

Sustainable Valorization of Domestic Onion Waste: Comprehensive Characterization for Nutrient Recovery and Waste Volume Reduction

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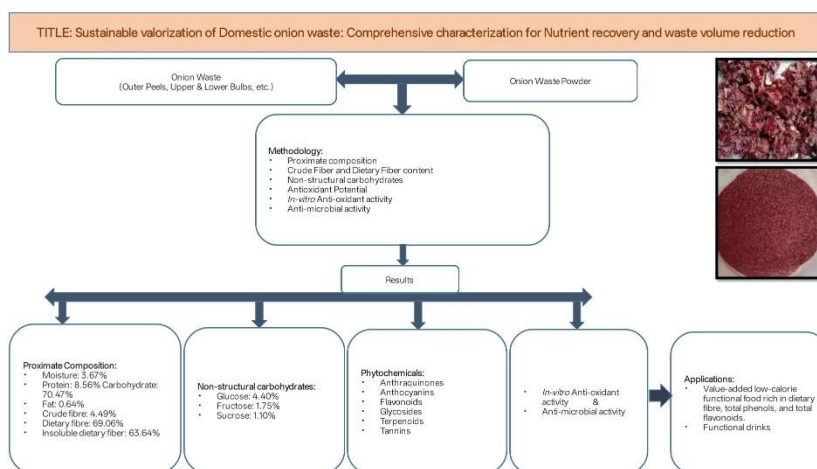
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GRAPHICAL ABSTRACT



ABSTRACT

Allium cepa L., commonly known as onion, is one of the most widely cultivated vegetables worldwide, valued for its characteristic flavor, aroma, and pungency. It is extremely concerning that around one million tonne of onion waste is produced throughout distribution, processing, and consumption. Characterization of onion waste is essential for its valorization. The study's goal was to identify the nutritional and nonstructural carbohydrate content, antioxidant, antimicrobial activity and phytochemical elements present in the waste. The onion waste was cleaned and dried at 60°C in an air-circulating tray dryer, and ground into a fine powder. It was found to contain moisture (3.67%), protein (8.56%), carbohydrate (70.47%), fat (0.64%), crude fibre (4.49%), dietary fibre (69.06%), and insoluble dietary fibre (63.64%) and provides 321.88 kcal of energy per 100 g. The non-structural carbohydrates in the onion waste were glucose (4.40%), fructose (1.75%) and sucrose (1.10%). The ethanolic onion waste extract was found to contain phytochemicals anthraquinones, anthocyanins, phenols, flavonoids, glycosides, terpenoids, flavonoids, and tannins. Using DPPH and hydroxyl radical scavenging activity, the antioxidant activity of ethanolic onion waste extract was revealed to be strong at various concentrations. These values ranged from 42.34% to 70.50%, 65.8 to 60.5%, respectively. The ethanol extract of onion waste was found to have the strongest anti-microbial effects on *Escherichia coli* and *Staphylococcus aureus*. Onion waste characterization provides valuable insights into its potential as a source of bioactive compounds facilitating its utilization in nutraceuticals and functional foods. This approach promotes sustainable waste management and resource utilization while unlocking the hidden potential of onion waste.

HIGHLIGHTS

The study explores characterization as well as functional potential of onion waste. The onion waste powder was found to be rich in dietary fibre. It is a good source of phytochemicals. Onion waste also possesses strong antioxidant and antimicrobial activities.

1. INTRODUCTION

Onion (*Allium cepa* L.) is considered as Queen of Kitchen, a commonly used crop that incorporates in

the daily diet for most of the regions and is economically important all over the world. It is also consumed as basic ingredient for preparation of salad,

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stews, and soups and as a cooked vegetable for major population (Gupta et al., 2025). Industrial processing of onion includes production of onion flakes, powder, oil and pickle. The global production of onion is around 105 million tonnes (MT) with China, India, Egypt, United States of America and Iran as the five major contributors. India is the second largest onion producing country in the world after China. The production of onion in the year 2025 is estimated around 31.7 million tonnes which is around 25% of the global onion production (World Population Review, 2025). Onions are mainly grown in temperate regions and are categorized based on colour and pungency. The round shaped onions are widely grown and are red, white and yellow coloured (Britannica, 2025).

Apart from the taste, onion also provides health benefits to its consumer. Traditionally, onion has been used as medicine in Asia due to its various health benefits. It acts as stimulant and has therapeutic characteristics since centuries for the treatment of cold, cough, bronchitis, and influenza. It also safeguards the human body from cancer, fungal and bacterial infection, reduces blood pressure, decreases thickening of blood, lowers heart stroke and overall reduces the cardiovascular diseases (Singh and Khar, 2022; Jain et al., 2019).

There is huge demand of onions worldwide. As onions are so commonly consumed, the volume of domestic onion waste is much greater than that of industrial onion waste and its environmental impact is significantly higher. Globally, around 1MT of onion waste is generated (Jaganmohanrao, 2025). When the onion waste decomposes in the environment and is combined with soil, it also leads to nutrient degradation through spread of post-harvest fungi, which in turn has an impact on the atmosphere. When raw onion waste with high sulphur content and rapidly fermentable organic matter is added to soil, soil microbes break down sulphur-containing compounds, producing sulphate and H^+ ions that lower soil pH, which can change nutrient solubility and lead to nutrient imbalances, temporarily shifting the soil microbial community, sulphur oxidation and reducing the availability of other nutrients like nitrogen or phosphorus due to changed microbial competition and nutrient transformations, resulting in nutrient degradation in the soil (Liang et al., 2025). Due to its potent flavour of sulphur compounds and taste, onion waste is not ideal for use as high concentrations of feed, and it cannot be used as inorganic fertilizer since it serves as a substrate for the phylogenetic agents'

quickest growth (Chorolque et al., 2022). The method and procedure for using it need to be developed. The wastes are made up of onion outer skin, bulbs, outer fleshy scales, roots, peels, damaged, infected and undersized bulbs, etc. They are categorized in three different categories: industrial waste, domestic waste and supply chain or distribution waste. The onion waste amounts to around 38% of the fresh onion weight and about 10% of onions are wasted as distribution losses (El Mashad et al., 2019). Domestic onion waste amounts to around 20% of the total onion production in India (Bose, 2025). Onion waste is a rich source of bioactive compounds such as phenols, flavonoids and flavanols. The flavonoid content of the onion waste is up to 10 g/kg more than the flavonoids content in the edible part of the onion (Akdeniz et al., 2018). The presence of these bioactive compounds gives the medicinal properties useful in prevention of neurodegenerative disorders, diabetes, cancer, cardiovascular diseases, microbial infections, and erectile dysfunction (Kumar et al., 2022b).

The onion waste is capable of producing a variety of useful substances, including bioactive compounds e.g., phytochemicals, dietary fibre, and proteins, as well as other products such as bio-colorants, edible oils, enzymes, organic acids, activated carbon, degradable plastic composites, cosmetics, bio-sorbent, resins, medicines, foods and feeds, methane, biopesticides, etc. (Zahid and Khedkar, 2022; Zahid et al., 2025; Thakur and Modi, 2024). Shahid et al. (2023) examined production of bioethanol from onion waste with co-culture fermentation using *Saccharomyces cerevisiae* and *Pichia pastoris*. Bioethanol concentration of 22.72 g/L with energy 681.6 kJ/L was produced with the coculture fermentation at 30°C for 86 h at pH 5. The presence of reducing sugars helped in greater yield of bioethanol from monoculture fermentation using *Saccharomyces cerevisiae*. The onion wastes are nutrient-rich and can also serve as a substrate for the production of industrial amino acids, single cell proteins, essential oils, and exogenous enzymes, all of which lead to products with added value. Similarly, the management for food industry waste is the demanding concern of consumer to protect the environment (Khedkar and Singh, 2017).

The dry matter in onion is mainly composed of (around 80%) non-structural carbohydrates in the form of fructo-oligosaccharides (FOS), sucrose and reducing sugars e.g. glucose and fructose that make up the majority of the dietary reserves and energy

source taking part in the growth and metabolism of onions (Aisara et al., 2021). FOS are the sugar substitutes that have no calories and are not carcinogenic, which helps to boost immune system performance and gastrointestinal physiology and are used in the bakery, dairy and confectionery industry (Kherade et al., 2021).

In order to make use of onion waste, the present endeavour was conducted to investigate the nutritional content, phytochemical composition, non-structural carbohydrates composition, antioxidant, and antimicrobial activity. The study helped in evaluating the functional potential of onion waste for sustainable resource utilization.

2. METHODOLOGY

2.1 Materials

The red onion waste (Pusa Red variety) was procured from a local market in Jasola Vihar, Delhi, India, 110025 and the chemicals used for the analytical purpose were purchased from Sigma-Aldrich, India.

2.2 Sample preparation

The red onion waste was washed with distilled water two to three times in order to remove all the dirt and dust adhering to the waste. Thereafter, the waste was dried in a tray drier (Bionics Instruments, India) at $60 \pm 2^\circ\text{C}$ by placing a fine layer of waste material on individual tray for uniform drying of the material till constant weight was achieved. The sample was then ground into fine powder by using an automatic grinding machine (Maharaja Whiteline Mixer Grinder, India) and was sieved through BS30 (500 microns) sieve. For subsequent investigation, the powdered material was kept in an airtight container and refrigerated at 4°C . Figure 1 represents the powdered onion waste sample that was used for further analysis.

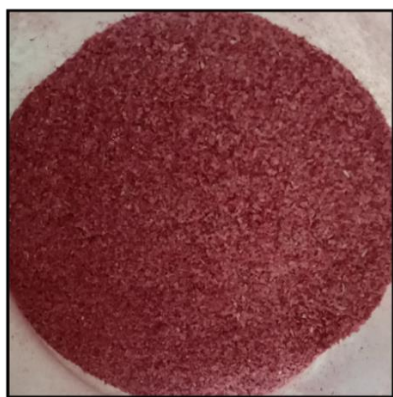


Figure 1. Onion waste powder

2.3 Determination of proximate composition of onion waste

The proximate composition, including moisture, crude protein, ash, crude fat, carbohydrate and energy content was analysed following the standard procedures described by (AOAC, 2023; AACC, 2025).

2.3.1 Determination of moisture content

The moisture content of powdered onion wastes sample was determined by the standard hot air oven method (AACC, 2025). Around 10 g of sample was heated in hot air oven (Labindia Instruments, India) at a temperature of $110 \pm 2^\circ\text{C}$ until the constant weight was achieved. The moisture content of the onion sample was obtained as follows:

$$\text{Moisture (\%)} = \left[\frac{(\text{Wt. of original sample} - \text{Wt. of dried sample})}{\text{Wt. of original sample}} \right] \times 100$$

2.3.2 Determination of crude protein content (Kjeldahl Method)

The crude protein of powdered onion sample was estimated by Kjeldahl Method which includes protein digestion using conc. H_2SO_4 , distillation with 40% NaOH and titration with 0.116 N HCl in a Kjeldahl (Techno reach, India) apparatus (AOAC, 2023).

%Nitrogen was calculated by using the formula:

$$\% \text{Nitrogen} = (V_s - V_b) \times M_{\text{acid}} \times 0.01401 \times 100 W$$

Where; V_s =volume (mL) of acid required to titrate sample; V_b =volume (mL) of acid required to titrate the blank; M_{acid} =molarity of acid; W =weight of sample (g). Then, percentage crude protein in the sample was calculated from the % Nitrogen as % crude protein = $\%N \times F$, where, F (conversion factor), is equivalent to 6.25.

2.3.3 Determination of ash content

Ash content is the inorganic residue obtained by the complete burning of material. About 5-10 g sample was weighed in a tared crucible. Crucible was placed in muffle furnace (Bionics Scientific, India) and heated at $525-550^\circ\text{C}$ for 6 hrs, until the ash was obtained. The crucible containing ash was allowed to cool in a desiccator and then reweighed (AOAC, 2023). The % ash content was calculated by the following:

$$\text{Ash (\%)} = \frac{\text{Wt. of ash}}{\text{Wt. of sample taken}} \times 100$$

2.3.4 Determination of crude fat content

The crude fat content of onion waste sample was determined by Soxhlet (Bionics Scientific, India) extraction method (AOAC, 2023). About 3.0 g of moisture free sample was weighed and transferred to a thimble. The thimble was placed in the Soxhlet apparatus. Around 75 mL petroleum ether was poured through the sample in the flask and allowed to reflux for 24 hrs. The thimble was removed and petroleum ether was recovered for re-use. The flask was subjected to heat at $100 \pm 2^\circ\text{C}$ until it was free from petroleum ether. After drying it was cooled in a desiccator and weighed (AACC, 2025). The % crude fat was estimated by the following:

$$\text{Crude Fat (\%)} = \frac{\text{Wt. of fat}}{\text{Wt. of original sample}} \times 100$$

2.3.5 Determination of total carbohydrate

The total carbohydrate content of onion waste sample was determined by the difference method (Khedkar et al., 2023).

$$\% \text{ Carbohydrate} = 100 - (\% \text{ moisture} + \% \text{ crude fibre} + \% \text{ protein} + \% \text{ lipid} + \% \text{ ash})$$

2.3.6 Determination of energy value of onion samples

The energy value of the samples was determined by multiplying the protein content by 4, carbohydrate content by 4 and fat content by 9 (AOAC, 2023).

$$\text{Energy value} = (\text{Crude Protein} \times 4) + (\text{Total carbohydrate} \times 4) + \text{Crude fat} \times 9$$

2.3.7 Determination of crude fibre and dietary fibre content

The crude fibre content of the sample was obtained using the procedure described in AOAC (2023). Around 2 g of defatted powdered onion waste was taken into a flask and 100 mL of 0.255 N H_2SO_4 was added for the acid wash. The mixture was then heated under reflux with heating mantle at $400 \pm 5^\circ\text{C}$ for one hour. Subsequently, alkali wash was done with 100 mL of 0.313 M NaOH. The mixture was filtered through a fibre sieve cloth, after which 10 mL of acetone was added to dissolve the remaining organic constituents. The residue was washed twice with 50

mL of hot water and then transferred into a pre-weighed crucible. The crucible containing the residue was oven-dried at $110 \pm 2^\circ\text{C}$ overnight to remove residual moisture, cooled and weighed (W1), after which it was subjected to ashing at $525\text{--}550^\circ\text{C}$ for 4 hrs in a muffle furnace. The crucible containing the white and grey ash, free of carbonaceous material, was cooled in a desiccator and weighed to obtain (W2). The % Crude Fibre content was estimated by the following:

$$\text{Crude Fibre(\%)} = \left(\frac{W1 - W2}{\text{Wt. of sample}} \right) \times 100$$

The total dietary fibre (TDF), soluble dietary fibre (SDF), and insoluble dietary fibre (IDF) contents of the powder were determined by the enzymatic-gravimetric method, using the Bioquant 1.12979.0001 total dietary fibre assay kit (Merck, Germany).

2.4 Determination of non-structural carbohydrates of onion waste

The sugar content of powdered onion wastes sample was estimated by High Performance Liquid Chromatography (Shimadzu LC-2010HT with RI detector) as per the standard procedure mentioned in AOAC (2023). The HPLC column was Luna 5 μm NH_2 100Å LC column (250×4.6 mm). The standard sugar solution was made by combining 3.804 g of fructose, 3.010 g of glucose, and 0.602 g of sucrose in a 100 mL volumetric flask, dissolving them in 50 mL of water, and then adding CH_3CN to volume to create the mobile phase. Under operating conditions of flow rate of approximately 1.0 mL/min, ambient temperature of approximately 23°C , detector was set so that 380 g fructose gives full scale peak and mono, di, and tri-saccharides are eluted from column under the influence of molecular weight, fructose, glucose, and sucrose are separated and quantified in 20 min. To create the test sample, 5 g of onion waste powder was weighed in a tiny beaker and transferred to a 50 mL volumetric flask with 25 mL of water. Then, using a clarity kit, it was promptly diluted to volume with CH_3CN and filtered through a 0.45- μm filter. 10 μL of standard solution was injected into chromatograph. The retention time were established; peak height and reproducibility were measured. The whole procedure was repeated for onion waste sample. The glucose, fructose, and sucrose from integrator values or from peak heights were calculated by the formula given below:

$$\text{Weight percent sugar} = 100 \times \frac{P_0}{P} \times \frac{V_0}{V} \times \frac{W}{W_0}$$

Where; P_0 and P is peak heights (or integrator values) of onion waste solution and standard, respectively; V_0 and V is onion waste solution and standard (50 and 100 in mL) solution, respectively; W_0 and W is g onion waste sample (5 g) and standard, respectively.

2.5 Phytochemical screening and antioxidant potential of onion waste

2.5.1 Preparation of extract

The onion waste extract was prepared by mixing 50 g of powdered sample with 250 mL of ethanol (95%) and incubating the suspension overnight at room temperature under shaking conditions. Extraction was conducted until the extraction solvent was colourless. The extracts obtained after each extraction cycle were pooled and filtered using Whatman filter paper no. 1 and finally concentrated for 25 min on a rotary vacuum evaporator (Hahn Shin Scientific, India) with a vacuum of 562 mmHg, temperature 40°C, and 200 rpm. The concentrated extract was stored at 4°C to stop oxidation and for further use. Similarly, the methanol and hexane extracts of the onion waste powder were also prepared.

2.5.2 Qualitative determination of phytochemical screening

The ethanolic extracts of onion waste were subjected to qualitative phytochemical screening. The methods used were Molisch's, Fehling's, alkaloid, foaming, ferric chloride (FeCl_3), alkali, Borntrager's, and Keller-Killani tests for qualitative determination of anthraquinones, anthocyanins, flavonoids, glycosides, terpenoids, flavonoids, and tannins respectively (Singh et al., 2022; Sayeed et al., 2020).

2.5.3 Determination of total phenolic content (TPC)

Phenols are secondary plant metabolites that serve as defence chemicals. The total phenolic content in ethanolic, methanolic, and hexane onion waste extract were estimated by Folin-Ciocalteu reagent, as described (Sayeed et al., 2020). One mL of ethanolic extract was mixed separately with 10 mL of deionized water and 1.5 mL undiluted Folin Ciocalteu's reagent. After 5 min, 4 mL sodium carbonate (Na_2CO_3) (20%, w/v) was added, and volume was adjusted to 25 mL

with deionized water. The mixture was incubated at 45°C for 30 min in a water bath and the absorbance was measured at 765 nm in UV-Vis Spectrophotometer (Shimadzu Scientific Instruments, UV-2700i). The assay was performed in triplicates. Calibration curve was plotted using Gallic acid as reference standard and the results were expressed as milligram gallic acid equivalents (mg GAE [gallic acid equivalent])/g of extract.

2.5.4 Determination of In-vitro antioxidant activity of onion waste

In-vitro antioxidant activity of ethanolic onion waste extract was determined using two different methods: 2,2-diphenylpicrylhydrazyl (DPPH) free radical scavenging activity, and Hydroxyl radical scavenging activity (HRSA). Apart from ethanolic extract, the methanolic and hexane extracts were also used for the determination of *in-vitro* antioxidant activity of onion waste. Tests were carried out in triplicates.

2.5.4.1 DPPH radical scavenging activity

The free radical scavenging activity of three different onion extracts and ascorbic acid as positive control was measured in terms of hydrogen donating or radical-scavenging ability using the stable radical DPPH by the method as described with slight modifications (Sayeed and Thakur, 2019). 3 mL of freshly made DPPH solution (0.004%) in ethanol were mixed with 2 mL of each extract and the control at varying concentrations (100, 50, and 10 g/mL). The reaction was kept for 30 min and the absorbance was measured at 515 nm using a spectrophotometer. The experiments were carried out for triplicates. The colour becomes purple to yellow, indicating the scavenging potential of the extract. The percentage inhibition of DPPH free radical scavenging activity was calculated using the following equation:

$$\text{Percentage inhibition (\%)} = \left(\frac{A_0 - A_s}{A_0} \right) \times 100$$

Where; A_0 =absorbance of negative control, A_s =absorbance of sample.

2.5.4.2 Hydroxyl radical scavenging activity (HRSA)

The hydroxyl scavenging activity of three different onion extracts in methanol, hexane and ethanol was determined by the method as described (Sayeed et al., 2020). The reaction mixture contained 200 mL of pre-mixed ferric chloride (100 mM) and

Ethylenediaminetetraacetic Acid (EDTA) (100 mM) solution (1:1; v/v), 500 mL of 2-deoxyribose (2.8 mM) in phosphate buffer (50 mM, pH 7.4), 100 mL of H₂O₂ (200 mM). A 100 L addition of 300 mM ascorbate started the reaction, which was then allowed to proceed for 1 hour at 37°C. After adding 0.5 mL of the reaction mixture to 1 mL of TCA (Trichloroacetic acid) (2.8% w/v; aqueous solution), the reaction mixture received 1 mL of 1% aqueous TBA (Thiobarbituric acid). The mixture was heated on a boiling water bath for 15 min and the absorbance at 532 nm was measured in comparison to a blank (the same solution but without reagent). The percent inhibition was calculated by the following equation:

$$\text{Percentage inhibiting activity} = \frac{A_0 - A}{A_0} \times 100$$

Where; A=absorbance of sample, A₀=absorbance of control.

2.6 Determination of anti-microbial activity of onion waste

2.6.1 Preparation of two different onion waste extract and antibiotic susceptibility

An equal weight about 50 g of powdered onion waste was dissolved in 250 mL of ethanol, and hexane separately and kept overnight at shaker for proper mixing. Finally, it was filtered through Whatman filter paper no. 1 and concentrated in the rotary vacuum evaporator to obtain a final yield of 9 mL/50 g for antimicrobial activity testing. Streptomycin (1 mg/mL of sterile distilled water) was used as standard antibiotic and positive control (Singh and Katoch, 2020).

2.6.2 Microbial strains

Microorganisms were obtained as lyophilized cultures from Microbial Type Culture Collection (MTCC, Chandigarh, India). Microorganisms were as follows: MTCC/9760 of Gram-positive bacteria, *Staphylococcus aureus* and MTCC/1302 of Gram-negative bacteria, *Escherichia coli*.

2.6.3 Preparation of test microorganisms

Test bacteria were grown on nutrient agar slants for 24 hrs at 37°C and then stored at 4°C. The inhibitory activity of extracts, and antibiotic susceptibility was tested against bacteria namely *Escherichia coli* and *Staphylococcus aureus* by Agar well diffusion method (Kumari et al., 2016). Pure

cultures of the test microorganisms were aseptically added to test tubes filled with sterile nutritional broth before being incubated at 37°C for 24 hours. 6mm-diameter wells in agar were drilled and inoculated with test-bacteria broth cultures (by swabbing using sterile cotton swabs). The extracts, negative control (Ethanol, Hexane respectively), and Streptomycin were transferred into the respectively labelled wells. The plates were incubated at 37°C for 24 hours in upright position and the zone of inhibition was recorded.

3. RESULTS AND DISCUSSION

3.1 Proximate composition

The proximate composition of the powdered onion waste is represented in Table 1. The Carbohydrates (70.47 g/100 g) predominated in the onion waste whereas the fat content was low (0.64±0.01 g/100 g) and protein was 8.56%.

Table 1. Proximate composition of onion waste powder per 100 g (n=3)

Parameter (g)	Onion waste powder
Moisture content	3.67±0.20
Crude protein (%N x 6.25)	8.56±0.04
Crude fat	0.64±0.01
Crude fibre	4.49±0.05
Ash content	5.00±0.21
Carbohydrates	70.47±0.47
Energy value (kcal)	321.88±5.06
Total dietary fibre (TDF)	69.06±0.21
Soluble dietary fibre (SDF)	8.88±0.08
Insoluble dietary fibre (IDF)	63.64±0.13

The value given in the table represents the mean value±SD of three individual replicates.

The onion waste powder was found to be a good source of carbohydrates (70.47%), dietary fibre (69.06%) and protein (8.56%). Kumar et al. (2022a) indicated the protein content in onion waste at around 8.3-15.6% dm (dry matter). Protein contributes to the production of hormones which regulates the body function such as growth, repair, and replacement of tear tissues of the body.

Additionally, carbohydrates serve as a substrate for the production of aromatic amino acids and phenolic compounds and act as an alternative source of glucose (Gupta et al., 2025). A higher content of carbohydrates can be beneficial to human health, as they not only serve as a primary source of energy but also play a catalytic role in various biochemical reactions during metabolism. Crude fibre content in

the onion waste was found to be 4.49 g/100 g. [Dinkecha et al. \(2017\)](#) noted the crude fibre content of onion between 3.82-5.15%. Crude fibre is recognised as functional food ingredient that acts as specific ingredient. The presence of fibre content in diet improves digestion and acts as functional food ingredient for controlling oxidative processes in food products. The consumption of crude fibre is essential for proper digestion and waste elimination from the body. Moreover, the contraction of muscular walls of the digestive tract is stimulated by fibre, thus counteracting constipation ([Melani, 2025](#)). The total dietary fibre in powdered onion waste depends on cultivars. It promotes the management of diabetes mellitus and protects the body against cardiovascular disease, colorectal cancer and obesity. The low moisture content (3.67%) in the onion waste powder reveals that the product is less prone to deterioration, and could be used for preservation, therefore, less susceptible to the action of micro-organisms. The high ash content (5%) in onion waste indicates the presence of rich mineral content in the product, highlighting nutritional significance ([Bilge et al., 2016](#); [Damanik et al., 2023](#)).

3.2 Non-structural carbohydrates

The non-structural carbohydrates of powdered onion waste are shown in [Table 2](#). The study evaluated the content of glucose, fructose and sucrose at around 4.40%, 1.75%, 1.10%, respectively.

Non-structural carbohydrates play an important role in plants responses against drought and frost stress. Glucose is the most common non-structural carbohydrate, followed by fructose, sucrose, and low-molecular-weight fructans or fructo- oligosaccharides (FOS) in onions. These are considered as main carbohydrate reserves of onion. They accumulate during bulbing and are then catabolized during regrowth and the sprout development of the bulbs. [Sidhu et al. \(2019\)](#) noted the sugar composition of freeze dried Indian red onion variety as % dry weight basis at glucose (17%), fructose (7.4%) and sucrose (11.7%). High levels of reducing sugars i.e. glucose and fructose are responsible for the more browning during frying or drying of onions. These reducing sugars take part in the fermentation process and are an important parameter for yield and productivity of the fermentation products ([Shahid et al. 2023](#)). [Cho et al. \(2021\)](#) studied the potential of developing biosugar, an alternative bee feed from onion waste that has a similar composition to that of honey. Multiple investigations

suggest that non-structural carbohydrates may be involved in the control of xylem water transport in the horticultural product.

Table 2. Non-structural carbohydrates composition in powdered onion waste (per 100 g) (n=3)

Parameters (g)	Onion waste powder
Glucose	4.40±0.01
Fructose	1.75±0.01
Sucrose	1.10±0.01

The value given in the table represents the mean value±SD of three individual replicates.

3.3 Phytochemical composition

[Table 3](#) shows the phytochemical composition of the ethanolic onion extract. The study indicated the presence of anthraquinones, anthocyanins, phenols, carbohydrates, flavonoids, glycosides, terpenoids, tannins etc., and the absence of alkaloids, sterols and saponins. The obtained phytochemical compounds possess both physiological as well as medicinal activities.

The obtained phytochemical compounds possess both physiological as well as medicinal activities. [Marefati et al. \(2021\)](#) noted that the tannins investigated in the skin of *Allium cepa* have antioxidant properties, and their presence confirms the anti-inflammatory properties in vegetables, which describes its usage to treat ulcers, earaches, and as an antitussive. Alkaloids are extremely helpful in medicine and are employed in the creation of a number of beneficial medications ([Dalhat et al., 2018](#)). Presence of alkaloids suggests that the onion waste can be utilized as an analgesic, anti-inflammatory, anticancer, antibiotic, and antispasmodic due to their existence ([Letchuman et al., 2025](#)). Saponins, which are glycosides of sterols and triterpenes, are found in more than 70 plant groups. They have been found to have antitussive properties and work as emulsifying agents ([Timilsena et al., 2023](#)). The presence of flavonoids also possesses metal chelating properties that build the stability of the product, via stopping the generation of free radicals ([Rodríguez-Arce and Saldias, 2021](#)).

3.4 Total phenolic content

Onion waste, particularly outer dry skins and peels, constitutes a high-value source of phenolic compounds. Quantitative TPC determination through the Folin-Ciocalteu method enables characterization and potential standardization of extracts for functional

use. Optimization of extraction conditions and proper solvent selection are essential for maximizing phenolic recovery, ultimately contributing to sustainable waste valorisation strategies.

Table 3. Qualitative phytochemical screening of ethanolic onion waste extract

S.No.	Test compounds	Extract test	Sample
1.	Saponins	Frothing	-
2.	Anthraquinones	Borntrager's	++
3.	Anthocyanins	Sodium hydroxide	+
4.	Carbohydrates	Fehling's	+
5.	Flavonoids	Sulphuric acid	+
6.	Glycosides	Keller-Killani	+
7.	Phenols	Ferric chloride	++
8.	Proteins & Amino Acids	Xanthoproteic	+
9.	Sterols	Liebermann-Buchard	-
10.	Tannins	Ferric chloride	+++
11.	Terpenoids	Liebermann-Buchard	+

Note: (+): Indicates the presence of phytochemicals; (-): Indicates the absence of phytochemicals; (++ & +++): Indicates the medium and high level of concentration resp.

The TPC in the ethanolic onion waste extract was found to be 320.11 mg/g GAE. Many scholars have investigated the phenols in overall onion waste. [Singh et al. \(2017\)](#) reported high concentration of total phenolic compounds (418 mg GAE/g of extract) in 70% ethanolic extract of onion waste. Onion waste has a high concentration of free phenolics, which contributes to their antioxidant and antiproliferative properties, making them an effective selection for functional foods. [Kumar et al. \(2022a\)](#) reviewed the total phenolic compounds in different composition of onion peel/skin based on different varieties, agronomic conditions of the region in which they were cultivated, and the extraction techniques used. In another study, total phenolic compounds in onion waste including skin and peel were obtained at around 19.7-415 mg GAE/g of extract. [Paesa et al. \(2022\)](#) also reported the presence of TPC (177 mg GAE/g of extract) in the onion waste.

3.4.1 In-vitro antioxidant activity

The antioxidant and free radical scavenging properties of three different onion waste extracts (Methanol, Hexane and Ethanol) are associated with their medicinal benefits. DPPH radical scavenging activity and Hydroxyl radical scavenging activity (HRSA) tests were used to assess the antioxidant activity of three distinct onion waste extracts. The antioxidant property of the extracts generated was assessed by the DPPH free-radical scavenging method which is based on the exchange of hydrogen atoms between the antioxidant and the stable DPPH free

radical diseases ([Singh et al., 2017](#); [Singh et al., 2026](#)). The DPPH and Hydroxyl radical scavenging activity (%) of ethanolic onion waste extract at concentrations of 10, 50, and 100 g/mL, ranged from 42.34% to 70.50%, 65.8 to 60.5%, respectively. Similarly, the DPPH and HRSA of methanolic onion waste extract at different 10, 50, and 100 g/mL, ranged from 43.46 to 59.19%, 59.70 to 57.60%, respectively. [Tables 4 and 5](#) presents the scavenging activity of the three onion waste extracts using the DPPH and HRSA methods respectively.

The onion waste exhibited higher levels of antioxidant activities as DPPH radical scavenging and HRSA. It was also noted that the HRSA antioxidant activity was higher as compared to DPPH radical scavenging activity. It may be due to the different antioxidant mechanisms of these molecules on the free radicals and their chemical environment. In research conducted to study the antioxidant potential of onion peel extracts using DPPH, lipid peroxidation and ferric thiocyanate method, DPPH method with ethanolic extract showed highest antioxidant activity. The high antioxidant activity of onion peel extract is attributed to the richness of organosulfur compounds, polyphenols and flavonoids in it ([Chakraborty et al., 2022](#)). [Singh et al. \(2017\)](#) noted the percent radical scavenging activity of methanol onion waste extract by using DPPH methods to be 83.7%. [Kumar et al. \(2022a\)](#) noted that ethanolic extraction was best suited for total phenolic content of onion waste considering the polarity of bio active molecules. [Masood et al. \(2021\)](#) observed that the total flavonoids and phenolic

content of ethanolic extract of onion peel were significantly higher when compared to that of onion bulb. Also, ethanolic extract of onion peel also presented better antioxidant and free-radical

scavenging activity as compared to the ethanolic extract of bulb. Antioxidant activities contribute to the beneficial health effects of phenolic compounds (Zeb, 2020).

Table 4. Percentage scavenging activity of three onion waste extracts at different concentrations at 765 nm using DPPH method

Concentration (µg/mL)	A _{Methanol}	% Scavenging activity	A _{Hexane}	% Scavenging activity	A _{Ethanol}	% Scavenging activity
10	0.805	43.4±0.31	0.787	44.7±0.17	0.821	42.3±0.17
50	0.753	47.1±0.23	0.632	55.6±0.19	0.692	51.4±0.20
100	0.581	59.1±0.31	0.496	65.1±0.17	0.482	70.5±0.18

Where, A_{Methanol}, A_{Hexane}, and A_{Ethanol} are the absorbance of methanol, hexane, and ethanol onion waste extract, respectively.

Note: The value given in the table represents the mean value±SD of three individual replicates.

Table 5. Percentage scavenging activity of three onion waste extracts at different concentrations at 765 nm using hydroxyl radical scavenging activity (HRSA)

Concentration (µg/mL)	A _{Methanol}	% Scavenging activity	A _{Hexane}	% Scavenging activity	A _{Ethanol}	% Scavenging activity
10	1.021	59.7±0.21	1.011	58.7±0.21	1.082	65.8±0.22
50	1.014	59.0±0.13	1.008	58.4±0.31	1.041	61.7±0.19
100	1.000	57.6±0.21	1.001	57.7±0.17	1.029	60.5±0.18

Note: The value given in the table represents the mean value±SD of three individual replicates.

3.5 Antimicrobial activity

The antimicrobial activity of two different onion waste extracts and antibiotic susceptibility tests results have been presented in Table 6. As compared to hexane, ethanolic onion waste extract was found to be significant in inhibiting test microorganisms (Figure 2). Least inhibitory effect was observed in case of hexane extract of onion waste. Standard antibiotics caused higher levels of inhibition than the ethanolic and hexane extracts. Gram positive bacteria (*S. aureus*) have exhibited significant inhibitory effects compared to Gram negative bacteria (*E. coli*). The Minimum Inhibitory Concentration (MIC) values ranging from between 1,000-1,250 µg/mL. The antibiotic caused high inhibition of gram-positive bacteria than gram negative bacteria. Ethanol and hexane independently (negative control) did not cause inhibition of bacteria.

Results were evaluated by measuring the existence or nonexistence of inhibition zone around the well against the microorganism. The appearance of inhibitory zone around the well was taken as positive for antimicrobial activity. The extracts demonstrated inhibitory effect against tested bacterial strains.

Plant extracts are known to possess antimicrobial activity, asserting their role in combating microbial infections. The ethanolic extract of the onion waste showed greater antimicrobial

activity against gram-positive bacteria (*S. aureus*) proving its potential in controlling food poisoning diseases. The findings align with the results of the study by Puišo et al. (2023) who investigated the antimicrobial activity of the red-onion-peel-extract hydrogels and films containing silver nanoparticles were the most effective against *Staphylococcus aureus*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Pseudomonas aeruginosa* bacteria. Bag and Chattopadhyay (2015) investigated the antimicrobial effect of *A. cepa* against *E. coli* and *S. aureus* and reported the larger inhibitory effect on *S. aureus* than on *E. coli*. Naqvi et al. (2020) reported the absence of inhibition zone against *Bacillus cereus*, *Bacillus megaterium*, and *Staphylococcus aureus*.

Table 6. Antimicrobial activity of onion waste and Streptomycin

S. No.	Treatment	Inhibition of test bacteria (mm)	
		<i>S. aureus</i>	<i>E. coli</i>
1	Streptomycin	3.6	3.5
2	Ethanol	0	0
3	Hexane	0	0
4	Extract (Ethanol + Onion waste)	3.2	2.2
5	Extract (Hexane + Onion waste)	1.8	1.1

Plant extracts are known to possess antimicrobial activity, asserting their role in combating microbial infections. The ethanolic extract of the onion waste showed greater antimicrobial activity against Gram-positive bacteria (*S. aureus*) proving its potential in controlling food poisoning diseases. The findings align with the results of the study by Puišo et al. (2023) who investigated the antimicrobial activity of the red-onion-peel-extract hydrogels and films containing silver nanoparticles

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Figure 2. Antimicrobial activity of ethanolic extract on *Staphylococcus aureus*

4. CONCLUSION

The rapid expansion of global onion production and processing has led to the accumulation of substantial agro-industrial residues, presenting significant challenges for environmental sustainability and waste management. In alignment with circular economy principles, the valorization of onion-derived waste into functional food ingredients represents a sustainable pathway for reintegrating biomass into value chains. The present study provides a comprehensive characterization of onion waste, revealing its richness in carbohydrates, proteins, and dietary fibre, along with a diverse array of bioactive phytochemicals including flavonoids, tannins, glycosides, anthocyanins, terpenoids, and other phenolic compounds. The demonstrated antioxidant and antimicrobial activities further highlight its functional relevance.

The incorporation of onion processing by-products into food systems as powders, extracts, and microencapsulated formulations underscores their potential to enhance nutritional quality, antioxidant

capacity, and prebiotic functionality. Such strategies exemplify circular bio resource utilization by converting processing residues into high-value functional ingredients. However, the large-scale implementation of onion waste reutilization remains complex and requires robust scientific validation of health claims to ensure regulatory compliance and consumer acceptance. Future in vitro and in vivo investigations are essential to elucidate bioavailability, stability, and interactions within complex food matrices. Advancing research in this domain will accelerate innovation in the food sector while promoting sustainable development through the circular and resource-efficient utilization of agricultural by-products.

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AUTHOR CONTRIBUTIONS

Experimental run, Data Collection, Writing manuscript Original Draft: Anila Zahid; Conceptualization, Methodology, Manuscript Review and Editing: Renu Khedkar; Visualization, Supervision: Shashi Sharma; Analysis, Manuscript Review and Editing: Sanjay Rajput.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

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