusion method against GRAM-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*) strains of bacteria compared with positive and negative controls. From the proximate analysis, the highest moisture and water content were found in the peel sample of *Lagenaria siceraria*. Out of ten qualitative tests, protein, fatty acid, flavonoid, alkaloid and xanthoprotein were detected in all five samples. Among the quantitative estimations, *Lagenariasiceraria* showed the highest amount of polysaccharides ( $85.82 \pm 0.12$  mg DE/g DW), ascorbic acid ( $2.48 \pm 0.14$  mg AAE/g FW), thiamine ( $24.46 \pm 0.13$  mg TE/g DW), polyphenols ( $86.36 \pm 0.10$  mg GAE/g DW), flavonoids ( $49.59 \pm 0.07$  mg QE/g DW), minerals like K, Ca and Mg and 72.35±0.40% inhibition by DPPH. Simultaneously a significant amount of protein ( $63.59 \pm 0.13$  mg BSAE/g FW), the amino acid ( $7.84 \pm 0.02$  mg AAE/g DW), minerals like Na, Zn and B and 88.76±0.10% inhibition by  $H_2O_2$  were found in *Cucumis sativus*. At a higher concentration, all samples were exhibited significant antimicrobial activity which laid out a strong correlation with previously screened phytonutrients and antioxidants. The overall findings suggested that these underutilized vegetable parts can be utilized in the processing of potential functional foods as well as pharmaceuticals rather than thrown out as agro-waste.



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## Introduction

Vegetables are considered to be a significant source of nutrients, minerals, dietary fibre, antioxidants and other beneficial phytochemicals.<sup>1</sup> People are health conscious nowadays and hence, different vegetables find a place in daily diet that in-turn produce a large amount of biodegradable agro wastes.<sup>2</sup> This waste is mainly composed of skin, stem, peel, rind, seed, shell and pomace.<sup>3</sup> In recent time, many scientific investigations reported the potential of these unused parts as the source of important phytochemicals like polyphenols, flavonoids, alkaloids, sugars, vitamins, minerals and many more.<sup>4</sup> Besides, they have many pharmacological effects in the health care system as antimicrobial, antifungal, antibacterial, anti-mutagenic, cardioprotective and neuroprotective.<sup>5</sup>

Potato is an edible starchy tuber of plant *Solanum tuberosum* (ST) Synonym *Battata tuberosa* (L.) Hill, belonging to the nightshade family, Solanaceae. As potato peels were reported to have higher polyphenol content (such as gallic acid, caffeic acid) than flesh, it can be suggested to use as natural antioxidant.<sup>6</sup> Cucumber is a widely used vegetable grown in creeping vine plant *Cucumis sativus* (CS) Synonym *Cucumis rumphii* Hassk., which is in the gourd family of Cucurbitaceae. The researchers identified that the peel of cucumber was comprised of flavonoids, triterpenoids, antioxidants, vitamin C, K and other trace elements along with minerals.<sup>7</sup> Raw banana is a staple food produced by the plant *Musa acuminata* (MA) Synonym *Musa cavendishii* Lamb., belongs to the Musaceae family. Due to high antioxidant status, banana peel is proven to be helpful in reducing plasma oxidative stress.<sup>8</sup> Cauliflower belongs to cruciferous vegetable in the species of *Brassica oleracea* (BO) Synonym *Brassica arborea* Steud., belonging to the cabbage family, Brassicaceae. As the stem and leaves of cauliflower are delineated to have iron,  $\beta$ - carotene, digestive crude protein along with starch and amino acid, it can be utilized as a dietary fibre supplement.<sup>9</sup> Bottle gourd or Calabash is a nutritious vegetable grown in running vine plant *Lagenaria siceraria* (LS) Synonym *Cucumis Lagenaria* (L.) Dumort., which belongs to the gourd family, Cucurbitaceae. The peel of bottle gourd was identified as a great source of soluble dietary fibres, amino acids,  $\beta$ - carotene, and ascorbic acid, which was beneficial to lower the serum cholesterol.<sup>10</sup>

Therefore, the present study was focused on these five selected underutilized parts for analyzing the proximate parameters and estimating the nutritional composition and evaluating the antioxidant and antimicrobial activity.

## Materials and Methods

### Plant Samples Collection

The current study was executed in the biotechnology laboratory of Techno India University, West Bengal on January-June, 2019. The plant parts were collected from Salt Lake, Kolkata. Kolkata is positioned at 22.5726° N, 88.3639° E and is situated 9.15 m from the sea level with alluvial soil type. Kolkata has a wet and dry climate condition with an annual average temperature of 26.8°C, relative humidity 70.8% and rainfall is 1735 mm. The samples were thoroughly washed with water, and the peels and stem were separated carefully. Then the peels were cleaned and sundried for 12-15 days. These studied samples were then grounded to fine dust and stored in polythene bottles at 4°C till the time of experiments.

### Collection of Microbial Strains

Pure cultures were collected from Department of Microbiology, Calcutta University, West Bengal, India.

### Chemical and Reagents

Analytical graded reagents and chemicals were used in all experiments. Folin-ciocalteu, Aluminum chloride, Ascorbic acid, Starch, Ninhydrin, Chloroform, Methanol and Acetic acid were procured from Merck Life Science Private Limited, Mumbai. Bovine Serum Albumin, L-Lysine, Agar and Broth were purchased from Hi Media, Mumbai. Gallic acid, Hydrogen peroxide and Sodium hydroxide were supplied by SDFCL, Mumbai. Quercetin, DPPH, Acetone and Caffeine were obtained from SRL, Mumbai. Dextrose and Ammonium hydroxide were purchased from Finar Limited, Ahmedabad. For quantitative study in the current research work, a spectrophotometer (Systronics 117) was used to measure the particular absorbance.

### Preparation of Extracts

#### Preparation of Crude Extracts

The crude extracts of samples were obtained by grinding finely cut 1 g of fresh sample with 25 mL

solvent (double distilled water). All the extracts were kept over a shaker for vigorous shaking for 24 hours for effective extraction of the bioactive compounds. Next, the extracts were clarified by centrifugation at 10,000 rpm for 10 min. The supernatant was stored and diluted as needed in the different assays.

#### Preparation of Aqueous Extracts of dry samples

1 g of dry samples were mixed with 25 mL of solvent (double distilled water) and kept on the rocker for 24 hours for extraction. Then the extracts were clarified by centrifugation at 10,000 rpm for 10 min. The supernatant was diluted as required for further studies.

#### Proximate Analysis

##### Estimation of Total Moisture Content

Using standard method,<sup>11</sup> the total moisture content of the samples were determined and calculated by the following formula,

$$MC_{wb} = [(W_i - W_f) / W_i] \times 100$$

Where  $MC_{wb}$  is expressed as total moisture content on a wet basis,  $W_i$  is initial weight, and  $W_f$  is the final weight.

##### Estimation of Relative Water Content

With the help of standard protocol,<sup>12</sup> relative water content (RWC) was estimated and calculated by the following formula,

$$RWC = [(F_w - D_w) / (T_w - D_w)] \times 100$$

Where  $F_w$  = Fresh Weight,  $T_w$  = Turbid Weight,  $D_w$  = Dry Weight

##### Estimation of Water-Soluble and Insoluble Portion

Firstly, the weight of a filter paper was taken. Then 100mg of fresh samples were homogenized with double distilled water and filtered through that filter paper. After filtration, the weight of filter paper with the insoluble part was measured.<sup>13</sup> Water-soluble and insoluble part of the samples were determined using the following formula,

$$\begin{aligned} \text{Insoluble Portion } (W_i) &= W_2 - W_1 \\ \text{Soluble Portion } (W_s) &= 100 - W_i \end{aligned}$$

Where  $W_1$  = weight of filter paper,  $W_2$  = weight of filter paper with insoluble part

##### Estimation of pH

To determine the pH of the aqueous extracts, the standard method was used.<sup>14</sup> Sample extract was prepared by homogenizing 5 g fresh plant sample with 10 mL double distilled water, and the pH of the filtrate was evaluated using a calibrated pH meter.

##### Estimation of Conductivity

5 g of fresh samples were extracted with 10 mL of double distilled water and filtered. Then the conductivity of these filtrates was determined after calibrating conductivity meter with standard solutions.

##### Qualitative Screening

To detect the presence of carbohydrate by Molisch's test,<sup>15</sup> protein by Biuret test,<sup>16</sup> fatty acids or fixed oils,<sup>17</sup> amino acid by Ninhydrin test,<sup>18</sup> reducing sugars,<sup>19</sup> polyphenols by  $FeCl_3$  and  $KMnO_4$  method,<sup>20</sup> flavonoids by alkaline reagent test,<sup>21</sup> alkaloids by Wagner test,<sup>22</sup> xanthoprotein<sup>23</sup> and cardiac glycoside by Keller-Kelliani's test,<sup>24</sup> standard protocols were used.

##### Nutritional Quantification

##### Estimation of Polysaccharides

In accordance with standard protocol,<sup>25</sup> total polysaccharide was quantified by spectrophotometric assay at 490 nm using dextrose as a standard reagent. The results were expressed as mg Dextrose Equivalent/g of Dry Weight of sample (mg DE/g DW).

##### Estimation of Protein

Total protein content was estimated by the Lowry method, using Bovine Serum Albumin (BSA) as a standard reagent.<sup>26</sup> The absorbance was measured at 660 nm. The contents were indicated as mgBSA Equivalent /g of Fresh Weight of the sample (mg BSAE/gFW).

##### Estimation of Lipid

Total lipid content was quantified by the solvent extraction method.<sup>27</sup> Samples were transferred to a separating funnel and washed with chloroform and methanol. The mixture was shaken vigorously, and lipid was extracted with chloroform. Considering the

given formula, the results were expressed as % lipid present in dry samples,

Total Lipid Contents = (lipid weight in aliquot × chloroform layer volume) / aliquot volume

#### Estimation of Amino Acid

With the help of standard protocol, the amino acids of the samples were quantified spectrophotometrically at 570 nm using lysine as a standard reagent.<sup>28</sup> Amino acid contents were expressed as mg Lysine Equivalents/g of Dry Weight of the sample (mg LE/ g DW).

#### Estimation of Ascorbic Acid

Quantification of ascorbic acid of the samples was evaluated by iodine and iodate solution in a redox titration method utilizing ascorbic acid as a standard reagent.<sup>29</sup> The equation:  $V_1S_1 = V_2S_2$  was used for calculation. The results were indicated as mg Ascorbic Acid Equivalent/g of Fresh Weight of the sample (mg AAE/ gFW).

#### Estimation of Thiamine

Thiamine determination was executed according to the methodology by Dutta *et al.*<sup>30</sup> The absorbance was measured at 360 nm, using a standard reagent. Results were expressed as mg Thiamine equivalent per gm of Dry Weight (mg TE/ g DW).

#### Determination of Mineral Contents

As the quality of many foods and medicines depends upon the content and type of minerals, it is essential to investigate the mineral composition. The standardized dry ashing method<sup>31</sup> was used to estimate the macro elements like Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) and microelements like Zinc (Zn) and Boron (B). The 5 g of samples were kept into a crucible for 1 hour in a muffle furnace at 500°C for preparation of ash. Next, the ash was digested with HCl and HNO<sub>3</sub> mixture (1:3). The volumes of the digested samples were completed to 50 mL with double distilled water, and mineral contents were determined by atomic absorption spectrophotometer (AAS). The results were expressed in terms of mg/g of Dry Weight.

#### Phytochemical Quantification

##### Estimation of Polyphenols

The polyphenol content of the samples was evaluated by the Folin-Ciocalteu method, using

Gallic acid as standard<sup>32</sup> and are expressed as mg Gallic Acid Equivalent per g of Dry Weight (mg GAE/ g DW).

##### Estimation of Flavonoids

According to the Aluminum Chloride colorimetric assay,<sup>33</sup> total flavonoids were quantified, using Quercetin as a standard reagent and contents are expressed as mg Quercetin Equivalent per g of Dry Weight (mg QE/ g DW).

##### Estimation of Alkaloids

Total alkaloid was estimated by the standard protocol, mentioned in John *et al.*,<sup>34</sup> Samples were extracted with chloroform, and the absorbance was read at 470 nm, using caffeine as standard. Total alkaloid content was expressed in mg Caffeine equivalent/ g of Dry Weight (mg CE/ g DW).

##### Estimation of Cardiac Glycoside

Cardiac glycosides of the samples were quantitatively determined, according to Solich *et al.*<sup>35</sup> The absorbance was read at 495nm, using Digoxin as standard. The results were expressed as mg Digoxin Equivalent/g Dry Weight (mg DE/g DW).

##### Determination of Antioxidant Activity

##### Scavenging Activities on DPPH Free Radicals

The free radical scavenging property of the extracts was determined using the DPPH solution in methanol by the standard method.<sup>36</sup> The absorbance (OD) value was measured at 517 nm using ascorbic acid as standard. The scavenging activity was expressed as Ascorbic Acid Equivalent (AAE), in terms of percentage of inhibition from the following formula,

$$\% \text{ Inhibition} = [(A_0 - A_1)/A_0] \times 100$$

Where A<sub>0</sub> and A<sub>1</sub> represent the absorbance of the control, and of extract or standard, respectively.

##### Scavenging Activities on H<sub>2</sub>O<sub>2</sub> Free Radicals

The scavenging activities of the extracts on H<sub>2</sub>O<sub>2</sub> radical were evaluated with the help of the reference method using Gallic acid as standard by taking absorbance at 230 nm.<sup>37</sup> The antioxidant activity was expressed as Gallic Acid Equivalent (GAE), as percentage inhibition from the following formula,

$$\% \text{ Inhibition} = [(A_0 - A_1)/A_0] \times 100$$

Where  $A_0$  and  $A_1$  are the OD of the control, and of the extract or standard respectively.

#### Determination of Antimicrobial Activity

Kirby-Bauer's Disc diffusion susceptibility method<sup>38</sup> was used to determine the antibacterial activity of the vegetable-waste extracts against Gram-positive bacterial strain, *Staphylococcus aureus*, (denoted by J on microbial plates) and Gram-negative bacterial strain, *Escherichia coli* (denoted by H on microbial plates).

**Positive Control:** Streptomycin

**Negative Control:** Distilled Water

#### Statistical Analysis

All the experimental data (except mineral analysis, as it was done in a singlet) were expressed as average  $\pm$  standard deviation (SD) after performing the measurements in triplicates. Statistical analysis was determined by one way ANOVA followed by Bonferroni's Post Hoc test using MS Excel Software. In the graphical representation, the statistically significant values ( $p < 0.05$ ) were denoted by different letters on the bars.

## Results

### Proximate Analysis

Results obtained from the proximate analysis were presented in Table 1. The highest moisture content (92.94%), as well as water content (96.28%), were observed in LS. The lowest amounts of moisture (85.67%), as well as water content (78%), were observed in BO. By seeing the high moisture content of the five samples, it can be concluded that a very high level of water  $\geq 75\%$  making this by-product highly perishable and requiring immediate use or stabilization to prevent fermentation and mould growth. But the observed percentage of the soluble portion was the highest (95.9%) in BO and the lowest (71.4%) in ST. The pH of these five samples were found to be within the acidic range (pH= 5.16 to 6.28). Acidity of the BO (pH=5.16) and CS (pH=6.28) were found to be highest and lowest respectively. The conductivity of these five samples was ranged from 0.80 to 2.00 mS/cm. The highest conductivity was showed in ST and the lowest in CS.

**Table 1: Result of Proximate Analysis**

Sample	Total Moisture Content (%)	Relative Water Content (%)	% of Insoluble portion	% of Soluble portion	pH	Conductivity (mS/cm)
ST	89.19	91.84	28.6	71.4	5.22	2.00
CS	90.41	83.36	12.3	87.7	6.28	0.80
MA	89.54	93.57	12.8	87.2	6.19	1.60
BO	85.67	78.00	4.1	95.9	5.16	1.20
LS	92.94	96.28	7.1	92.9	5.30	1.30

**Table 2: Result of Qualitative Screening**

Test Name	ST	CS	MA	BO	LS
Carbohydrate	+	-	+	-	+
Protein	+	+	+	+	+
Fatty Acid	+	+	+	+	+
Amino Acid	-	-	+	-	+
Reducing Sugar	-	+	-	-	+
Polyphenol	-	-	+	-	+
Flavonoid	+	+	+	+	+
Alkaloids	+	+	+	+	+
Xanthoprotein	+	+	+	+	+
Cardiac Glycoside	+	-	+	-	+

Where, "+" PRESENT & "-" ABSENT

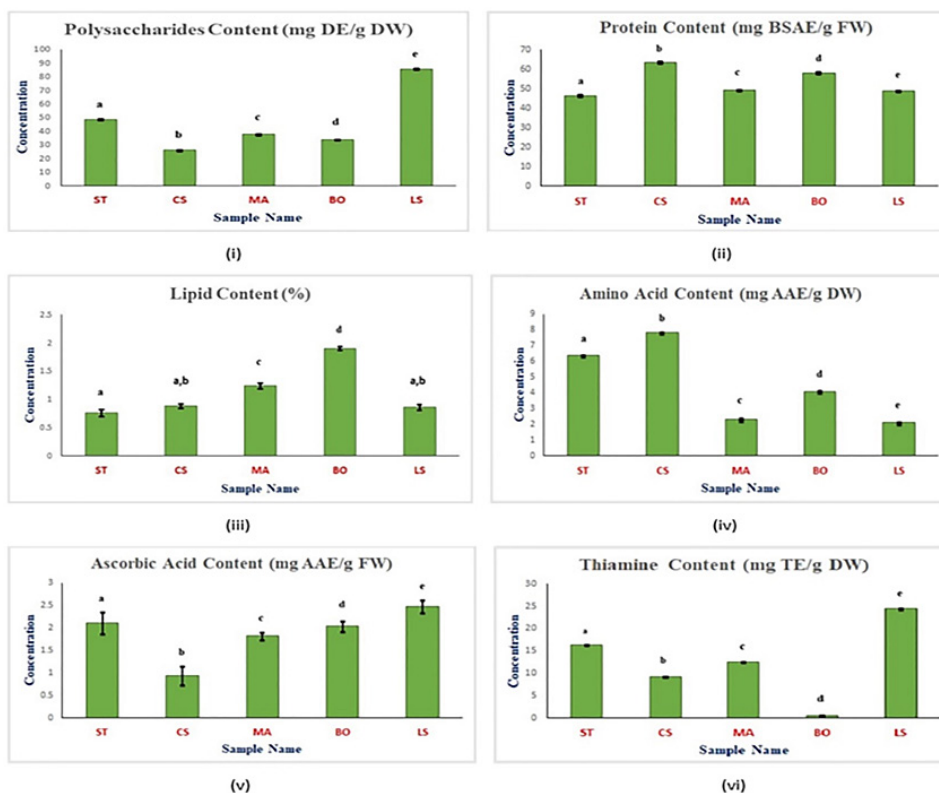
### Qualitative Analysis

The results of the ten qualitative tests were represented in Table 2. It was observed that protein, fatty acid, flavonoid, alkaloid and xanthoprotein were identified in all five samples. All the ten tests were shown positive in LS. Among the 10 tests, 9 tests were also found to be positive in MA. The results indicated that the experimental samples could be considered highly nutritionally as well as pharmaceutically potent phytochemical resources.

### Nutritional Analysis

#### Polysaccharides

From Figure 1(i), it was observed that highest and lowest polysaccharide content was exhibited by LS (85.82 $\pm$ 0.12 mg DE/g DW) and CS (26.16 $\pm$ 0.10 mg DE/g DW) respectively.



**Fig. 1: Nutritional Analysis(i) Polysaccharides Content (mg DE/g DW), (ii) Protein Content (mg BSAE/g FW), (iii) Lipid Content (%), (iv) Amino Acid Content (mg AAE/g DW), (v) Ascorbic Acid Content (mg AAE/g FW), (vi) Thiamine Content (mg TE/g DW)**

\* Statistically significant values ( $p < 0.05$ ) were denoted by different lower case letters on the bars.

### Protein

The amounts of protein in the five samples were presented in Figure 1(ii). From the results, it can be interpreted that all the samples contain a significant amount of protein. The highest and the lowest amount of protein were found to be present in the peels of CS ( $63.59 \pm 0.13$  mg BSAE/g FW), and the peels of ST ( $46.50 \pm 0.20$  mg BSAE/g FW) respectively.

### Lipid

The amounts of lipid in the five samples were presented in Figure 1(iii). Significant amount of total lipids was detected in the stem of BO ( $1.90 \pm 0.03\%$ ). On the other side, the lowest amount was observed in the peels of ST ( $0.76 \pm 0.06\%$ ).

### Amino Acid

From Figure 1(iv), it was observed that the amino acid content of CS ( $7.84 \pm 0.02$  mg AAE/g DW) was significantly higher than the other samples. But the

peel of LS showed the minimum amount ( $2.11 \pm 0.03$  mg AAE/g DW).

### Ascorbic Acid

The results of this assay were depicted in Figure 1(v). The amount ranged from  $0.94 \pm 0.21$  mg AAE/g FW (peel of CS) to  $2.48 \pm 0.14$  mg AAE/g FW (peel of LS).

### Thiamine

The thiamine content of these five samples was represented in Figure 1(vi). It was clearly observed that the amount in the peels of LS ( $24.46 \pm 0.13$  mg TE/g DW) was significantly higher than other samples. An insignificant amount ( $0.53 \pm 0.11$  mg TE/g DW) was detected in the stem of BO.

### Mineral Analysis

Eight important macro as well as micro elements were quantified in five test samples using AAS, and the amounts were presented in Table 3.

The macroelements like Ca, Mg, K and Na as well as microelements like Zn and B were found to be present in the stem of BO in highest amount with

respect to other four samples. However, the peels of ST contain highest amount of Fe and Cu with respect to others.

**Table 3: Result of Mineral Analysis (mg/g Dry Weight)**

Sample	Ca	Mg	K	Na	Fe	Cu	Zn	B
ST	1.41	1.44	37.79	0.83	0.43	0.04	0.044	1.45
CS	7.04	2.60	37.59	2.03	0.08	0.01	0.047	3.35
MA	4.05	1.29	45.21	0.63	0.06	0.009	0.044	0.89
BO	17.51	2.73	100.52	2.30	0.07	0.006	0.044	8.75
LS	3.11	1.40	28.85	0.71	0.12	0.01	0.026	2.97

### Phytochemical Analysis

#### Polyphenols

The total polyphenol content of these five samples was shown in Figure 2(i). It was clearly observed that the amount of polyphenol was ranged from  $5.80 \pm 0.09$  mg GAE/g DW (stem of BO) to  $86.36 \pm 0.10$  mg GAE/g DW (peel of LS) in the samples under study.

#### Flavonoids

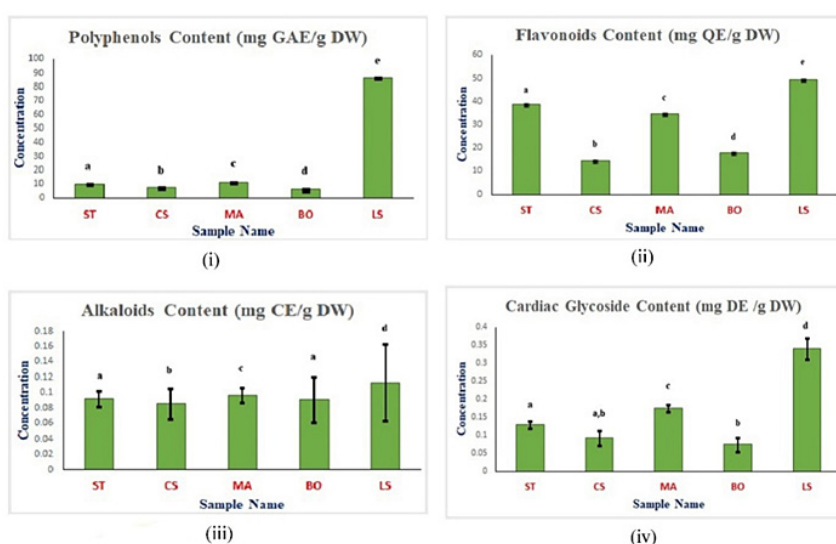
From the Figure 2(ii), the maximum flavonoid amount ( $49.59 \pm 0.07$  mg QE/g DW) was observed in the peel of LS, and the peel of CS showed the minimum amount ( $14.36 \pm 0.08$  mg QE/g DW).

#### Alkaloids

Total alkaloids content of these five samples were estimated in Figure 2 (iii). The highest amount was shown in the peels of LS ( $0.113 \pm 0.05$  mg CE/g DW). On the other side, the peel of CS exhibited the minimum amount ( $0.086 \pm 0.02$  mg CE/g DW).

#### Cardiac Glycosides

The cardiac glycoside content of these five samples was shown in Figure 2(iv). Among the samples, the higher amount ( $0.34 \pm 0.01$  mg DE/g DW) was observed in the peel of LS. But a very negligible amount ( $0.07 \pm 0.02$  mg DE/g DW) was presented in the stem of BO.



**Fig. 2: Phytochemical Analysis (i) Polyphenols Content (mg GAE/g DW), (ii) Flavonoids Content (mg QE/g DW), (iii) Alkaloids Content (mg CE/g DW), (iv) Cardiac Glycoside Content (mg DE/g DW)**

\* Statistically significant values ( $p < 0.05$ ) were denoted by different lower case letters on the bars.

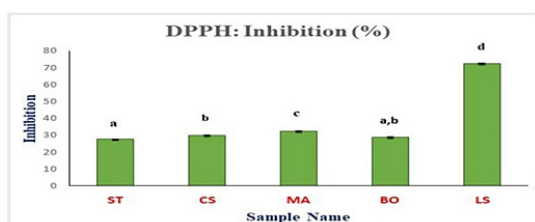
The present study highlighted the dependence of the functional activity of the bioactive compounds to each other since they are highly correlated. The

calculated correlations coefficient between the various bioactive compounds were represented in Table 4.

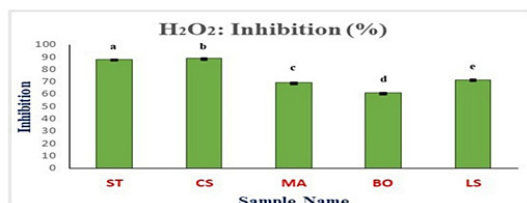
**Table 4: Correlation between Bioactive Components**

Correlation Parameters	Correlation Equation	The correlation coefficient (r)
Polyphenol & Flavonoid	$y = 0.3121x + 23.568$	0.5457
Polyphenol & Alkaloid	$y = 0.0003x + 0.0891$	0.8862
Polyphenol & Cardiac Glycoside	$y = 0.0029x + 0.0928$	0.9062
Flavonoid & Alkaloid	$y = 0.0006x + 0.0772$	0.7241
Flavonoid & Cardiac Glycoside	$y = 0.0062x - 0.0309$	0.7412
Alkaloid & Cardiac Glycoside	$y = 10.007x - 0.7957$	0.9463

\*Coefficient (r) values can range from +1 (positive relationship) to -1 (negative relationship)



(i)



(ii)

**Fig. 3: Total Antioxidant Activity (i) DPPH Scavenging Results (%), (ii) H<sub>2</sub>O<sub>2</sub> Scavenging Results%**

\*Statistically significant values ( $p < 0.05$ ) were denoted by different lower case letters on the bars.

### Antioxidant Activity

#### DPPH Radical Scavenging Assay

From Figure 3(i), the percentage inhibition by quenching the DPPH radical ranged from  $27.78 \pm 0.21\%$  in peel sample of ST to  $72.35 \pm 0.40\%$  in peel sample of LS.

Simultaneously, the total antioxidant content of these five samples was also calculated. The peel of LS showed a significantly higher amount of antioxidant ( $37.57 \pm 0.22$  mg AAE/g DW). The comparatively lower amount of antioxidant activity was detected

in the stem of BO ( $13.91 \pm 0.13$  mg AAE/g DW) as well as in the peel of ST ( $13.34 \pm 0.11$  mg AAE/g DW).

#### H<sub>2</sub>O<sub>2</sub> Radical Scavenging Assay

From Figure 3(ii), the percentage inhibition by H<sub>2</sub>O<sub>2</sub> assay ranged from  $60.87 \pm 0.22\%$  in the stem of BO to  $88.76 \pm 0.10\%$  in peel sample of CS.

During the calculation of total antioxidant content, it was observed that the significantly higher amount of antioxidants were presented in the peel of CS ( $46.72 \pm 0.05$  mg GAE/g DW) and the peel of ST ( $46.20 \pm 0.09$  mg GAE/g DW). The comparatively lower amount of antioxidant was exhibited in the stem of BO ( $30.80 \pm 0.12$  mg GAE/g DW).

**Table 5: Correlation coefficient (r) between the Bioactive Components and the Antioxidant Activities (DPPH and H<sub>2</sub>O<sub>2</sub>)**

Correlation Coefficient (r)	DPPH	H <sub>2</sub> O <sub>2</sub>
Polyphenol	0.9931	0.0307
Flavonoid	0.4952	0.0018
Alkaloid	0.8842	0.1296
Cardiac Glycoside	0.9015	0.0258
Ascorbic Acid	0.3159	0.2462

\*Coefficient (r) values can range from +1 (positive relationship) to -1 (negative relationship)

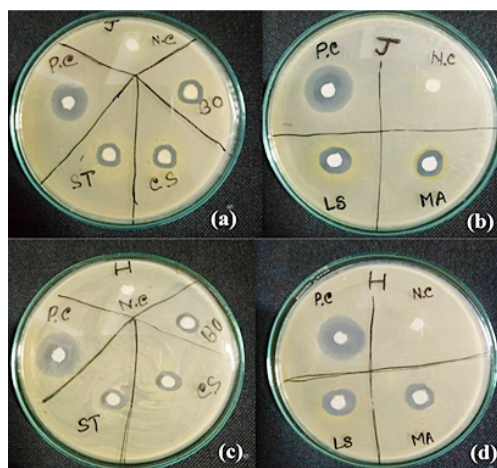
To establish a correlation between the phytonutrient and antioxidant activity, we have calculated a positive statistical relationship between bioactive compounds and antioxidant inhibitions, represented in Table 5.



### Antimicrobial Activity

These five underutilized parts of the vegetables exhibited significant zone of inhibitions (mentioned in Figure 4) at a higher concentration against the

tested *S.aureus* as well as *E.coli*, indicating these plant extracts have notable antibacterial properties compared with a standard antibiotic (streptomycin) and solvent (distilled water).



**Fig. 4: Antimicrobial Activity(a) and (b) Zone of Inhibition against *S. aureus*, (c) and (d) Zone of Inhibition against *E. coli***

**Table 6: Antimicrobial Activity: Zone of Inhibitions (mm)**

Organism Name	<i>Staphylococcus aureus</i> (J)	<i>Escherichia coli</i> (H)
Sample Name	Zone Diameter (mm)	Zone Diameter (mm)
Positive Control (PC.)	18.3	20.3
Negative Control (NC.)	Nil	Nil
ST	6.3	6.5
CS	6.6	6.3
MA	6.8	7.7
BO	6.5	5.6
LS	8.3	8.2

The results (Table 6), highlighted the zone diameter, produced by the five samples against the two strains.

### Discussions

In this comparative study, the chosen five vegetables are widely used in India as well as in other countries. So the amounts of unused parts of these vegetables are huge, and hence discarded as organic waste from both households and food-processing industries. This study was done to decipher the possibility to reuse these agro-wastes by evaluating their bioactive compounds as well as

antioxidant and antimicrobial activities. The results of proximate analysis, moisture content and relative water content of five samples were comparable to literature values of Gupta and Joshi.<sup>39, 40</sup> An investigation conducted by Khattak and Rahman, showed that the appreciable amount of polyphenol, flavonoids as well as antioxidant activity by DPPH and  $H_2O_2$  were detected in the peel of S.T.<sup>41</sup> The results obtained from the phytochemical analysis as well as antibacterial activity of the CS peel in the present assay was supported by a previous report by Foong *et al.*<sup>42</sup>

Agricultural wastes can be used in the production of single-cell protein as they are good sources of metabolites to support microbial growth.<sup>43</sup> The peel of LS exhibited a significant amount of polysaccharide among all the five samples. Results were in line with the findings of Akter *et al.*<sup>44</sup> and showed the presence of high concentration of nutritional and phytochemical compounds in the powdered peel of LS. It was also found to be a rich reserve of minerals like calcium, potassium, magnesium, sodium and boron which was in congruence with the study of Ghosh & Chatterjee<sup>40</sup> and Rahman.<sup>45</sup>

Protein is crucial dietary components to supply nitrogen, potassium, sulfur and other substances for growth. As the peel of CS showed a high amount of protein and amino acids, it can be considered as a good source of nitrogen.<sup>46, 47</sup> According to Rodzali *et al.*<sup>48</sup> the unripe banana peel possessed higher antioxidant and antimicrobial activities due to the presence of phenols, flavonoids and minerals like calcium and potassium which were aided with this current research data of MA. Surprisingly, the stem of BO showed a significant amount of lipid compared with other samples. It had also contained the highest amount of potassium and calcium which can correlate with Baloch *et al.*<sup>49</sup> The study of Khan *et al.*<sup>50</sup> and Ghosh *et al.*<sup>51</sup> reported a positive correlation between the total antioxidant capacity with the plasma polyphenolic level, which was justified by the calculated records.

These bioactive compounds, as well as antioxidants, are used to enhance the nutritional and therapeutic potentiality of processed products as recorded in Siriwardhana *et al.*<sup>52</sup> According to Hintz *et al.*, in

the food industry, plant antimicrobial compounds have potential use as bio-preservatives and bio-insecticides, with potential use against various foodborne pathogens.<sup>53</sup> Therefore, these selected vegetable waste may be converted to wealth if used in proper way in food and pharmaceutical industries.

### Conclusions

This study on underutilized parts of the vegetables highlighted that, they are not at all waste but may be converted to a wealth if they are used properly. Developing as well as under developed and economically weak countries can implement the use of the agro-waste for mankind. In the present study, the peels of LS has acquired attention as a potential unused wealth and hence, it can be used for bioprospecting. More research in the domain of waste to wealth conversion related to present domain is still needed to fight against malnutrition and food scarcities around the world.

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### Conflict of Interest

The authors declare no conflict of interest.

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