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Comparative Studies on Nutritive and Antinutritive Composition of Onions (*Allium cepa)* Bulb and Leaves

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Abstract

Onion (*Allium cepa*) is a widely used vegetable for flavoring food and is known to have medicinal properties. In this study, the nutritive and antinutritive content of onion bulbs and leaves was comparatively studied. The proximate composition, amino acid profile, and quantification of antinutrients were determined through standard and established analytical techniques. Both plant parts exhibited distinct compositional differences, as shown in the results. The crude protein (17.37 %) and fat (16.47 %) content of the bulb was higher, while the ash (11.47 %) and carbohydrate (71.70 %) content of the leaves was higher. Both samples were moderately distributed for crude fibre and moisture. The antinutrient analysis showed higher amounts of oxalate (22.14 %), alkaloids (19.71 %), and flavonoids (22.11 %) in the bulb, while the leaves had higher phytate content (83.02 mg/100 g). The leaves had TEAA content (48.27 %) compared to the bulbs (39.17 %). The essential amino acids most abundant in both samples were leucine, whereas the bulb and leaves were rich in glutamic acid and aspartic acid, respectively, which are non-essential amino acids. In general, the amino acid profile of both samples was acidic. Onion bulbs and leaves thus have very different nutritional and antinutritional contents. The leaves are more mineral, richer in essential amino acids, and also have a higher mineral content compared to bulbs, which are richer in protein and fat and have more phytate. The results highlight the need to take both parts of the plant into account when using it in nutrition to maximize its nutritional advantages while mitigating anti-nutrient properties.

Keywords: *Allium cepa*; Amino acid profile; Bulb; Leave; Nutritional value

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Introduction

Plants are a valuable source of bioactive natural products that make a major contribution to human health, general well-being, and environmental sustainability. They have been the focus of traditional medicine across various cultures in the world, and they are the main therapeutic assets [1]. In the past, numerous pharmacological therapies used today have plant-based derivatives, and many drugs developed using phytochemicals were discovered decades ago [2]. These active products have been found to serve as protective components for plants and have medicinal value for humans [3]. In the recent past, cancer and cardiovascular disease prevention have been linked with the intake of species, fresh fruits and vegetables, as well as teas with natural antioxidants [4].

In addition to their therapeutic and medicinal importance, plants are of significant nutritional importance and are important ingredients in the diets of urban and rural people worldwide. They furnish the human body with essential nutrients, such as vitamins (A, B-complex, C), a wide range of minerals, carbohydrates, proteins, lipids, and antioxidants [5, 6]. Roots, bulbs, stems, bark, leaves, flowers, fruits, seeds, and gums contain bioactive constituents and can also serve as edible dietary materials [7].

Allium cepa is a well-developed plant that has not only nutritional but also medicinal importance. The nutritional content of Allium species has been widely studied in different parts of the world [8]. Moreover, modern biomedical studies have also begun to confirm the therapeutic value of their bioactive components [7]. Phytochemical studies have shown that *Allium* species are rich in a wide range of compounds, which include essential oils, steroidal sapogenins, saponins, tannins, carbohydrates, proteins, vitamins, flavonoid glycosides, organic acids, amino acids, fatty acids, and alkaloids [9, 10]. Onion (*Allium cepa*), belonging to the family *Amaryllidaceae*, is one of the most commonly eaten species in this genus. It is widely consumed as a spice, and it is appreciated due to its unique taste. Different parts of the plant are consumed extensively, such as the fleshy and scaly leaves, stems, bulbs, and flowers [11]. Allium cepa is also used in traditional medicine, although it is used in its culinary use. It is commonly used as an ingredient in foods like salads, pickles, curries, and juices, and has been known to have a therapeutic effect against diseases like asthma, bronchitis, atherosclerosis, etc. [12].

Alliumcepa is a bulbous perennial or biennial monocot plant belonging to the genus *Allium*, which has over 3700 species and over 250 genera [13]. They are the second most cultivated crop globally, following tomatoes, with a cultivation area exceeding 3.4 million hectares [14, 15]. Nigeria is notable for its significant *Alliumcepa* production, particularly in the northern regions, which account for over 80 percent of the country's output [16].

Plate 1: Image of onion roots, leaves, and a developing bulb

Plate 1 illustrates the growth of red onion (*Allium cepa*) plants, showing partially exposed bulbs and healthy green shoots developing in soil under field conditions. This adaptable plant can be used in a variety of ways, such as eating the raw bulbs, extracting fresh juice, and cooking, roasting, or frying them. *Allium cepa* has immense economic and nutritional value, as reflected in its widespread cultivation. *Allium cepa* has long been regarded as one of the most fundamental vegetables globally, celebrated not only for its culinary versatility but also for its profound implications for nutrition, health, and agriculture [17]. This study aimed to comparatively evaluate the nutritive and antinutritive composition of the bulb and leaves of *Allium cepa.*

Materials and Methods

Sample collection

The *Allium cepa* samples (bulbs and leaves) were collected from the Central Market, Kaduna South, Kaduna State. It was purchased in substantial amounts and transported to Lafia for preparation.

Sample preparation

The onion bulbs and leaves were dried in an oven at the Muhammadu Buhari Research Institute, Federal University of Lafia, Nasarawa State. They were then cut into small pieces and dried in an oven. This drying method took approximately one week to complete. This was performed under strict supervision to avoid excessive drying and burning of the sample. The samples were dried for six days at room temperature. The samples were ground into a fine powder using an electric blender. The sample was defatted using a chloroform/methanol mixture at a ratio of 2:1 (5 g) for 15 h in a Soxhlet extraction apparatus [18].

Proximate composition

All proximate composition parameters were determined according to the standard methods described by the Association of Official Analytical Chemists (AOAC) [18]. The moisture content was determined using Method 934.01, by drying in an oven at 105 °C until constant weight was reached [19]. Crude protein was determined by the microKjeldahl method with an acid (sulfuric acid) digestion of the sample and then an alkaline (sodium hydroxide) distillation, and a nitrogen-to-protein conversion factor of 6.25. Crude fat was determined using hexane extraction in a Soxhlet extraction system (Method 996.06). Crude fiber was determined as the combustible and insoluble organic residue obtained after the sample was subjected to acid (H_2SO_4) digestion and then alkaline (NaOH) distillation, while Method 923.03 was used for ash content, quantified as the inorganic residue remaining after incineration of the sample at 550 °C until loss of organic matter [19]. Carbohydrate content was estimated by difference as described by Paul and Southgate [20].

Antinutrient content determination

The titration method described in AOAC [19] was used to determine the oxalate content. Phytate was evaluated as described by Haug and Lantzsch [21]. Saponins, alkaloids, flavonoids, tannins, cyanide, phytate, and total phenols were determined for each sample using standard methods described by the AOAC [19] and Eze and Obinwa [22].

Amino acid analysis

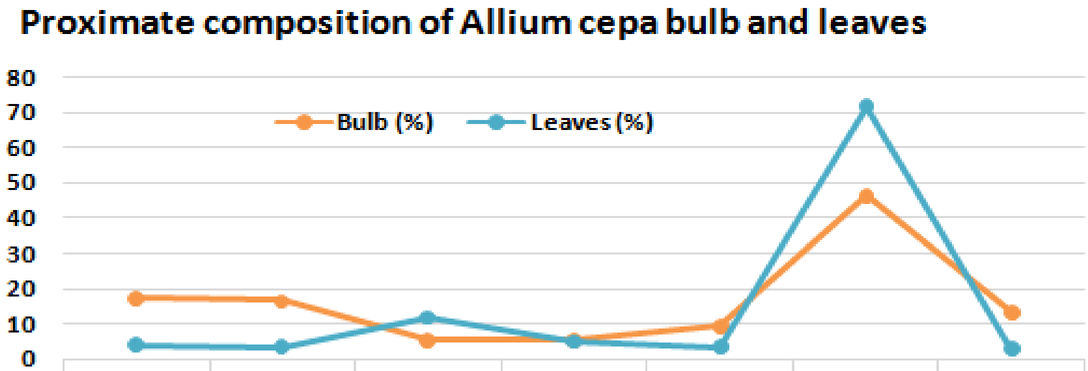
Amino acid composition was determined following the chromatographic method described by Peace and Gilani [23]. Samples were hydrolyzed with 6 M hydrochloric acid at 110 ^{0}C for 24 h to release constituent amino acids. The hydrolysate was filtered, neutralized, and subjected to pre-column derivatization. The amino acids were then separated and quantified using high-performance liquid chromatography equipped with an appropriate detector. Tryptophan was determined after alkali (NaOH) hydrolysis using a colorimetric method.

Statistical analysis

The energy value of every sample was determined as the summation of the contribution of the macronutrients calculated as carbohydrates x 17 kJ, crude protein x 17 kJ, and crude fat x 37 kJ based on the existing procedures [24]. The content of fatty acids was calculated by multiplying the value of crude fat by a conversion factor, i.e., fatty acids = crude fat x 0.8.

Results and Discussion

The nutritional content expressed as the proximate composition of *Allium cepa* bulbs and leaves showed significant variations, as shown in Fig. 1. The leaves (3.78 %) of *Allium cepa* show lower protein content than the onion bulb (17.37 %). This trend is consistent with the findings of Hussein *et al.* [7], who reported higher protein values in the bulb part than in the shoot part of *Allium calocephalum*. Gupta *et al.* [25] affirm this assertion by reporting that the bulb of Allium species generally has higher protein content due to its role as a storage organ. Extending the scope of this research to other plants, the onion bulb has a higher protein content than that reported by Aremu *et al.* [24]. Good plant foods are those that contain above 12 percent of their caloric value in the form of protein [26]. The *Allium cepa* bulb is a good source of protein, and frequent consumption of high-protein foods is a good addition to the diet [27]. There was a significant difference in the fat content of the bulb (16.47) and leaves (3.24) of *Allium cepa* as indicated in the laboratory analysis. Dietary fats were crucial in physiological functions, such as insulation and protection of vital organs, and transporting fat-soluble vitamins. Moreover, both protein and dietary fat are known to provoke the secretion of gastric inhibitory peptide (GIP) by the small intestinal mucosa and thus, assist in the regulation of metabolism. The reasonably good macronutrient content of *Allium cepa* also highlights the nutritional potential of this vegetable to consumers, since diets high in the essential macronutrients usually correlate with better health outcomes [24].



	Crude protein	Fat	Ash	Crude Fibre	Moisture	Carbohydrate	Fatty acid
Bulb (%)	17.37	16.47	5.19	5.31	9.32	46.38	13.18
Leaves (%)	3.78	3.24	11.47	4.77	3.37	71.7	2.59

Carbohydrate = 100 – (Crude Protein +Fat + Ash + Crude Fibre +Moisture)

Figure 1: Comparative proximate composition content of onion (*Allium cepa)* bulb and leaves

The high fat content recorded in the bulb can be better explained by the assertion of Sharma *et al.* [28], which states that plant storage organs, such as bulbs, typically accumulate higher lipid levels relative to other parts. Shehu *et al.* [29] reported a lower fat content in onion bulbs (14.50 %). This disparity could be due to geographical location or the presence of other minerals, suggesting a potential influence of environmental factors on mineral accumulation. In contrast, the ash content was greater in the leaves (11.47 %) than in the bulb (5.19 %), which is in agreement with the ash content (5.50 %) obtained by Sharma *et al.* [28] for *Allium cepa* bulb. In comparison with other spices, garlic plants were found to contain lower values of ash (1.39 %), while ginger plants had a high ash value (7.00 %) [28]. The high ash content observed in the leaves of onion plants is a trend commonly observed in leafy vegetables, suggesting that leaves are richer in minerals [21, 29, 30].

Adding onions to the daily diet, especially to the low-fiber meals, is a feasible diet measure to avoid constipation. The health benefits of consuming dietary fiber are not new, as a high-fiber diet has been linked to low levels of serum cholesterol, decreased incidence of some types of cancer and bowel illnesses, and an increase in health and well-being [31]. In addition, proper dietary fiber has been known to be helpful in digestive health and has been associated with the prevention and treatment of diseases like obesity, diabetes, and other gastrointestinal problems, including colorectal cancer [32]. The crude fiber analysis indicated little disparity between the values of the bulb (5.31 %) and leaves (4.77 %). A recent investigation by Shehu *et al.* [29] reported 27.39 % for garlic, 22.00 % for ginger, and 9.50 % for onion bulb crude fiber, which is much higher than the values obtained in this study. A nuanced analysis of different plant parts adds depth to our understanding of the variability in crude fiber content within *Allium cepa*. The moisture content of onion bulbs (9.32 %) was higher than that of onion leaves (3.37 %), which are generally low and within the recommended dietary allowance (RDA) (3 – 10) [24] but lower in comparison to some common spice plants [33, 34]. Low moisture content ensured a long shelf life of the samples without microbial spoilage [35]. The carbohydrate content of the leaves was higher than that of the bulb. A similar analysis reported 51.50 % carbohydrate content in the bulb of the plant, which is comparable to the values obtained in this study [29].

The difference in carbohydrate content found in *Allium cepa* highlights its relevance as a possible source of dietary energy, considering the indispensability of carbohydrates in energy generation. The daily carbohydrate food intake is advised to be 50-100 g, providing about 60 percent of the overall energy consumption in a balanced diet [27]. In addition, low-carbohydrate diets, which contain low fat levels, are linked to better blood pressure management and decreased chances of becoming overweight. The estimated fatty acid content was higher in the bulb (13.18 %) compared to the leaves (2.59 %) as showed in Fig. 2, and this result suggests that the lipid concentration in the bulb section of the plant is higher. When the energy of the *Allium cepa* bulbs was measured in kJ/100 g, the energy value of the *Allium cepa* bulbs was higher than that of the leaves (1693.14 vs. 1403.04 kJ/100 g). This implies that the two components of the plants have significant energy densities that are commensurable to other cereal crops [36], although the bulb has a relatively higher energy input.

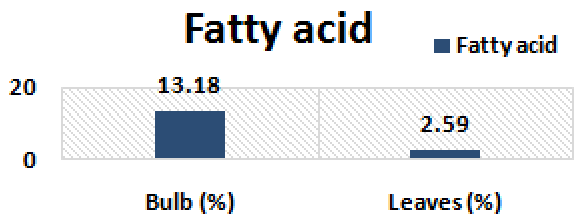
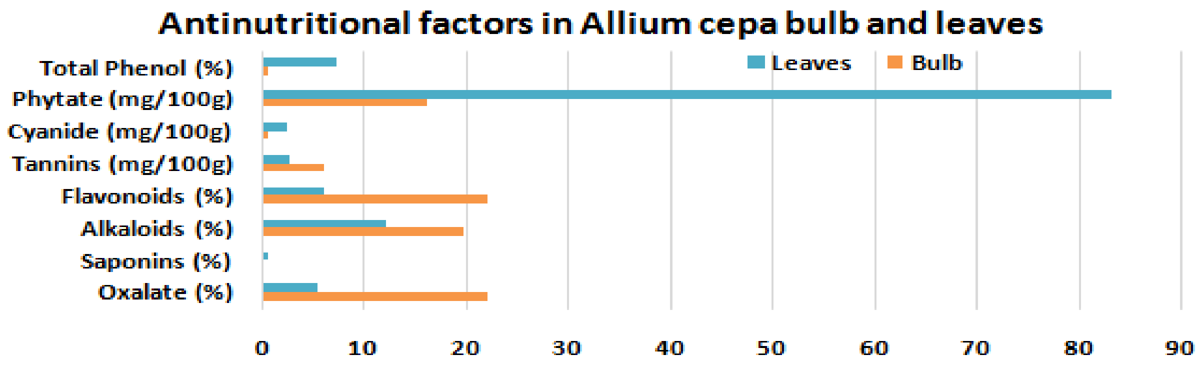


Figure 2: Comparative fatty acid content of onion (*Allium cepa)* bulb and leaves

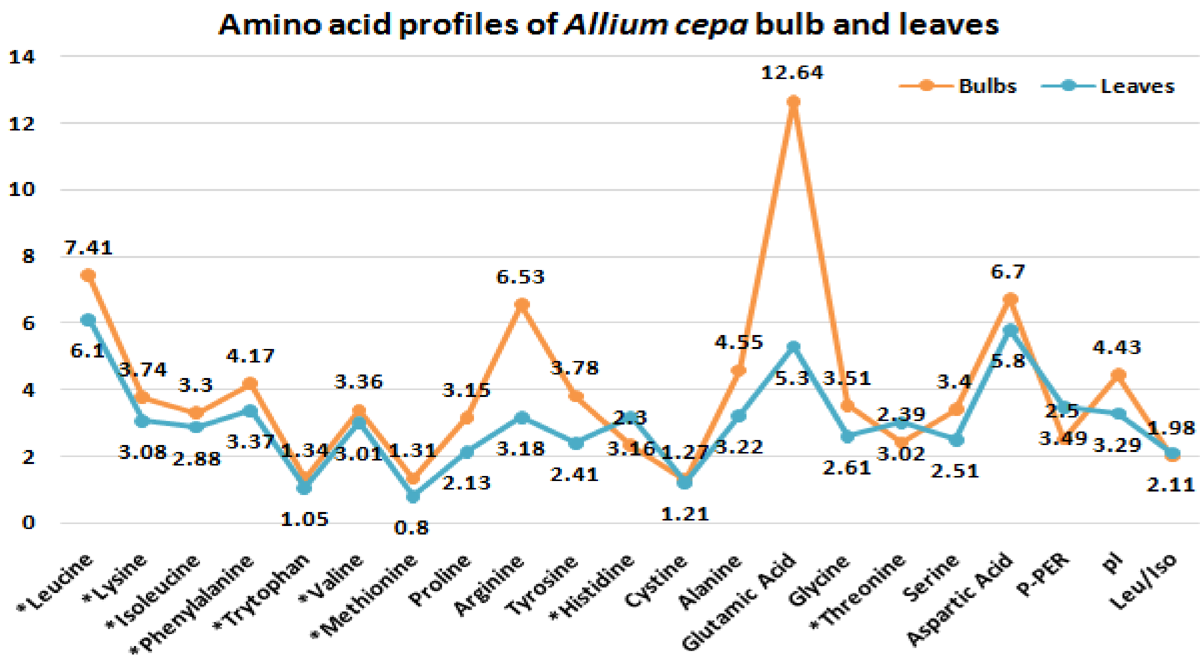
Figure 3 presents the results of the anti-nutrient contents of *Allium cepa* bulbs and leaves. *Allium cepa* contains oxalate levels of 22.14 and 5.52 % in the bulb and leaves, respectively. The *Allium cepa* bulbs are in agreement with the oxalate values obtained for *X. aethiopica* (22.23 %) and *P. guineense* (18.42 mg/100 g) but are higher than those of *M. myristica* (0.50 %), *A. melegueta* (0.07 %), *and P. biglobosa* (1.17 %) [34]. The lower oxalate content of the leaves of *Allium cepa* indicates its broader utilization in food universally. Oxalates cause irritation and swelling in the mouth and throat, and phytate, which inhibits digestive enzymes, is a significant antinutrient. Studies done by John *et al*. [37] showed that although oxalates are common in vegetables, their concentration varies greatly depending on the part of the plant. The higher saponin content in the leaves (0.62 %) compared to that in the bulbs may be advantageous for reducing cholesterol, although excessive consumption could interfere with protein digestion. According to Zaynab *et al*. [38], saponins are often more concentrated in plant leaves owing to their protective functions. In comparison to some edible spices, *Allium cepa*has an oxalate value that exceeds those in *P. guineense* (0.16 %), *X. aethiopica* (0.18 %), *M. myristica* (0.16 %), *T. tetrapetra* (0.18 %), and *A. sativum* (0.14 %) but is lower than *G. latifolium* (2.70 %) [33]. Alkaloids and flavonoids possess antioxidant properties and provide health benefits by acting against cancer and heart disease [36]. The alkaloid content of the plant varied from 19.71 % in the bulb to 12.18 % in the leaves, implying a significant difference in their values. This trend also applies to flavonoid content, which was 22.11 % in the bulb and 6.03 % in the leaves.

Allium cepa was found to contain 6.13 mg/100 g of tannin in the bulb and 2.65 mg/100 g in the leaves. It is well known that tannins have antibacterial properties, mainly due to their capacity to bind proteins and create water-soluble and stable complexes, which can disrupt the cell membranes of bacteria [39]. Nevertheless, the concentration of tannins in the two parts of plants is comparable to the concentration of tannins in food additives commonly consumed [33]. The concentration of phytates varied between 16.25 mg/100 g in the bulb and 83.02 mg/100 g in the leaves, showing a greater chelating potential in the leafy part. The concentration of cyanide was measured as 0.54 mg/100 g in the bulb and 2.59 mg/100 g in the leaves, which is far below the allowable level of 200 mg/kg fresh weight in vegetables and forages [40]. Even though cyanogenic glycosides have the potential to release hydrogen cyanide and thus cause impairment to cellular respiration, the concentrations shown in this paper are deemed safe to be consumed. Phenolic compounds are also important antioxidants in plant matrices that are known to be important in the scavenging of reactive oxygen species like hydroxyl and peroxide radicals, and this reduces cytotoxicity and cancer risk. The overall phenolic content in this research was 0.67 mg/100 g of the bulb and 7.31 mg/100 g of the leaves, which indicates the high antioxidant potential of the leafy part. Moreover, extracts of plants with a high concentration of antimicrobial phytochemicals are gaining growing acceptance as an alternative medicine to traditional antibiotics, especially in the context of increasing antimicrobial resistance [41].



	Oxalate (%)	Saponins (%)	Alkaloids (%)	Flavonoids (%)	Tannins (mg/100g)	Cyanide (mg/100g)	Phytate (mg/100g)	Total Phenol (%)
Leaves	5.52	0.62	12.18	6.03	2.65	2.59	83.02	7.31
Bulb	22.14	0.22	19.71	22.11	6.13	0.54	16.25	0.67

Figure 3: Antinutritional factors of the onion (*Allium cepa*) bulb and leaves

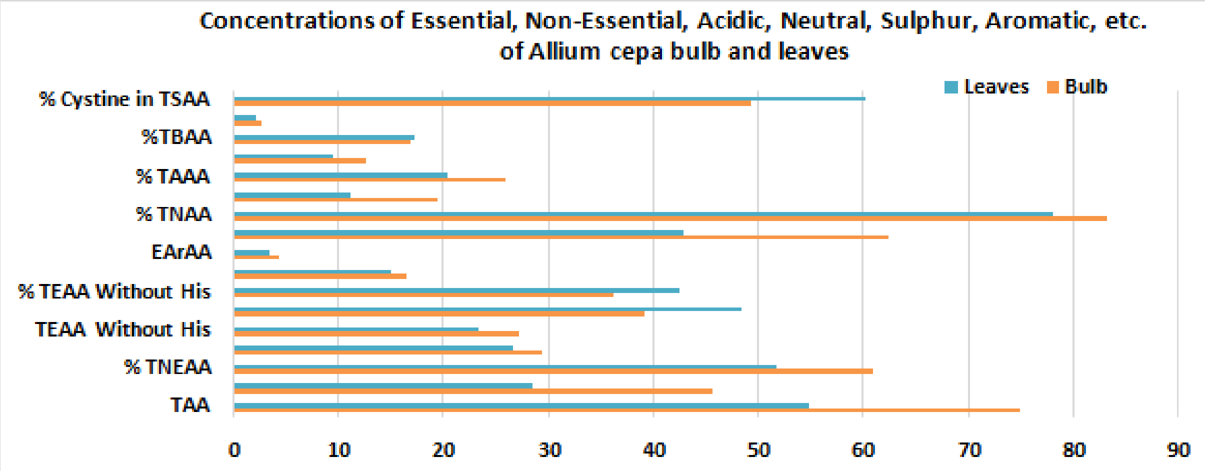


*= Essential amino acid

Figure 4:Amino acid profiles of the Onion (*Allium cepa)* bulb and leaves

Figure 4 shows the amino acid profiles of *Allium cepa* leaf and bulb. Leucine was found to be the most common essential amino acid (EAA) in the two samples, with the concentrations of 7.41 g/100 g crude protein in the bulb and 6.10 g/100 g crude protein in the leaves. The glutamic acid (12.64 g/100 g crude protein) was the most abundant non-essential amino acid (NEAA) in the bulb, and aspartic acid (5.80 g/100 g crude protein) was the most abundant in the leaves. Tyrosine is a non-essential amino acid that is used to produce various biologically significant substances, such as thyroid hormones and melanin, the pigment that makes hair, eyes, and skin colorful [42]. It was also found to have a concentration of 3.78 g/100 g crude protein in the bulb and 2.41 g/100 g crude protein in the leaves. An essential parameter that can be used to assess the quality of proteins is the predicted protein efficiency ratio (P-PER), which revealed that both samples had a reasonable nutritional protein content [22, 43]. Moreover, the ratios of leucine/isoleucine (Leu/Ile) determined in the present study are in line with the values in earlier studies by Aremu *et al.* [24, 36]. The computed isoelectric point (pI) was between 4.43 in the bulb and 3.29 in the leaves, which was consistent with previous results [24]. The parameter is especially helpful in the prediction of protein behavior and the optimization of protein isolates precipitation of biological materials [44].

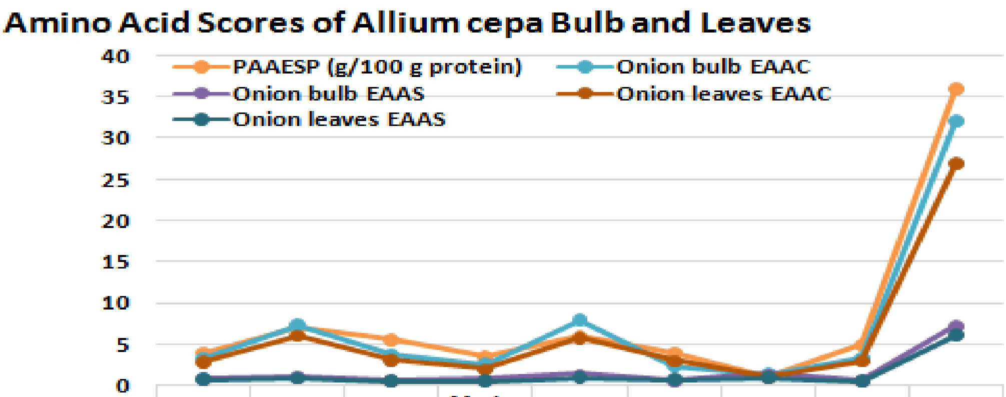
Nutritive quality of any protein is mostly identified by its capacity to satisfy the needs of the body in terms of nitrogen and essential amino acids [24]. The total essential amino acid (TEAA) content (with histidine) in the current study was between 39.17 % in the bulb and 48.27 % in the leaves (Fig. 5). These values are similar to those seen in selected oilseeds (33.3 – 53.6 %) [45] and soybean (46.5 %) [46], which suggests the possibility of *Allium cepa* as an additional source of protein. Moreover, the percentage of total acidic amino acids (TAAA) was more than the percentage of total basic amino acids (TBAA) in all samples, indicating the proteins to be more acidic in nature [47]. Total sulfur amino acid (TSAA) content was 2.58 g/100 g of crude protein in the bulb and 2.01 g/100 g of crude protein in the leaves, which is lower than the recommended level of 5.8 g/100 g crude protein in infants [43].



	TAA	TNEAA	% TNEAA	TEAA With His	TEAA Without His	% TEAA With His	% TEAA Without His	EAAA	EArAA	TNAA	% TNAA	TAAA	% TAAA	TBAA	%TBAA	TSAA	% Cystine in TSAA
Leaves	54.84	28.37	51.73	26.47	23.31	48.27	42.51	14.93	3.37	42.81	78.06	11.1	20.24	9.42	17.18	2.01	60.2
Bulb	74.85	45.53	60.83	29.32	27.02	39.17	36.1	16.46	4.17	62.28	83.21	19.34	25.84	12.57	16.79	2.58	49.22

Total Amino Acid (TAA), Total Non-Essential Amino Acid (TNEAA), Total Essential Amino Acid (TEAA), Essential Aliphatic Amino Acid (EAAA), Essential Aromatic Amino Acid (EArAA), Total Neutral Amino Acid (TNAA), Total Acidic Amino Acid (TAAA), Total Basic Amino Acid (TBAA), Total Sulphur Amino Acid (TSAA)

Figure 5: Concentrations of essential, non-essential, acidic, neutral, sulphur, aromatic, etc. of the onion (*Allium cepa*) bulb and leaves



	Isoleucine	Leucine	Lysine	Meth + Cys (TSAA)	Phen + Tyr	Threonine	Trythophan	Valine	Total
PAAESP (g/100 g protein)	4	7	5.5	3.5	6	4	1	5	36
Onion bulb EAAC	3.3	7.41	3.74	2.58	7.95	2.39	1.34	3.36	32.07
Onion bulb EAAS	0.83	1.06	0.68	0.74	1.33	0.6	1.34	0.67	7.25
Onion leaves EAAC	2.88	6.1	3.08	2.01	5.78	3.02	1.05	3.01	26.93
Onion leaves EAAS	0.72	0.87	0.56	0.57	0.96	0.76	1.05	0.6	6.09

Figure 6: Amino acid scores of the onion (*Allium cepa*) bulb and leaves

The amino acid scores (Fig. 6) showed that the value of the bulb sample was relatively high in comparison to the leaves. Nevertheless, except for leucine, phenylalanine + tyrosine, and tryptophan in the bulb, tryptophan in the leaves, the majority of the essential amino acids were below the reference pattern of the FAO/WHO [22]. This would imply that the diets that are largely composed of *Allium cepa* would need to be supplemented with some of the necessary amino acids, especially methionine, cysteine, valine, isoleucine, threonine, and lysine. It is not a secret that many of the important amino acids, including methionine (and cysteine), lysine, and tryptophan, are commonly low in plant protein sources [48]. In line with this, methionine and cysteine (TSAA) were found to be the first limiting amino acids of the two samples, whereas isoleucine and lysine were found to be the second limiting amino acids.

Conclusion

This study indicates that *Allium cepa* has significant amounts of nutritional constituents and antinutritional factors, although there were significant differences between the leaf and the bulb samples. The leaf had a greater concentration of carbohydrates and mineral constituents, as compared to the bulb, which had a higher level of protein and fat. Essential amino acids (lysine and phenylalanine) were also found to be higher in the bulb. The leaves, on the other hand, had a higher predicted protein efficiency ratio (P-PER), indicating that the protein in the leaves was relatively more efficient in promoting growth. Comprehensively, these findings indicate nutritional promise that both the bulb and leaves of *Allium cepa* exhibit. Taken in proper amounts, they may play a significant role in the fulfilment of human nutritional needs, as well as normal growth and improved resistance to malnutrition diseases.

Conflict of interest: The authors have declared that there is no conflict of interest reported in this work.

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