Nutritional Evaluation of Cassava Meal Components and Maize in Securing Feed and Food

Shahabuddin Ahmed [1,2], Mrityunjoy Biswas [2*], Atiqur Rahman Sunny [3], Farhana Irin [4], Md Faruk Hossain [5], Md Mostafizur Rahman [5], Md Abu Bakar Siddique [5], Md. Alauddin [6], Mrinal Kanti Debnath [2], Md. Pallob Hossain [2], Tufael [3, 7]

Abstract

Background: Cassava and maize are significant crops globally, contributing to both human and animal nutrition. However, there's limited comprehensive research on their nutritional composition across various sections. This study aimed to analyze the main nutritional elements in different parts of cassava and maize to bridge this gap and potentially impact dietary recommendations and food security measures. Methods: Samples of fully matured cassava roots and leaves, as well as maize kernels, were collected and processed into flour. Physico-chemical properties, including ash content, crude protein, crude fat, crude fiber, nitrogen-free extract, metabolic energy, amino acids, minerals, and DPPH free radical activity, were analyzed using established methods. Results: Significant variations were observed in the nutritional composition across different sections of cassava and maize. Cassava leaves exhibited high ash content and crude protein, while maize flour showed higher crude fat. Cassava root and leaf flour mixture had notable mineral content and DPPH free radical activity. Cassava leaves (T3; 44.35±0.70) had the lowest nitrogen-free extract (NFE) concentration, while cassava roots (T2; 82.55±1.33) had the greatest. It's interesting to note that cassava leaves had the highest free radical activity (71.66±1.19) compared to other leaves. Conclusion: Understanding the nutritional profile of cassava and maize sections can inform dietary recommendations and farming practices. Utilizing cassava and its byproducts, particularly in poultry feed, shows promise for improving growth performance, carcass characteristics, and meat quality. This could benefit small-scale chicken farmers by reducing costs and enhancing agricultural productivity.

Keywords: Nutrition, Cassava, maize, proximate analysis, amino acids, minerals, free radical activity

Significance | This study determined the nutritional composition of cassava and maize, pivotal crops for food and animal feed production globally, offering insights into dietary recommendations, agricultural practices, and food security measures in regions reliant on these staples.

*Correspondence. Dr. Mrityunjoy Biswas, Department of Agro Product Processing Technology, Jashore University of Science and Technology, Jashore- 7408, Bangladesh
E-mail: mrityunjoy_appt@just.edu.bd

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1. Introduction

Cassava meal (Manihot esculenta Crantz), belonging to the genus Manihot and family Euphorbiaceae, has seen a notable surge in global production since 2000, with an annual increase of approximately 100 million tonnes (Feregrino-Pérez et al., 20028; FAO, 2014; Kuddus et al., 2021). Since the 1960s, cassava root output has been steadily rising, with a remarkable increase of over

Author Affiliation.
[1] Department of Animal Nutrition, Faculty of Veterinary, Animal and Biomedical Sciences, Khulna Agricultural University, Bangladesh
2 Department of Agro Product Processing Technology, Faculty of Applied Science and Technology, Jashore University of Science and Technology, Jashore- 7408, Bangladesh
3 Pathfinder Research and Consultancy Center, Bangladesh
4 Health and Nutrition Care Center, Khulna, Bangladesh
5 Department of Biological Sciences, St. John's University,New York, USA
6 Department of Nutrition and Food Technology, Faculty of Applied Science and Technology, Jashore University of Science and Technology, Jashore- 7408, Bangladesh
7 IBN Sina Diagnosis and Imaging Center, Dhaka, Bangladesh

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40% between 1997 and 2007, resulting in 76 million tonnes more being utilized as animal feed (Feregrino-Pérez et al., 20028; FAO, 2014; Kuddus et al., 2021). Crude protein and carbohydrates constitute the primary components of the root's composition (Stupak et al., 2006; Kuddus et al., 2020; Alam et al., 2023). Each hectare yields approximately 10 tonnes of dry cassava leaves, which are abundant in protein, minerals, carotenes, and vitamins B1, B2, and C (Khieu et al., 2005; Kuddus et al., 2022; Hossain et al., 2023). These leaves can be harvested four to five months after planting without causing harm to the root.

Maize (Zea mays L.), acclaimed as the "queen of cereals," owes its status to remarkable genetic potential and rich nutritional content (Hoopen and Maiga, 2012). As a cornerstone of global agriculture, maize significantly impacts food systems, catering to both human and animal needs (De Bosque et al., 1988; Bressani, 1991; Dado, 1999; Milupi, 2019). Widely cultivated across 166 countries, maize occupies over 160 million hectares, thriving in diverse environments (Bhupender K. et al., 2012). In industrialized nations like the US, EU, and Canada, maize is predominantly utilized as animal feed or as a raw material for various industries (De Bosque et al., 1988; Bressani, 1991; Dado, 1999; Milupi, 2019). However, its versatility extends to Asian countries, where maize serves both human and animal sustenance needs (De Bosque et al., 1988; Sunny et al., 2017). Emerging nations exhibit varied maize utilization patterns, reflecting its adaptability and significance (De Bosque et al., 1988; Sunny et al., 2017). Despite its global prominence, maize's role in India's food landscape is noteworthy, ranking as the third-most significant food crop after rice and wheat (De Bosque et al., 1988; Sunny et al., 2017). A significant portion of maize production in India is allocated for food consumption, seed purposes, wet milling, animal feed, and poultry feed, highlighting its multifaceted contributions to food security and industrial applications (De Bosque et al., 1988; Sunny et al., 2017).

Research on the nutritional composition of various parts of cassava and maize has been limited to date. This study aimed to address this gap by comprehensively analyzing the main nutritional components, including carbohydrates, proteins, lipids, vitamins, and minerals, present in the roots, leaves, and grains of both crops. The findings of this study could have significant implications for dietary recommendations, agricultural practices, and strategies aimed at ensuring food security in regions reliant on maize and cassava.

2. Materials and Methods

2.1 Sample gathering and preparation

The experimental samples were taken at their fully matured state, with the exception of the leaves, which were taken before they turned brown and transported to the analytical lab of the Department of Agro Product Processing Technology at Jashore University of Science and Technology in Jashore. Fresh cassava roots were sliced into thin slices and cassava leaves were chopped after the bruised, wounded, and damaged cassava roots were sorted. Then, maize, diced cassava leaves, and sliced cassava root were put in a cabinet dryer (FP 240-UL, USA). The samples were allowed to dry before being ground into a fine powder using a heavy-duty grinder and sieved using a conventional 40-mesh sieve. The flour samples were carefully sealed in a high-density polyethylene container and kept for later examination.

2.2 Experimental grouping

The groups were designated and maintained as follows:

Group T1: Maize flour

Group T2: Cassava root flour

Group T3: Cassava leaves flour

Group T4: Cassava root 50% and Cassava leaves 50% flour

2.3 Physico-chemical properties

2.3.1 Ash Content

The AOAC (2016) approach was employed to quantify the ash content of cassava and maize. Each sample received two grammes of material, which were measured and then put into a silica-based crucible. After that, the crucible was heated to 600°C for three to six hours while being housed inside a muffle furnace. The crucible was then dried and its mass was determined when it had cooled down. Once the crucible had been reheated for 0.5 hours, its weight was recorded to confirm that the ashing process had been completed. Three further measurements produced the same results after the previously described process was continued until the ash attained a primarily whitish or greyish tone. Using the following formula, the percentage of ash content was calculated:

$$\text{Ash content (\%)} = \frac{\text{Residue weight (g)}}{\text{Sample weight (g)}} \times 100$$

2.3.2 Crude Protein

The Micro-Kjeldahl method previously mentioned by Zhang et al. (2005) was used to determine the total nitrogen concentration. Utilising a factor of 3.24, the protein content that was obtained was computed as nitrogen. After being broken down at 380°C with sulfuric acid and a catalyst mixture present, the sample's nitrogen content was changed to ammonium sulphate. Nitrogen and protein % were determined using the following formulas, after the digest was distilled with a sodium hydroxide (NaOH) solution that had been titrated and charmed by boric acid to release the ammonia.

$$\text{Nitrogen } (N_2)\ \% = \frac{(V_1 - V_2)\ \times N \times 0.014}{\text{Weight of sample (g)}} \times 100$$

Where, V_1 = ml of HCl for sample; V_2 = ml of HCl for Blank and N = Normality of HCl

$$\text{Protein content (\%)} = \text{Nitrogen (\%)} \times \text{Conversion factor (3.24)}$$

2.3.3 Crude fat

The AOAC (2005) soxhlet extraction method was used to determine the fat content of the sample. After carefully weighing the 5 g dried samples in a filter paper, they were placed inside the thimble. After being put in the Soxhlet extraction chamber, the thimble was extracted with ethanol for eight hours at a condensation rate of three drops per second. The weight of the extraction flask before and after extraction was subtracted to determine the percentage of fat.

$$\text{Crude fat (\%)} = \frac{\text{Weight of empty flask (g)} - \text{Weightof flask with extract (g)}}{\text{Weight of sample (g)}} \times 100$$

2.3.4 Crude fibre

The methodology outlined by the AOAC (2005) was used to determine the crude fibre content. After weighing the 2 g flour sample, it was put into a glass beaker with a capacity of 600 ml. 200 cc of sulfuric acid was added to the beaker almost to the boiling point while bumping grains were added. Subsequently, the samples were periodically rotated while boiling for 30 minutes. Refluxing was then filtered and fitted with a rubber cap. Following filtration, the residue was cleaned with warm water and 12.5% sodium hydroxide until it was completely dry. After being removed from the crucible, the residue was dried for two hours at 130 °C and then chilled in a desiccator. After the samples were ashened at 550 °C and allowed to cool, the crude fibre content was determined by measuring the final weight and calculating the percentage.

2.3.5 Nitrogen free extract and Total Carbohydrates

The nitrogen-free extract was derived (on a dry matter basis) by deducting the total of crude protein, crude fat, crude fibre, and total ash from factor 100.

% NFE = 100- (% CP + % C fat + % CF + % ash)

2.3.6 Metabolic energy

The following formula was used to compute the metabolizable energy (ME) using Pauzenga's (1985) method:

ME (kcal/kg DM) = (37 x % CP) + (81.8 x % fat) + (35.5 x % NFE).

2.4 Amino Acid

The approach of Baxter (1996) was used to perform the composition of amino acids. 6M HCl was used to hydrolyze the defatted sample (100 mg) for 24 hours at 110 C. After the hydrolyzed sample was filtered via a 2 µm membrane filter and redissolved in Na citrate buffer (pH 2.2), it was fed into the High-Performance Amino Acid Analyzer (Biochrom 20, Auto Sampler Version, Amersham Pharmacia Biotech., Sweden). The FAO (1990) reference pattern was used to compare the levels of different amino acids, which were expressed as grammes per 100 g of protein.

2.5 Minerals

The tested powder was dissolved in a solution of nitric and perchloric acids (4:1, v/v) in order to determine the minerals present. An atomic absorption spectrophotometer (Thermo Electron Crop., S series, AA spectrometer, Type S4AA system, built in China) was used to analyse minerals, including Ca. The phosphomolybdovanate technique was used to determine the phosphorus concentration (Lees, 1968; Pauzenga, 1985; AOAC, 2005).

2.6 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) free radical activity

We used the protocol outlined by Feregrino-Pérez et al. (2008) to test the cassava gari's ability to scavenge DPPH radicals. after making some changes. 150µL of DPPH (1 mM) was added to the 40µL sample solution in a 96-well microplate (New York, USA). Using a multimode reader (Tecan SPARK 10M, V1.2.20, Austria), the solution was mixed for 40 seconds, and it was then incubated for 40 minutes in a dark area. Utilizing a multimode reader (Tecan SPARK 10M, V1.2.20), the absorbance was measured at 517 nm following incubation. Using the Trolox as a benchmark, the outcomes were assessed.

2.7 Statistical Analysis

The experimental data for each parameter was measured and statistical analysis was performed in order to provide a more thorough explanation. Every data set was completed in duplicate, with three total. Statistical analysis was conducted using analysis of variance (ANOVA) and the Statistical Package for Social Sciences (SPSS) software 17.0 (IBM INC., New York). The results were represented as the mean ± standard deviation (SD) and statistical significance was examined.

3. Results and discussion

3.1 Physical-chemical characteristics

3.1.1 Content of ash

There were noticeable differences between the ash contents of the various sections of maize and cassava. The T3 sample had the highest ash content (7.54±13) out of all the samples, whereas the T1 sample had the lowest ash value (2.1±10). As compared to T2 (2.96±0.05) and T3, the ash concentration (5.64±10) of the T4 sample is much higher. Similar findings have been reported by Boukhers et al., (2022), who found that 57–125 g/kg of ash is present in cassava leaves.

3.1.2 Content of Crude Protein

There was a substantial ($p<0.5$) difference in the crude protein content between the samples (Table 1). T3 sample had the highest crude protein concentration (19.75±0.34), whereas T1 sample had the lowest crude protein level (2.55±0.06). On the other hand, the crude protein content (11.22±0.52) in the T4 sample was lower than in T3 and greater than in T1. Because of cultivar heterogeneity, the crude protein content of cassava root is higher than Boukhers et al.,

Table 1. Physical and chemical characteristics of maize and cassava meal component.

Treatment	Ash	Crude Protein	Crude Fat	Crude Fibre	NFE	ME kcal/kg
T1	2.1±10^{d}	8.91±0.08^{c}	4.36±0.06^{b}	1.98±0.06^{d}	71.24±1.44^{b}	3175.85±7.42^{a}
T2	2.96±0.05^{c}	2.55±0.06^{d}	0.98±0.04^{c}	3.44±0.15^{c}	82.55±1.33a	3061.8±12.42^{b}
T3	7.54±13^{a}	19.75±0.34^{a}	6.85±0.17^{a}	12.56±0.39^{a}	44.35±0.70^{d}	2825.75±16.02^{d}
T4	5.64±10^{b}	11.22±0.52^{b}	4.412±0.10^{b}	8.234±0.34^{b}	63.754±0.97^{c}	2999.145±16.58^{c}
LSD	0.1896	0.5905	0.1990	0.5057	2.1607	25.62
CV%	2.21	2.94	2.54	4.07	1.75	0.4512

Table 2. Amino acid content of cassava meal component and maize.

Treatment	Lysine	Methionine
T1	1.64±0.02^{b}	0.81±0.02^{a}
T2	0.075±0.00^{d}	0.035±0.00^{d}
T3	1.828±0.04^{a}	0.37±0.01^{b}
T4	0.97±0.02^{c}	0.195±0.00^{c}
LSD	0.0493	0.0235
CV%	2.31	3.53

Table 3. Minerals content of cassava meal component and maize.

Treatment	Ca	P
T1	0.03±00^{d}	0.34±0.01^{c}
T2	0.21±0.01^{c}	0.223±0.01^{d}
T3	2.12±0.05^{a}	0.854±0.02^{a}
T4	1.148±0.02^{b}	0.5365±0.01^{b}
LSD	0.0485	0.0238
CV%	2.92	2.57

Table 4. DPPH free radical scavenging activity of cassava meal component and maize

Treatment	DPPH (%)
T1	65.25±0.98^{b}
T2	50.68±1.00^{d}
T3	71.66±1.19^{a}
T4	60.57±1.16^{c}
LSD	2.0420
CV (%)	1.74

(2022) observations. Similar findings about the crude protein content of cassava leaves have been reported by Ravindran (1992).

3.1.3 Content of crude fat

There was an almost significant variation in the crude fat content between the different portions of cassava and whole maize flour (Table 1). The T3 samples had the highest crude fat content (6.85±0.17), while the T2 sample had the lowest crude fat level (0.98±0.04). However, the crude fat percentages of the T1 and T4 samples (4.36±0.06 and 4.412±0.10, respectively) were noticeably similar. Similar findings regarding the crude fat content of cassava leaves have been

reported by Ravindran (1992). The percentage of crude fat in different kinds of maize varied from 3.21 to 7.71%, according to Uchechukwu-Agua et al. (2010).

3.1.4 Content of Crude Fibre

There was an almost significant difference in the fibre composition between the different portions of cassava and whole maize flour (Table 1). Out of all the samples, the T3 sample had the highest crude fibre content (12.56±0.39), whereas the T1 sample had the lowest (1.98±0.06). The crude fibre content (8.234±0.34) in the T4 sample is considerably greater than that of T2 (3.44±0.15) and lower than that of T3. Similar findings have been reported by Ravindran (1992), who found that 48–290 g/kg of crude fibre can be found in cassava leaves. The amount of crude fibre in cassava roots is larger than what Eliangela de Morais Teixeira (2005) found. Corn powder's crude fibre concentration is consistent with the findings ofUchechukwu-Agua et al. (2010).

3.1.5 Nitrogen-Free Formula

There was an almost significant difference in the NFE content between the different portions of cassava and whole maize flour (Table 1). Out of all the samples, the T2 sample had the highest NFE level (82.55±1.33), whereas the T3 sample had the lowest NFE content (44.35±0.70). NFE content (71.24±1.44) in the T1 sample is significantly greater than that of T4 (63.754±0.97) and lower than that of T2. Because of cultivar heterogeneity, the nitrogen free extract of maize is higher than what E O Akinfala and Tewe (2001) observed.

3.1.6 The Content of Metabolic Energy

varying portions of cassava and whole maize flour had nearly noticeably varying amounts of metabolic energy (Table 1). The T1 sample had the highest metabolic energy content (3175.85±7.42) out of all the samples, whereas the T3 sample had the lowest metabolic energy content (2825.75±16.02). Metabolic Energy content of the T2 sample is 3061.8±12.42, which is significantly greater than that of the T4 sample (2999.145±16.58) and lower than that of the T1 sample. Cassava roots and leaves have a larger Metabolic Energy content than Yeoh and Truong (1996) observed, owing to cultivar variety.

Legends: At 5% significance, results are shown as mean ± standard deviation; distinct superscript letters in a column denote significant differences; T1: maize flour; T2: cassava root flour; T3: cassava leaf flour; T4: 50% maize flour with 50% cassava root flour. Metric Energy is ME, and Nitrogen Free Extract is NFE.

3.2 Amino acid

There were notable differences observed in the amino acid composition (Lysine and Methionine) between the various components of cassava and maize flour (Table 2). Lysine levels were lowest in the T2 sample (0.075±0.00) and highest in the T3 sample (1.828±0.04). The T4 samples had a notably higher lysine content (0.97±0.02) than the T4 samples. Regarding methionine, the T1 sample had the largest amount (0.81±0.02), whereas the T2 sample had the lowest amount (0.035±0.00). The T3 sample had lower methionine levels (0.37±0.01) than the T1 sample, but higher levels (0.195±0.00) than the T4 sample.

Legends: The mean ± standard deviation of the results is shown; distinct superscript letters in the column denote significant differences at 5%: T1 represents maize flour, T2 represents cassava root flour, T3 represents cassava leaf flour, and T4 represents 50% cassava root flour plus 50% cassava leaf flour.

3.3 Minerals

The mineral content of the sample (Ca and P) is shown in Table 3. These components are necessary for the physiological development and general health of animals. One or both of these mineral components may be deficient in an animal, which would result in a poor nutritional state. The T4 sample had the highest Ca and P content (1.148±0.02 and 0.5365±0.01, respectively), while the T3 sample had a larger Ca and P content (2.12±0.05 and 0.854±0.02, respectively). The T1 sample had the lowest Ca concentration (0.03±00), but the P content (0.34±0.01) was larger than the T2 sample (0.223±0.01). On the other hand, the T2 sample showed significantly more Ca (0.21±0.01) but less P (0.223±0.01) than the T1 sample. Strain variance may have contributed to the greater calcium and phosphorus content of cassava leaves compared to the findings of Ravindran (1992).

Legends: The mean ± standard deviation of the results is shown; distinct superscript letters in the column denote significant differences at 5%: T1 represents maize flour, T2 represents cassava root flour, T3 represents cassava leaves flour, and T4 represents 50% cassava root flour plus 50% cassava leaf flour.

3.4 Free radical activity result

The found substantial variations in the DPPH concentration of the different sections of cassava and maize are shown in Table 4. Antioxidants prevent tissue damage brought on by free radicals by scavenging free radicals, promoting their breakdown, or preventing their formation. Of all the samples, the T3 sample had the greatest DPPH concentration (71.66±1.19), whereas the T2 sample had the lowest DPPH level (50.68±1.00). The DPPH concentration of T1

(65.25±0.98) is much higher than that of T4 (2.96±0.05) and lower than that of T3. Boukhers et al. (2022) reported similar results using the same DPPH (%) in cassava leaves. Omar et al. (2012) made a comparable observation that states the DPPH (%) of the cassava root is the same.

Legends: The results are shown as mean ± standard deviation; at 5%, significant differences are shown by different superscript letters in the column. T1: maize flour; T2: cassava root flour; T3: cassava leaf flour; T4: 50% flour from cassava roots with 50% flour from cassava leaves.

3.5. Controlling Poultry Disease using Nutritional Feed Strategies

Increased disease resistance and decreased infection risk in chicken production are directly related to the nutritional makeup of the feed. The intricate relationship between immune function and food must be understood in order to design effective disease management strategies for chicken production systems (Boukhers et al., 2022). The functioning of the immune system and lowering susceptibility to infections depend on vital nutrients including vitamins and minerals. The gut microbiota is kept under check by include prebiotics, probiotics, and symbiotics in meal compositions (AOAC, 2016). Feed components with antioxidants boost immunity and reduce the risk of disease by preventing oxidative stress-related damage (Kumar et al., 2011). By modifying feed formulations to meet the specific requirements for amino acids of various chicken species and growth stages, robust immune response and disease resistance are preserved. A mismatch in the amino acid profiles can erode an individual's resistance to illness and increase susceptibility. Because nutritious feed practices offer several benefits, including improved immunity system performance, reduced susceptibility to disease, and increased overall well-being and productivity, they are therefore an essential part of efforts to prevent poultry diseases.

4. Conclusions

Poultry products, particularly meat, hold significant potential to fulfill dietary requirements due to their short raising period and low feed conversion ratio (FCR). The growth and quality of chicken carcasses are directly influenced by the energy and protein content in the diet. Introducing cassava meal as a protein and energy source can enhance the growth performance, carcass characteristics, and meat quality of broiler chickens. This presents promising benefits for small-scale chicken farmers, enabling them to produce broiler feed more affordably, increase revenue, and expand their agricultural activities.

Taken together, the study demonstrated the nutritional composition of cassava and maize, emphasizing their significance in global agriculture and food security. Cassava, experiencing a substantial surge in production since 2000, serves as a vital food and feed source, with its roots and leaves rich in essential nutrients. Maize, acclaimed as the "queen of cereals," plays a pivotal role in meeting dietary needs worldwide, particularly in industrialized nations where it is predominantly utilized as animal feed. The research findings underscore the potential of cassava and maize as valuable dietary resources, with implications for agricultural practices and food security measures, especially in regions reliant on these crops. Moreover, the comprehensive analysis of the nutritional components of cassava and maize provides valuable insights for optimizing dietary recommendations and formulating strategies to ensure food security. Furthermore, this study showed potential of cassava meal in enhancing the growth performance and meat quality of broiler chickens, offering promising advantages for small-scale chicken farmers. This study filled gaps in understanding cassava and maize nutrition, aiding sustainable agriculture and food production. It emphasized their global significance and suggested ways to enhance their nutritional value and agricultural yield, contributing to broader discussions on food security and sustainability.

Author contributions

SA, MB, and ARS conceptualized the study, conducted fieldwork, analyzed the data, wrote the original draft, edited the manuscript, acquired funding, and reviewed it. FI, MFH, MMR, and MAB contributed to research design, validated the methodology, analyzed data, visualized results, reviewed, and edited the manuscript. MA and MKD conceptualized the study, conducted investigations, visualized data, reviewed, edited, and proofread the manuscript. MPH and TM conceptualized the study, validated the methodology, analyzed data, conducted investigations, reviewed, acquired funding, supervised the project, and edited the manuscript. All authors approved the manuscript after reading the published version.

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Competing financial interests

The authors have no conflict of interest.

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