

Cassava (*Manihot esculenta* Crantz) root as a substitute of maize for broiler diets – Evidence from growth performance, carcass characteristics, hematobiochemical profile, meat quality and sensory properties

Shahabuddin Ahmed

Khulna Agricultural University

Hemayet Hossain

Sylhet Agricultural University

Khadiza Akter Brishty

University of Dhaka

Asraful Alam

Jashore University of Science and Technology

Md. Amir Hossain

Khulna Agricultural University

Md. Sazedul Karim Sarker

BLRI: Bangladesh Livestock Research Institute

Aminul Islam

BLRI: Bangladesh Livestock Research Institute

Md. Alauddin

Jashore University of Science and Technology

M Shalim Uddin

BARI: Bangladesh Agricultural Research Institute

Md. Masudur Rahman

Sylhet Agricultural University

Abdulrahman Alasmari

University of Tabuk

Akbar Hossain

tanjimar2003@yahoo.com

Bangladesh Wheat and Maize Research Institute <https://orcid.org/0000-0003-0264-2712>

Md. Mahfujur Rahman

Sylhet Agricultural University

Mrityunjoy Biswas

Jashore University of Science and Technology

Research Article

Keywords: Broiler, cassava root meal, growth performance, phenolic content, meat quality, flavonoid content

Posted Date: November 3rd, 2025

DOI: <https://doi.org/10.21203/rs.3.rs-7785923/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Cassava (*Manihot esculenta* Crantz) root as a substitute of maize for broiler diets – Evidence from growth performance, carcass characteristics, hematobiochemical profile, meat quality and sensory properties

Shahabuddin Ahmed^{1,2}, Hemayet Hossain³, Khadiza Akter Brishty⁴, Asraful Alam², Md. Amir Hossain⁵, Md. Sazedul Karim Sarker⁶, Aminul Islam⁶, Md. Alauddin^{7,8}, M Shalim Uddin⁹, Md. Masudur Rahman¹⁰, Abdulrahman Alasmari¹¹, Akbar Hossain^{12*}, Md. Mahfujur Rahman¹³, Mrityunjoy Biswas²

¹ Department of Animal Nutrition, Faculty of Veterinary, Animal and Biomedical Sciences, Khulna Agricultural University, Khulna 9202, Bangladesh; drsahmedvet@gmail.com (S.A.)

² Department of Agro Product Processing Technology, Jashore University of Science and Technology, Jashore 7408, Bangladesh; a.alam@just.edu.bd (A.A.), mrityunjoy_appt@just.edu.bd (M.B.)

³ Department of Anatomy & Histology, Sylhet Agricultural University, Sylhet 3100, Bangladesh; hemayet.vabs@student.sau.ac.bd (H.H.)

⁴ Department of Zoology (GSSC), University of Dhaka, Dhaka, Bangladesh; brishtydu20@gmail.com (K.A.B.)

⁵ Department of Poultry Science, Faculty of Veterinary, Animal and Biomedical Sciences, Khulna Agricultural University, Khulna 9202, Bangladesh; amir.hossain.1418@gmail.com (M.A.H.)

⁶ Poultry Research Center, Bangladesh Livestock Research Institute, Savar, Dhaka 1341, Bangladesh; sazdulkarim@yahoo.com (M.S.K.S.); dr.aminul@blri.gov.bd (A.I.)

⁷ Department of Nutrition and Food Technology, Faculty of Applied Science and Technology, Jashore University of Science and Technology, Jashore 7408, Bangladesh; mdalauddin_nft@just.edu.bd (M.A.)

⁸ Department of Biochemistry and Molecular Biology, Faculty of Biological Science and Technology, Jashore University of Science and Technology, Jashore 7408, Bangladesh.

⁹ Oilseeds research Center, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, 1701, Bangladesh; shalimuddin40@gmail.com (M.S.U.)

¹⁰ Department of Pathology, Sylhet Agricultural University, Sylhet 3100, Bangladesh; rahmanmm.dpp@sau.ac.bd (M.M.R.)

¹¹ Department of Biology, Faculty of Science, University of Tabuk, Tabuk 71491, Saudi Arabia; ab.alasmari@ut.edu.sa (A.A.)

¹² Soil Science Division, Bangladesh Wheat and maize Research Institute, Dinajpur, 5200, Bangladesh; tanjimar2003@yahoo.com (A.H.)

¹³ Department of Medicine, Sylhet Agricultural University, Sylhet 3100, Bangladesh; mahfuj.vet-med@sau.ac.bd (M.M.R.)

*Corresponding author: Akbar Hossain: tanjimar2013@yahoo.com (corresponding author)

Cassava (*Manihot esculenta* Crantz) root as a substitute of maize for broiler diets – Evidence from growth performance, carcass characteristics, hematobiochemical profile, meat quality and sensory properties

Abstract: The abundance and affordability of cassava root, a carbohydrate-dense tuber, in tropical regions have drawn attention to it as a possible substitute of conventional energy source in poultry ration. This study investigated the impact of substituting maize meal with varying amounts of cassava root meal on the growth performance, carcass characteristics, hemato-biochemical parameters, meat composition and sensory properties of broiler chickens. In this study, 400 broiler chicks (Arbor Acres) were assigned to four treatment groups: T₁ (0%, diet without cassava root meal; CRM) and T₂, T₃ and T₄ containing 10%, 20% and 30% cassava root meal, respectively. Each group had five replicates consisting of 20 birds each, and trial ran for 35 days. The results indicated that broilers on the T₂ group had significantly higher body weight, feed intake and feed efficiency ratio, with a lower FCR. T₂ also showed exceptional carcass characteristics without adversely affecting meat quality and blood parameters of broilers. The proximate composition of breast and thigh muscles showed significant changes. Diet having 10% CRM had the highest amount of total phenolic content, total flavonoid content and DPPH scavenging activity along with the best overall acceptability. In summary, our research indicates that cassava root meal can be used as a substitute for maize grains in broiler diets, without any adverse effects on the broiler's growth performance and general health status. It is recommended that maize can be replaced by 10% CRM for promoting the growth, meat quality and healthy blood profile of broilers.

Keywords: Broiler, cassava root meal, growth performance, phenolic content, meat quality, flavonoid content

Abbreviations

AA	Arbor Acres
ADG	Average Daily Gain
ALT	Alanine Aminotransferase
ALP	Alkaline Phosphatase
ANOVA	Analysis of Variance
AST	Aspartate Aminotransferase
CF	Crude Fiber
CRM	Cassava Root Meal
CP	Crude Protein
DCP	Dicalcium Phosphate
DL	Drip Loss
DPPH	2,2-Diphenyl-1-picrylhydrazyl

EE	Ether Extract
EDTA	Ethylene Diamine Tetra Acetic Acid
FCR	Feed Conversion Ratio
FER	Feed Efficiency Ratio
FBW	Final Body Weight
HDL	High-Density Lipoprotein
HCN	Hydrogen Cyanide
IRRI	International Rice Research Institute
LDL	Low-Density Lipoprotein
LSD	Least Significant Difference
ME	Metabolizable Energy
MCH	Mean Corpuscular Hemoglobin
MCHC	Mean Corpuscular Hemoglobin Concentration
MCV	Mean Corpuscular Volume
NFE	Nitrogen Free Extract
NRC	National Research Council
PCV	Packed Cell Volume
RH	Relative Humidity
RBS	Random Blood Sugar
RBC	Red Blood Cell
STAR	Statistical Tool for Agricultural Research
TPC	Total Phenolic Content
TFC	Total Flavonoid Content
TFI	Total Feed Intake
WHC	Water Holding Capacity
WBC	White Blood Cell

1. Introduction

Poultry production is one of the fastest-growing sectors in the livestock industry worldwide, driven by the increasing demand for high-quality protein sources such as chicken meat [1]. However, the high and variable cost of conventional feedstuffs (especially maize) present major constraints to sustainable broiler production. As the main source of energy in poultry feed, maize represents a large proportion of feed costs and must also contend with human consumption and industrial use [2]. Now-a-days it is an alarming issue for the inadequate supply of maize as main energy source feed ingredient for livestock

feeding [3]. The increasing growth of the animal's sector and the continuous increase of the global population have caused growing concern about the challenge for food supplies between humans and animals. This issue holds significant impact, particularly in developing countries like Bangladesh. Therefore, it is vital to evaluate alternatives to energy that have the ability to substitute grain. Cassava (*Manihot esculenta*) has superior land productivity, with yields ranging from 25 to 60 metric tons per hectare, surpassing those of maize [2]. Furthermore, cassava meals have resulted in reduced manufacturing expenses and has a greater starch content that spans a wider range from 70% to 80% [4]. A study recommended the potentials of using cassava root as a viable substitute for maize in chicken feed [4]. Crude protein and carbohydrates are the main constituents of the cassava root [5–7]. Cassava roots are rich in carbohydrates, ash, crude protein, and minerals [8]. Moreover, it exhibited 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical activity [9]. Because of its elevated starch content, cassava root meals have the capacity to function as a viable substitute for maize and other cereal grains. The application of suitable processing techniques, such as boiling, sun-drying, marinating, and fermenting, can lower the amounts of cyanogenic glycosides in cassava [10]. Numerous research have looked at the effects of using pre-treated or cassava instead of maize meal as an energy source in chicken feed. They have also looked at how to increase the availability of glucose and improve the efficiency of its absorption [11–13]. The rising and falling demand for maize from both the human population and industrial consumers might potentially result in a substantial escalation in maize prices in Bangladesh. The search for alternatives to maize as a feed resource led to the cultivation of cassava root. Previous study has displayed that including cassava root concentrate into broiler meals might yield positive outcomes when the nutrients are appropriately harmonized [14]. However, the outcomes may change according to the specific ratios of various cassava sources, broiler species, and treatment methods. For small-scale chicken growers, this could result in lower costs and more agricultural efficiency. The impact of alternating fed maize to cassava root on growth performance, carcass features, and meat quality of broiler chickens, however, was not extensively investigated. The purpose of this study was to investigate the effects of replacing maize with cassava root on broiler chicken growth performance, carcass features, hemato-biochemical profile, breast and thigh meat composition, and sensory attributes.

2. Materials and Methods

2.1. Ethical statement

The Ethical Review Committee of the Jashore University of Science and Technology, Jashore, Bangladesh, provided permission for the animal-based research methods used in this study (ERC/FBST/JUST/2023-152).

2.2. Preparation of the cassava root meal

Freshly harvested cassava roots were cleaned, peeled, and chopped into smaller segments. Peeling significantly reduced cyanide content, particularly in sweet cassava varieties where hydrogen cyanide (HCN) is primarily concentrated in the peel. Chopped segments were sun-dried on protected concrete surfaces for seven days, reducing soluble cyanide compounds. Sun drying on slanted trays preserved linamarase enzyme activity, facilitating cyanogenic glycoside neutralization [15]. Dried cassava chips were ground into a fine powder and stored in polythene bags [16]. According to Ahmed *et al.* [8] the nutrient values of cassava root meal were as follows: ash 2.96%, crude protein 2.55%, crude fat 0.98%, crude fiber 3.44%, nitrogen free extract (NFE) 82.55% and metabolizable energy (ME) 3061.8 kcal/kg.

2.3. Experimental design, rations, treatments and management of broiler

In the feeding study, 400-day-old commercial broiler chicks (Arbor Acres, AA marketed by Nourish Poultry Hatchery Limited, Dhaka, Bangladesh) of either sex were weighed and assigned randomly into four treatment groups (T₁, T₂, T₃, and T₄), each consisting of five replications and twenty chicks per replications (a total of 100 birds per treatment), with the treatments being control, 10%, 20%, and 30% cassava root meal as an alternative to maize, accordingly. NRC (1994) standards were followed for creating the broiler ration, which consisted of a starter feed for the first 21 days and a grower feed for the next 22 to 35 days. The nutrient contents and trial feed ingredients utilized in this trial are all listed in Table 1.

Table 1: Proportion of ingredients used in formulating experimental diets (DM basis).

Item (%)	Treatments							
	T ₁		T ₂		T ₃		T ₄	
	STR	GR	STR	GR	STR	GR	STR	GR
Corn	57.00	60.00	51.30	54.00	45.60	48.00	39.90	42.00
Cassava Root	-	-	5.70	6.00	11.40	12.00	17.10	18.00
Rice polish	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00
Choline chloride	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Soybean meal	26.00	24.00	26.00	24.00	26.00	24.00	26.00	24.00
Probiozyme	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Esel dry	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Fishlog	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Turbotox	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
NaHCO ₃	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lysine	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Sqzyme SME	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Soybean oil	2.25	2.00	2.25	2.00	2.25	2.00	2.25	2.00
Hamecosaldry	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Hamecomolttox	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lime stone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DCP	0.80	1.00	0.80	1.00	0.80	1.00	0.80	1.00
Coccidiostat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
DB Vitamin	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Toxol powder	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100	100	100	100
Analyzed values								
Crude Protein %	21.07	20.34	20.70	19.95	20.33	19.57	19.97	19.18
Crude fat %	3.85	3.80	3.83	3.79	3.81	3.77	3.78	3.74
Crude fiber %	3.46	3.37	3.31	3.22	3.17	3.07	3.03	2.92
Calcium %	0.89	0.94	0.91	0.95	0.92	0.96	0.93	0.97
Phosphorus %	0.44	0.47	0.44	0.48	0.45	0.48	0.45	0.49
Methionine %	0.57	0.61	0.56	0.59	0.55	0.59	0.54	0.58
Lysine %	1.24	1.18	1.23	1.17	1.22	1.16	1.22	1.16
Calculated values								
ME kcal/kg	3038	3037	3038	3037	3034	3033	3030	3031
Digestible Protein %	18.12	17.50	17.68	17.03	17.23	16.56	16.79	16.09

Supplied per kilogram of diet - Vitamin A: 12500 IU; vitamin D3: 1250 IU; vitamin E: 18 IU; vitamin K3: 3.7 mg; thiamine: 1.8 mg; riboflavin: 6.6 mg; calcium pantothenate: 10 mg; niacin: 37.5 mg; pyridoxine: 32.5 mg; vitamin B12: 2.5 mg; Mn (manganese sulfate): 50 mg; Zn (zinc sulfate): 37.5 mg; Fe (ferrous sulfate): 25 mg; Cu (tribasic copper chloride): 7.5 mg. T₁ = Control; T₂ = 10% of Cassava root meal; T₃ = 20% of Cassava root meal; T₄ = 30% of Cassava root meal. DCP= Dicalcium Phosphate; ME = Metabolizable Energy. Starter (d 0 to 21); Grower (d 21 to 35); STR: Starter, GR: Grower.

The open-system chicken house that served as this study shed faced east to west to shield itself from the sun. Natural ventilation, curtain management, and an appropriate lighting system all helped to regulate the temperature and relative humidity (RH). Ample amounts of experimental foods and unlimited access to clean water were provided to broiler chickens every day as they were raised on a deep

litter floor. Using the CEVAC BIL, the experimental chicks were immunized against Newcastle Disease and Infectious Bronchitis. The CEVAC IBDL was used to vaccinate them against Infectious Bursal Diseases, in accordance with the guidelines provided by the manufacturer (Ceva-phylaxia Veterinary Biologicals Co. Ltd., Hungary). According to Akter et al. [17] recommendations, each of the management techniques has been carried out for rearing AA broiler.

2.4. Data collection and experimental procedure

2.4.1. Determination of growth performance

The chicks' initial live weights were recorded at the commencement of the investigation using an electronic weighing scale (Model: HESA 3303). We conducted a weekly analysis of the Final Body Weight (FBW), Total Feed Intake (TFI), Feed Conversion Ratio (FCR), Feed Efficiency Ratio (FER), and Mortality of broiler throughout the course of the investigation following the study [18–20].

Final Body Weight (FBW) gain = Final body weight – Initial body weight

Total Feed Intake (TFI) = Total feed supplied – Feed refusal

Feed Conversion Ratio (FCR) = $\frac{\text{Total Feed Consumption (g)}}{\text{Body Weight Gain (g)}}$

Average Daily Gain (ADG) = $\frac{\text{Final weight} - \text{Initial weight}}{\text{Days}}$

Feed Efficiency Ratio (FER) = $\frac{\text{Final body weight}}{\text{TFI}} \times 100$

Mortality (%) = $\frac{\text{Number of Birds Died}}{\text{Total number of birds at the beginning}} \times 100$

2.4.2. Measurement of carcass characteristics

At 35 days of age, two broilers (10 from each diet group) were randomly chosen from each replication, and they were killed by cervical disarticulation in order to assess the carcass characteristics, determine the weight of the internal organs, and get the necessary samples. Measured the percentage of the chicken's dressed weight that was made up of its thigh, drumstick, shank, breast muscle, wing and internal organs (spleen, gizzard, liver, heart, and small intestine). The organ weights of each bird were measured immediately after slaughtering, and the results were expressed as a percentage of the bird's live weight. Each sample was tested three times, and the mean value was utilized to ascertain the result

[21]. The organs' relative weight was subsequently estimated by utilizing the body weight at the time of slaughter [22].

2.4.3. Hematological and serum biochemical evaluation

Two broilers from each replicate (10 from each diet group) were randomly selected at the age of 35 days. Hematological characteristics were assessed by collecting blood from the wing veins and placing it in labeled containers that contained ethylene diamine tetra acetic acid (EDTA). In order to quantify serum metabolites, an additional set of blood samples was collected in simple vials. The serum was separated after the blood samples were allowed to coagulate following centrifugation. The method reported by Ogbuewu and Mbajorgu, [23] and Hossain et al. [18] was used to measure the hematological parameters, which include PCV, RBC, hemoglobin, WBC, lymphocytes, neutrophils, monocytes, eosinophils, basophils, MCH, MCV, and MCHC. AGAPPE Diagnostics Switzerland GmbH devised the AGGAPPE test kits, which were used to quantify a variety of blood biochemical markers (total protein, albumin, globulin, glucose, urea, creatinine, cholesterol, AST, ALT, and ALP). A BA-88A type semi-automatic chemistry analyzer from Mindray, Nansha, Shenzhen, China was used to evaluate the biochemical parameters of blood.

2.4.4. Meat quality analysis

After the required data on carcass characteristics had been recorded, samples of thigh and breast meat were taken from the same birds used for carcass cut evaluation. The breast and thigh meat samples were processed and placed in hermetically sealed plastic bags, then kept in a sub-zero freezer at a temperature of -4 °C for duration of 5 days. The proximate compositions (Moisture, CP, CF, EE, Ash, NFE, and metabolizable energy) of meat were conducted using the AOAC technique (AOAC, 2003). The proximate composition was expressed on a dry matter basis without any adjustments or modifications. The physical meat quality attributes were estimated by following the methods of Biswas and Mandal, [24].

Accordingly, a method outlined by Cheng et al. [25] was used to calculate the drip loss and water holding capacity of flesh from the breast and thigh. The following equation was used to calculate drip loss:

$$\text{Drip loss \%} = \frac{\text{Initial weight of fresh meat} - \text{weight after thawing}}{\text{Initial weight of fresh meat}} \times 100 \quad 193$$

The interior temperature of the meat was measured using a digital needle-tipped thermometer (H 1145, Hanna Instruments, Padova, Italy). The following formula Vargas-Ramella et al. [26] was used 194
to determine the cooking loss: 195
196

$$\text{Cooking loss \%} = \frac{\text{Weight of fresh meat} - \text{weight of cooked meat}}{\text{weight of fresh meat}} \times 100 \quad 197$$

A portable pH meter (Orion model 301; Orion, Beverly, MA, US) with an electrode was used to 198
measure the pH levels of the breast and thigh muscles after the animals were slaughtered. 199

The DPPH radical scavenging activity of the aqueous supernatant obtained from raw breast and 200
thigh meat was evaluated using the Blois method, as described by Alam et al. [7], with some modifica- 201
tions. Using an SP-870 TURNER Barnstead US analyzer, the absorbance of the solution was deter- 202
mined at a wavelength of 517 nm. An equation was used to quantify the DPPH radical scavenging 203
activity, and it is as follows: 204

$$\text{DPPH radical scavenging activity (\%)} = \left(1 - \frac{\text{Absorbance of sample}}{\text{Absorbance of control}}\right) \times 100 \quad 205$$

The total phenolics were determined by calorimetry using the Folin-Ciocalteu reagent and, with 206
somewhat modified methods, the methods described by Alam et al. [7]. The measurement of flavonoid 207
contents in the breast and thigh meat extracts was conducted using an updated colorimetric approach 208
described by Sakanaka et al. [27], with quercetin being used as the reference compound. Each sample 209
was tested three times to make determinations. 210

2.4.5. Sensory evaluation 212

A team of 10 panelists, who had received some training, were selected to do a sensory evaluation 213
of boiled flesh samples collected from the breast and thigh muscles. Every panelist consumed one sam- 214
ple for each treatment and evaluated their preferences according to the categories of color, taste, texture, 215
and flavor. A 9-point hedonic scale was used, where a rating of 1 indicated great dislike and a rating of 216
9 indicated high liking. 217

2.5. Statistical analysis

All collected data were subjected to one-way Analysis of Variance (ANOVA) using STAR (Statistical Tool for Agricultural Research) software (version 2.0.1, 2014), developed by the Biometrics and Breeding Informatics group of the PBGB Division, International Rice Research Institute (IRRI), Los Baños, Philippines. To investigate the dose response effect, orthogonal polynomial contrasts were used to test the linear and quadratic effects of cassava root meal. Treatment means were compared using the Least Significant Difference (LSD) test at a 5% level of significance to determine statistical differences among treatments. The GraphPad Prism 8.4 was used to make the graphs.

3. Results

3.1. Growth performance

The growth performance of broiler fed diets containing different levels of cassava root meal is presented in Table 2.

Table 2: Growth performance of experimental broilers diets on graded levels of cassava root meal (CRM).

Growth parameters	Treatments				Sig.
	T ₁	T ₂	T ₃	T ₄	
IBW (g)	44.86± 0.92	44.76± 1.06	44.58± 0.89	45.30± 1.13	ns
FBW (g)	1901.70± 0.73 ^d	2087.94± 0.66 ^a	1988.28 ± 0.64 ^b	1957.26±0.61 ^c	***
FBWG (g)	1856.84	2043.18	1943.70	1911.96	
ADG (g)	53.05	58.37	55.53	54.62	
Body weight (g)					
1 st Week	132.26 ± 1.03 ^d	164.60 ± 1.43 ^a	152.08 ± 0.93 ^b	145.34± 1.84 ^c	***
2 nd Week	379.08 ± 9.65 ^d	454.48 ± 1.17 ^a	432.54 ± 0.95 ^{bc}	427.22± 2.08 ^c	***
3 rd Week	733.56 ± 3.86 ^d	775.88 ± 2.20 ^a	760.54 ± 1.61 ^{bc}	750.40± 1.90 ^c	***
4 th Week	1304.68± 0.47 ^d	1397.70± 0.70 ^a	1376.52 ± 0.85 ^b	1361.40±0.65 ^c	***
5 th Week	1901.70± 0.73 ^d	2087.94± 0.66 ^a	1988.28 ± 0.64 ^b	1957.26±0.61 ^c	***
Total Feed intake (g)					
1 st Week	106.04 ± 1.24 ^c	117.04 ± 1.83 ^b	130.64 ± 1.27 ^a	130.76 ± 1.47 ^a	*
2 nd Week	420.82 ± 2.25 ^b	475.48 ± 1.27 ^a	473.02 ± 0.66 ^a	471.82 ± 0.91 ^a	**
3 rd Week	930.54 ± 5.29 ^d	975.46 ± 1.71 ^a	967.40 ± 6.22 ^{bc}	951.10 ± 1.65 ^c	**
4 th Week	1840.02± 0.15 ^d	1957.52± 0.38 ^b	1921.38 ± 0.71 ^c	1988.14± 0.96 ^a	***
5 th Week	3083.30± 0.68 ^d	3107.64± 0.25 ^a	3085.72 ± 1.08 ^b	3037.18± 1.49 ^c	***
Feed Conversion Ratio (FCR)					

Growth parameters	Treatments				Sig.
	T ₁	T ₂	T ₃	T ₄	
1 st Week	0.80 ± 0.004 ^c	0.71 ± 0.01 ^d	0.85 ± 0.003 ^b	0.90 ± 0.01 ^a	*
2 nd Week	1.11 ± 0.003	1.04 ± 0.003	1.09 ± 0.002	1.10 ± 0.006	ns
3 rd Week	1.26 ± 0.002	1.24 ± 0.003	1.27 ± 0.007	1.26 ± 0.005	ns
4 th Week	1.41 ± 0.002 ^b	1.40 ± 0.003 ^{bc}	1.39 ± 0.004 ^c	1.46 ± 0.005 ^a	*
5 th Week	1.66 ± 0.12 ^a	1.49 ± 0.005 ^c	1.58 ± 0.007 ^b	1.59 ± 0.003 ^b	*
Feed Efficiency Ratio (%)					
1 st Week	124.75 ± 0.42 ^b	140.80 ± 2.91 ^a	116.42 ± 1.36 ^c	111.17 ± 0.62 ^c	**
2 nd Week	90.11 ± 0.31 ^b	95.58 ± 0.32 ^a	91.44 ± 0.20 ^b	90.55 ± 0.56 ^b	*
3 rd Week	78.83 ± 0.15	79.54 ± 0.21	78.63 ± 0.42	78.89 ± 0.27	ns
4 th Week	70.90 ± 0.21 ^b	71.74 ± 0.32 ^a	71.64 ± 0.45 ^a	68.47 ± 0.03 ^c	*
5 th Week	61.67 ± .024 ^b	67.19 ± 0.53 ^a	64.43 ± 0.45 ^b	64.44 ± 0.26 ^b	*
Mortality (%)					
1 st Week	0.61 ± 0.32 ^b	0.56 ± 0.02 ^{ab}	0.54 ± 0.34 ^a	0.52 ± 0.23 ^a	*
2 nd Week	0.50 ± 0.01 ^c	0.34 ± 0.23 ^b	0.36 ± 0.07 ^a	0.42 ± 0.09 ^a	*
3 rd Week	0.31 ± 0.05	0.28 ± 0.087	0.28 ± 0.085	0.28 ± 0.34	ns
4 th Week	0.26 ± 0.03	0.26 ± 0.07	0.24 ± 0.028	0.25 ± 0.05	ns
5 th Week	0.24 ± 0.04 ^d	0.16 ± 0.023 ^c	0.19 ± 0.09 ^b	0.22 ± 0.078 ^a	*

The data represent the mean value of 100 samples per treatment; a,b,c d Means (± Standard error mean) with different super-script letters in rows are significantly different (* $P < 0.05$, ** $P < 0.01$ *** $P < 0.001$); T₁ = Control, T₂ = 10% of CRM, T₃ = 20% of CRM, T₄ = 30% of CRM; g = gram; FCR= Feed Conversion Ratio; FER= Feed Efficiency Ratio; ADG= Average Daily Gain; ns: non-significant ($P > 0.05$); IBW= Initial Body Weight, FBW= Final Body Weight, FBWG= Final Body Weight Gain; Sig.: Significance level

Initial body weights were similar among all treatments ($p > 0.05$), indicating uniformity at the start. However, significant differences ($p < 0.05$) were observed in final body weight, with the highest weight recorded in T₂ (2087.94 g), followed by T₃ (1988.28 g), T₄ (1957.26 g), and the lowest in control group T₁ (1901.70 g). A similar trend was noted in average daily gain (ADG), where T₂ birds showed superior growth (58.37 g/day). Weekly body weights and feeding intake were significantly influenced by treatments across all weeks ($p < 0.05$), with T₂ showing higher values. FCR was the best in T₂ during week 5 (1.49), while T₁ showed the poorest FCR (1.66). FER followed a similar pattern, being highest in T₂ across all weeks, particularly week 1 (140.80%) and week 5 (67.19%). Mortality rates remained low across all groups but showed slight variations, with T₂ consistently exhibiting lower mortality throughout the trial ($p < 0.05$). Overall, inclusion of cassava root meals at appropriate levels (T₂) enhanced broiler growth performance, efficiency, and survivability compared to other treatments (Table 2).

3.2. Carcass characteristics

The inclusion of cassava root meal in broiler diets significantly influenced carcass traits and internal organ development ($P < 0.05$) as shown in Table 3. The highest dressing percentage was observed in T₂ (75.50%), followed by T₃ (73.12%), with T₁ and T₄ showing lower values. Head, neck, thigh, drumstick, breast, abdominal fat, shank, crop, kidney, lung, spleen, liver, heart, and gizzard weights all differed significantly among treatments. Notably, broilers in T₂ consistently showed superior carcass yields, including highest values for breast (28.21%), drumstick (16.51%), and thigh (15.18%) weights. Internal organ weights such as kidney (1.54%), spleen (0.46%), liver (3.92%), and heart (1.49%) were also highest in T₂, indicating enhanced physiological development. The lowest values for most parameters were observed in T₁ and T₄, suggesting suboptimal utilization at those cassava inclusion levels. Proventriculus weight showed minor variation but remained statistically significant ($P = 0.031$) (Table 3).

Table 3: Carcass yield characteristics of experimental broilers diets on graded levels of cassava root meal at the age of 35 days.

Parameters	Treatments				Sig.
	T ₁	T ₂	T ₃	T ₄	
Dressing weight (%)	72.68 ± 0.52 ^b	75.50 ± 0.44 ^a	73.12 ± 0.47 ^b	72.64 ± 0.41 ^b	*
Head weight (%)	2.38 ± 0.02 ^d	2.65 ± 0.01 ^a	2.58 ± 0.01 ^b	2.50 ± 0.01 ^c	*
Neck weight (%)	4.35 ± 0.01 ^c	4.59 ± 0.04 ^a	4.53 ± 0.01 ^{ab}	4.44 ± 0.01 ^{bc}	*
Thigh weight (%)	13.42 ± 0.009 ^d	15.18 ± 0.02 ^a	14.28 ± 0.02 ^b	13.61 ± 0.007 ^c	*
Drumstick weight (%)	12.87 ± 0.01 ^d	16.51 ± 0.02 ^a	14.16 ± 0.02 ^b	13.84 ± 0.03 ^c	*
Wing weight (%)	11.34 ± 0.009	11.74 ± 0.73	12.33 ± 0.01	11.88 ± 0.02	ns
Breast weight (%)	23.31 ± 0.05 ^c	28.21 ± 0.02 ^a	25.32 ± 0.06 ^b	21.49 ± 0.03 ^d	**
Abdominal fat (%)	1.93 ± 0.01 ^c	2.37 ± 0.01 ^a	2.01 ± 0.007 ^c	2.13 ± 0.04 ^b	*
Shank weight (%)	3.74 ± 0.01 ^d	4.12 ± 0.009 ^a	3.95 ± 0.01 ^b	3.82 ± 0.008 ^c	*
Crop weight (%)	1.15 ± 0.01 ^d	1.82 ± 0.02 ^a	1.60 ± 0.02 ^b	1.23 ± 0.007 ^c	**
Kidney weight (%)	1.15 ± 0.01 ^d	1.54 ± 0.01 ^a	1.33 ± 0.01 ^b	1.24 ± 0.01 ^c	*
Lung weight (%)	1.33 ± 0.01 ^d	1.50 ± 0.02 ^a	1.43 ± 0.01 ^{bc}	1.38 ± 0.01 ^{cd}	*
Spleen weight (%)	0.19 ± 0.008 ^c	0.46 ± 0.01 ^a	0.34 ± 0.01 ^b	0.21 ± 0.02 ^c	**
Proventriculus weight (%)	0.55 ± 0.01 ^d	0.59 ± 0.008 ^{cd}	0.62 ± 0.01 ^{abc}	0.60 ± 0.01 ^{bcd}	*
Liver weight (%)	3.58 ± 0.01 ^d	3.92 ± 0.02 ^a	3.78 ± 0.01 ^b	3.69 ± 0.02 ^c	*
Heart weight (%)	1.26 ± 0.008 ^d	1.49 ± 0.02 ^a	1.41 ± 0.03 ^{ab}	1.35 ± 0.01 ^{cd}	*
Gizzard weight (%)	5.16 ± 0.01 ^b	5.60 ± 0.01 ^a	5.34 ± 0.01 ^b	5.19 ± 0.11 ^b	*

The data represent the mean value of 10 samples per treatment; a,b,c,d Means (± Standard error mean) with different superscript letters in rows are significantly different (* $P < 0.05$, ** $P < 0.01$); T₁ = Control, T₂ = 10% of CRM, T₃ = 20% of CRM, T₄ = 30% of CRM; ns: non-significant ($P > 0.05$). Sig.: Significance level

3.3. Hematological and biochemical parameters

Feeding graded levels of cassava root meal significantly influenced the hematological and biochemical profiles of broilers at 35 days ($P < 0.05$). Hemoglobin, RBC, PCV, MCH, and MCHC levels were highest in T₁ and T₂ but declined significantly in T₄. WBC count peaked in T₄ ($19,700 \times 10^9/L$), indicating a possible stress or immune response (Table 4).

Table 4: Hematological and biochemical parameters of broiler on graded levels of experimental diets of cassava root meal at the age of 35 days.

	Treatments						
Parameters	T ₁	T ₂	T ₃	T ₄	SEM	Linear	Quadratic
Hematological parameters							
Hb g/dl	10.02 ^a	9.12 ^b	9.26 ^b	8.20 ^c	0.37	4.24**	0.02
RBC x10 ⁶ /μl	2.53 ^a	2.32 ^b	2.23 ^b	2.18 ^c	0.08	0.19**	0.02
WBC x10 ⁹ /L	17240 ^c	18280 ^b	15540 ^d	19700 ^a	876.22	3229440**	7300800**
PCV %	28.64 ^a	27.68 ^b	27.70 ^b	25.30 ^c	0.71	15.00**	1.55**
MCV fL	128.76 ^b	130.60 ^b	128.80 ^b	120.10 ^a	2.36	116.04**	82.79**
MCH pg	45.40 ^a	43.32 ^{ab}	43.06 ^b	39.22 ^c	1.29	53.02**	2.32**
MCHC g/dl	35.60 ^a	33.34 ^{ab}	34.20 ^b	32.72 ^b	0.62	9.10**	0.45**
Neutrophil %	32.60 ^a	22.80 ^b	32.40 ^a	25.40 ^b	2.48	1310.44**	5.88**
Lymphocytes %	65.00 ^c	73.00 ^a	62.80 ^b	64.40 ^c	2.28	21.60**	30.72**
Monocytes %	2.00	2.60	2.60	2.40	0.14	0.22**	0.48**
Eosinophils %	1.60	3.40	2.40	2.60	0.37	0.60**	1.92**
Basophils %	00	00	00	1.08	0.27	1.57**	0.87**
Biochemical parameters							
RBS mg/dl	158.62 ^d	180.66 ^c	203.60 ^b	213.44 ^a	12.26	5267.81**	111.63**
Uric Acid mg/dl	3.83 ^d	4.55 ^c	4.86 ^b	4.94 ^a	0.25	1.99**	0.31**
Total Protein g/dl	2.73 ^c	2.95 ^a	2.91 ^a	2.77 ^b	0.05	0.00	0.09**
BUN mg/dl	6.64 ^c	7.52 ^b	6.67 ^c	7.77 ^a	0.29	0.94**	0.03**
Cholesterol mg/dl	110.62 ^b	100.78 ^a	111.56 ^c	117.42 ^d	3.45	145.73**	184.79**
Triglyceride mg/dl	108.62 ^a	80.60 ^d	89.64 ^c	96.40 ^b	5.90	114.42**	907.24**
HDL mg/dl	59.48 ^c	45.54 ^d	63.58 ^b	68.58 ^a	4.95	308.35**	269.04**
LDL mg/dl	29.34 ^c	39.32 ^a	29.92 ^b	29.34 ^c	2.45	14.12**	78.89**
AST U/I	187.72 ^b	208.84 ^a	167.18 ^d	183.44 ^c	8.58	445.54**	17.71**
ALT U/I	9.32 ^c	16.30 ^a	7.65 ^d	9.90 ^b	1.90	7.31**	16.85**
ALP U/I	8034 ^b	5288 ^d	8466 ^a	7282 ^c	703.71	127512**	1829883**

The data represent the mean value of 10 samples per treatment; a,b,c,d Means with different superscript letters in the same rows are significantly different. Hb= Hemoglobin; RBC= Red Blood Cell; WBC= White Blood Cell; PCV = Packed Cell Volume; MCV fL = Mean Corpuscular Volume (femtoliters); MCH pg= Mean Corpuscular Hemoglobin (picograms) MCHC g/dl= Mean Corpuscular Hemoglobin Concentration (grams per deciliter); RBS mg/dl= Random Blood Sugar (milligrams per deciliter); BUN mg/dl= Blood Urea Nitrogen (milligrams per deciliter); HDL mg/dl= High-Density Lipoprotein (milligrams per deciliter); LDL mg/dl= Low-Density Lipoprotein (milligrams per deciliter); AST U/I= Aspartate Aminotransferase (units per liter); ALT U/I= Alanine Aminotransferase (units per liter); ALP U/I= Alkaline Phosphatase (units per liter). SEM= Standard Error Mean; * $P < 0.05$; ** $P < 0.01$.

Lymphocyte percentages were highest in T₂ (73.00%) and lowest in T₃. Neutrophils were significantly elevated in T₁ and T₃. Basophils appeared only in T₄. Among biochemical parameters, random

blood sugar (RBS), uric acid, and BUN levels increased progressively with higher cassava inclusion, with maximum values in T₄. Cholesterol was lowest in T₂ and highest in T₄, while triglycerides were significantly reduced in T₂. HDL was highest in T₄ (68.58 mg/dl), and LDL peaked in T₂. Liver enzymes (AST, ALT, ALP) showed marked variation; ALT and AST were significantly elevated in T₂, indicating potential hepatic stress. ALP was highest in T₃ as shown in Table 4.

3.4. Proximate composition of meat

The inclusion of cassava root meal in broiler diets influenced the proximate composition of both breast and thigh muscles (Table 5). In the breast muscle, moisture, CP, EE, CF, and ash contents showed no significant variation ($P > 0.05$), except NFE and metabolizable energy (ME), where T₂ had the highest NFE (1.27%) and T₄ showed the highest ME (972.04 kcal/kg) ($P < 0.05$). Breast EE was highest in T₄ (2.00%) and lowest in T₂ (1.03%). In thigh muscles, CP varied significantly across treatments ($P = 0.027$), with the highest in T₃ (20.28%) and the lowest in T₁ (15.30%). Crude fiber and ash contents were also significantly different ($P < 0.05$), with T₄ showing the highest CF (1.03%) and T₃ having the highest ash (2.46%). NFE declined significantly from T₁ (7.99%) to T₄ (2.07%). ME was the highest in T₂ (1055.63 kcal/kg) and significantly lower in other treatments.

Table 5: Proximate composition of breast and thigh muscle of broiler on graded levels of experimental diets of cassava root meal at the age of 35 days.

Samples	Parameters	Treatments				SEM	Linear	Quadratic
		T ₁	T ₂	T ₃	T ₄			
Breast muscle	Moisture %	75.32	72.78	73.96	72.37	0.66	8.82**	0.68*
	CP %	21.27	22.65	22.98	22.52	0.37	2.49**	2.54**
	EE %	1.80 ^{ab}	1.03 ^c	1.60 ^{bc}	2.00 ^a	0.21	0.21**	1.03**
	CF%	0.85	0.81	0.50	1.06	0.12	0.02*	0.27**
	Ash %	1.23	1.30	1.30	1.82	0.14	0.47**	0.15**
	NFE %	0.39 ^{ab}	1.27 ^a	0.30 ^b	0.29	0.24	0.24**	0.59**
	ME (kcal/kg)	894.57 ^c	955.67 ^b	935.29 ^{ab}	972.04 ^a	16.72	6732.91**	438.63**
Thigh muscle	Moisture %	74.05	70.32	72.59	73.21	0.80	0.03	13.69**
	CP %	15.30 ^c	18.40 ^{ab}	20.28 ^a	18.33 ^{bc}	1.03	18.05**	19.13**
	EE %	1.2	1.7	1.8	1.5	0.13	0.15**	0.48**
	CF%	0.55 ^d	1.00 ^{bc}	0.70 ^c	1.03 ^a	0.12	0.19**	0.01*
	Ash %	0.90 ^d	1.01 ^{cd}	2.46 ^a	2.04 ^b	0.38	3.56**	0.21**
	NFE %	7.99 ^a	7.61 ^b	4.25 ^c	2.07 ^d	1.41	67.27**	2.59**
	ME (kcal/kg)	917.18 ^b	1055.63 ^a	928.02 ^b	920.38 ^b	33.52	2084.00**	16016.94**

The data represent the mean value of 10 samples per treatment; a,b,c,d Means with different superscript letters in the same rows are significantly different. kcal/kg= Kilo calorie/kg; CP= Crude Protein; EE= Ether extract; CF= Crude fiber; NFE= Nitrogen free extract; ME= Metabolizable energy. SEM= Standard Error Mean; * $P < 0.05$; ** $P < 0.01$.

3.5. Quality attribute of broiler meat

3.5.1. Breast Muscle

The effect of cassava root meal inclusion on meat quality traits is shown in Table 6. Drip loss (DL) and cooking loss (CL) in breast muscle were not significantly affected ($P > 0.05$), although CL was significantly lower in T₂ (27.58%) compared to the control T₁ (35.95%) ($P = 0.016$). Water holding capacity (WHC) significantly increased in T₂ (78.22%) compared to other treatments ($P = 0.0001$). A significant reduction in pH was observed in T₄ (5.65) compared to the other treatments ($P = 0.002$).

DPPH scavenging activity and antioxidant parameters (TPC and TFC) were significantly higher in T₂ (60.62 mg TE/100g, 36.40 mg GAE/100g, and 35.49 mg QE/100g, respectively) compared to other groups ($P < 0.05$). Color measurements showed that L* and b* values were significantly higher in T₄ (65.21 and 11.39, respectively), while the a* value was significantly higher in T₃ (3.80) ($P < 0.05$).

Table 6: Quality attributes of breast and thigh muscle of broiler on graded levels of experimental diets of cassava root meal at the age of 35 days.

Samples	Parameters	Treatments				SEM	Linear	Quadratic
		T ₁	T ₂	T ₃	T ₄			
Breast muscle	DL %	10.51	9.19	9.41	9.73	0.29	0.67	2.02
	CL %	35.95 ^a	27.58 ^c	33.39 ^{ab}	31.68 ^{bc}	1.76	7.35*	33.27**
	WHC %	71.50 ^c	78.22 ^a	73.16 ^b	74.21 ^{ab}	1.43	1.41	24.11**
	pH	6.21 ^b	6.12 ^b	6.11 ^b	5.65 ^a	0.13	0.43*	0.10
	DPPH scavenging activity (mg TE/100g)	44.98 ^c	60.62 ^a	51.94 ^b	51.76 ^b	3.20	20.39**	187.70**
	TPC (mg GAE/ 100g sample)	32.17 ^c	36.40 ^a	33.44 ^{ab}	33.19 ^{bc}	0.91	0.00	15.05**
	TFC (mg QE/ 100g sample)	27.94 ^c	35.49 ^a	35.34 ^{ab}	31.31 ^{bc}	1.81	14.88**	100.57**
	L*	63.71 ^{ab}	55.60 ^{bc}	46.50 ^c	65.21 ^a	4.30	3.17	539.48**
	a*	0.65 ^b	0.36 ^b	3.80 ^a	0.57 ^b	0.82	1.54**	6.48**
	b*	10.48 ^{ab}	9.65 ^{bc}	11.39 ^a	11.39 ^a	0.42	2.99**	0.52
Thigh muscle	DL %	7.15 ^a	4.15 ^d	5.24 ^c	5.73 ^b	0.62	1.51**	9.14**
	CL %	36.25 ^a	33.44 ^{bc}	32.55 ^c	35.36 ^{ab}	0.85	1.90	23.69**
	WHC %	71.55 ^c	74.81 ^a	72.21 ^{bc}	73.21 ^{ab}	0.71	0.85	3.83
	pH	6.45	6.39	6.33	6.10	0.08	0.18*	0.02
	DPPH scavenging activity (mg TE/100g)	57.80 ^b	73.38 ^a	72.29 ^a	57.39 ^b	4.41	0.79	696.32**
	TPC (mg GAE/ 100g sample)	42.17 ^b	66.17 ^a	41.30 ^b	44.08 ^b	5.94	54.95**	337.72**
	TFC (mg QE/ 100g sample)	44.43 ^b	72.35 ^a	44.55 ^b	48.52 ^b	6.70	36.18**	430.20**
	L*	55.24 ^a	54.30 ^a	48.23 ^b	56.38 ^a	1.82	1.49**	59.72**
	a*	2.49 ^a	2.35 ^a	0.98 ^b	2.35 ^b	0.36	0.48**	1.71**
	b*	9.32 ^{ab}	9.53 ^a	4.80 ^c	8.24 ^b	1.09	9.53**	7.82**

The data represent the mean value of 10 samples per treatment. a,b,c Means with different superscript letters in the same rows are significantly different. DL= Drip loss; CL= Cooking loss; WHC= Water holding capacity; TPC= Total phenolic content; TFC= Total flavonoid content; mg TE/100g sample= Milligram of trolox equivalent per 100g sample; mg GAE/ 100g sample= Milligram of gallic acid equivalent per 100g sample; mg QE/ 100g sample= Milligram of quercetin equivalent per 100g sample; L* = Darkness to lightness; a* = Greenness to redness; b* = Blueness to yellowness. SEM= Standard Error Mean; * $P < 0.05$; ** $P < 0.01$.

3.5.2. Thigh Muscle

In thigh muscle, DL significantly decreased with increasing cassava levels, with the lowest DL in T₂ (4.15%) and highest in T₁ (7.15%) ($P = 0.0001$). WHC significantly improved in T₂ (74.81%) ($P = 0.039$), and CL was significantly reduced in T₃ (32.55%) ($P = 0.017$). pH values were not significantly different among treatments ($P = 0.283$). T₂ also demonstrated significantly higher DPPH activity (73.38 mg TE/100g), TPC (66.17 mg GAE/100g), and TFC (72.35 mg QE/100g) than all other groups ($P < 0.0001$). The L* values were highest in T₄ (56.38), while T₃ had the lowest (48.23) ($P = 0.002$). Redness (a*) was significantly reduced in T₃ (0.98), while yellowness (b*) decreased significantly in T₃ (4.80) ($P = 0.0001$).

3.5.3. Sensory evaluation

The sensory assessment of the thigh and breast muscles from the experimental broilers is visualized in Fig. 1.

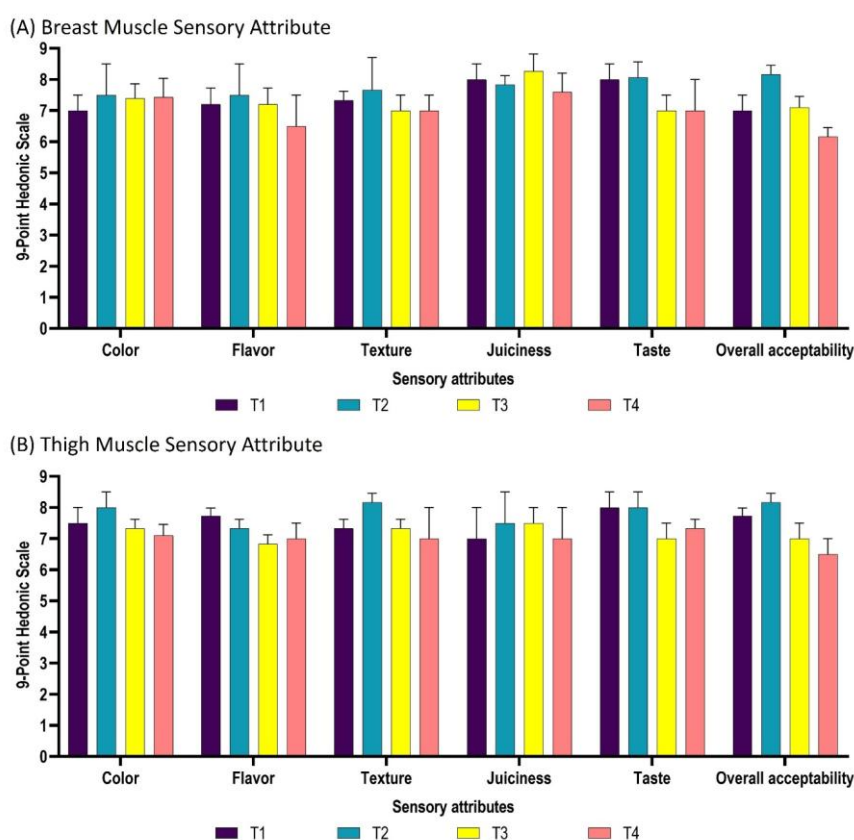


Figure 1: Sensory evaluation of meat/muscle; A (breast muscle) and B (thigh muscle). The data represent the mean value of 10 samples per treatment. T₁ = Control, T₂ = 10% of Cassava root meal, T₃ = 20% of Cassava root meal, T₄ = 30% of Cassava root meal.

In the breast muscle, there were no significant differences among the groups in terms of color, flavor, texture, juiciness, and taste, except for overall acceptability. Muscles from birds fed upto 10% cassava root meal (CRM) showed a significant improvement in overall acceptability compared to the control. In the thigh muscle, color and juiciness did not show significant variance among the groups. However, flavor, texture, and overall acceptability were significantly better in T₁ compared to the other groups. No treatment group significantly outperformed the control in terms of taste (Fig. 1).

4. Discussion

The use of cassava root meal (CRM) as an alternative to the conventional energy source maize has demonstrated ameliorative effects on growth performance, biochemical parameters, and meat quality attributes. The cassava root is a popular food source in many African regions and South America for human consumption. It is prepared into various foods, including cassava flour, tapioca, gari, fufu, cassava chips, cassava bread, cassava noodles, and alcoholic beverages [28]. It is widely used as an industrial product, similar to bioethanol, biodegradable plastics, textile and paper binders, adhesives, and glues [28,29]. Unfortunately, its use in livestock or poultry feed is infrequent due to a lack of knowledge on its beneficial effect on poultry as a substitute for maize.

The utilization of innovative feed additives and ingredients to promote broiler chicken production is being investigated on number of trails and the present study specifically focused on including cassava root meal into the diet. When compared to the other treatment groups, birds reared as control group showed a lower body weight and diet having 10% CRM showed higher body weights. The current finding was similar as that of [30], who noted that broilers' body weight and feed intake significantly improved when supplementing peeled CRM. A number of studies have shown that giving diets containing between 30 and 35 g/kg of seaweed meal to chickens has no effect on their ability to get weight [31,32]. In case of feed intake, the supplementing 10% CRM significantly influences more feed intake than the other groups. The trend in feed intake similarity across various diets aligns with the findings of Hassan et al. [15], who documented a notable decrease in feed intake in birds that were fed with more than 25% sun-dried CRM. Considering FCR, T₂ group had the lowest FCR throughout the experiment, indicating the most efficient feed utilization. The supplementation of CRM improves FER, suggesting a potential trade-off between feed intake and feed efficiency at higher levels of cassava root meal.

Nonetheless, this study agrees with the results of Yang et al. [33], who noted a significant increase in feed consumption in response to a diet's increased cassava meal content during the finisher phase. The findings of other studies reported no significant effects on broiler chickens align with the insignificant results obtained for daily feed intake, FCR, FER, and mortality in broiler chickens fed sun-dried CRM [34–37].

In broilers, cassava root meal enhances growth performance due to its high carbohydrate content, which serves as a readily available source of energy, contributing to metabolic and body weight gain. Its readily digestible starch helps improve nutrient utilization and feed productivity [37]. Good nutrient utilization from cassava can be achieved if it is processed correctly, as it contains low levels of anti-nutritional factors. Additionally, its presence could play a role in maintaining a healthy gut microbiome balance, helping beneficial bacteria and hindering the colonization of pathogens [30]. These effects collectively result in a better feed conversion ratio, improved protein synthesis, and increased growth performance in broilers compared to control broilers fed the standard maize diet.

Chukwukaelo et al. [11] discovered that including cassava meal in the diet resulted in a higher dressing percentage in terms of carcass composition. In this study, we observed that diet having 10% CRM had the highest dressing percentage. Similarly, Sultana et al. [38] found that head and thigh weights increased when subjects were fed diets containing 15% and 30% CRM. A study conducted by Abera et al. [39] revealed an increased proportion of liver in broilers that were fed a diet containing 15% cassava root and leaf meals. Conversely, Morgan et al. [40] reported that no notable alterations in yield weight while including 25% cassava meal in the diet. In addition, Abera et al. [39] and Adeyemo et al. [41] observed that broilers fed with 12% cassava meals had higher levels of lungs and kidneys, with the exception of the liver, which showed a more substantial increase when the cassava meal inclusion was at 25%. The high lung weight in broilers is linked to enhanced metabolic activity, which enables sufficient oxygen supply to meet the body's metabolic requirements [42,43]. Elnour et al. [44] reported that there were no significant alterations in the weights of breast, abdomen fat, or drumstick but substantial variations in spleen size when cassava root was included in the diet, with an inclusion rate of up to 40%. Abera et al. [39] confirmed that including 15% cassava in the diet resulted in a higher liver percentage. According to Ukachukwu et al. [45], liver enlargement and weight gain are associated

with detoxifying processes caused by anti-nutrients. In addition, Alahmari et al. [46] and Adedokun et al. [47] linked intestinal expansion to higher levels of indigestible fiber, whereas Alahmari et al. [46] attributed the increased weights of the kidneys and heart to the metabolic impact of anti-nutritional chemicals.

The inclusion of 10% CRM to broiler diets promotes an increase in carcass characteristics, as it enhances the supply of available energy, improves nutrient digestibility, and increases metabolic efficiency, ultimately leading to greater weight and muscle accretion. Differences among studies are attributable to the processing of cassava, levels of inclusion, broiler lines, feeding diets, and ambient conditions [48]. The existence or depletion of anti-nutritional factors, such as cyanogenic glycosides and indigestible fibre, also affects organ development and carcass yield, thereby leading to the limited results achieved by different research reports [47].

Blood indices are essential diagnostic tools for determining the metabolic, health, and nutritional status of broiler chickens [49]. They are employed for the evaluation of the nutritive quality of non-conventional feedstuffs [50]. The inclusion of cassava root in broiler diets resulted in decreased blood haemoglobin (Hb), packed cell volume (PCV), and red blood cell (RBC) values. However, all blood parameters were within the normal range (Hb: 7.0-13.0 g/dL, PCV: 22-35%, RBC: $2.5-3.5 \times 10^6/\mu\text{L}$) [51]. The higher MCV in the broilers on a 10% CRM diet implied larger RBCs with normal Hb content. The numbers of WBCs and CKCs, which are important for immunity, were not significantly different, and lymphocytes were within the normal range (51.17–75.33%) [52]. Higher root cassava content resulted in decreased MCV and MCH, a sign of both modified RBC size and set-up, which may increase the risk of anaemia. Increased MCH may be suggestive of regeneration anaemia [53]. The concentration of total protein levels, ranging from 3.32 to 4.57 g/dl for birds [41], was unremarkably maintained, denoting that dietary protein was not affected in quality. The broilers fed a diet with 10% CRM (T₂) showed lower total cholesterol and triglycerides ($p < 0.05$) compared to the control. The activities of AST and ALT were also significantly different between diets and fell within normal reference levels (167.18-208.84 and 7.65-16.30 U/L, respectively), as reported by [49]. Because increased levels of AST, ALT, and ALP can be a sign of liver disease, monitoring these values is essential. Results

corroborate Ogbuewu et al. [50], who associated serum protein status with dietary intake and noted that cassava root meal had no effect on serum proteins and preserved protein quality.

Proximate compositions of broiler breast and thigh muscles showed significant variation due to inclusion cassava root mix in the diets fed to broilers. According to Chukwukaelo et al. [11], the highest levels of cassava root mix were reflected in an increase CP and ME content while decreasing moisture as well as NFE. The CF, EE, and ash content decreased in breast muscle. On the other hand, the CF, EE and ash percentage in thigh muscle were increased. In this study, we found 10% of CRM improve ME rather 20%, 30% inclusion of CRM in broiler diet. Furthermore, the present study reveals that introduction of cassava root mix in broiler diets could cause an evident effect on nutritional attributes and energy content among multiple muscle tissues. Broiler production could be transformed, as crude protein and energy content are improved together with managing other nutritional factors such as moisture and fiber levels according to diet modifications which will lead to increased broiler meat quality by meeting consumer demand [11]. According to Bogosavljević-Bošković et al. [54], the primary elements influencing the chemical composition and quality of poultry meat are the kind of raw materials used and their chemical composition, as well as the ration's protein and energy values. Differences in the nutritional content of meats were seen in the quantities of protein and energy across treatment diets in the current study, and these differences were strongly correlated with the degree of replacement of cassava root meal.

Meat quality characteristics have a significant impact on consumers' purchasing behavior of products [55]. Characteristic parameters, such as color, pH, water-holding capacity (WHC), cooking loss, and juiciness, are important to the meat industry, enabling the production of high-quality value-added products [56]. Different treatments had a significant influence on the quality characteristics of breast and thigh muscles in this study. Drip loss was significantly decreased in the thigh muscles among the treatment groups, with the T₁ group demonstrating the lowest value. Cooking loss, however, was significantly ($P < 0.05$) higher in broilers fed the control diet (T₁). As meat pH has an effect on cooking loss, this is in line with Navid et al. [57] and Barbut et al. [58], who stated that pre- and post-slaughter treatments influence the pH of meat. A smaller value in cooking loss represents a more desirable meat quality because it loses less protein during cooking [59]. T₂ showed the highest levels of total phenolic

content (TPC) and total flavonoid content (TFC), as well as the highest antioxidant activity. The T₄, T₁, and T₂ had the highest L, a, and b* values, respectively, as measured by color. These results are corroborated by the studies of Bakare et al. [60], who proposed that cassava leaf products (CLP) enhance the stability of meat color and antioxidant capacity. In conclusion, T₂ (10% CRM) consistently performed the best across all quality parameters.

The results of the study indicated that the sensory attributes of broiler meat were not reduced as a result of the dietary treatments. Abubakar et al. [59] reported that meat colour is affected by muscle composition, structure, condition, and myoglobin type. Organoleptic tests did not reveal differences in meat colour among treatments, contrary to Daouda et al. [61], who observed that snail meal did not affect the colour of meat in broiler. Overall, flavor, which is related to both chemical composition and cooking-induced changes, was not affected. Texture, with tenderness being a major consumer preference [62], was scored as ranging from 7.02 to 8.14 in all groups. Juiciness, a characteristic associated with water-holding capacity and muscle protein structure [63], was also not negatively impacted. Panel differences might indicate variations in dietary habits [64]. The outcome is similar to that of Mayulu et al. [65], who observed that dietary treatments resulted in tastier and consumer-preferred broiled.

This study was limited to a single strain and short-term feeding trial, which may not reflect long-term health impacts or applicability to other poultry breeds. The anti-nutritional effects of cassava root meal have not been extensively studied, nor have the processing methods been varied. In addition, the environmental and economic implications of cassava sourcing and sustainability were not accounted for, and these can influence the adoption of this strategy among varying poultry production systems.

5. Conclusions

The results of this study show that replacing of maize meal by cassava root to broiler diets had no detrimental effects on growth performance and mortality rate of broiler. Considering the results of the growth performance, carcass characteristics, hemato-biochemical parameters, meat composition, and sensory attributes of the broiler that was fed graded amounts of cassava root meal, it is possible to draw the conclusion that cassava root can be used as a suitable substitute for maize in boiler productions, which consisted of a 10% inclusion of cassava root meal, was selected as the recommended option.

Author Contributions: Conceptualization, Shahabuddin Ahmed, Md. Mahfujur Rahman, Mrityunjoy Biswas and Hemayet Hossain; methodology, S Shahabuddin Ahmed, Hemayet Hossain, Khadiza Akter Brishty, Asraful Alam, Md. Amir Hossain, Md. Sazedul Karim Sarker, Aminul Islam, Md. Alauddin, Md. Masudur Rahman, Md. Mahfujur Rahman, Mrityunjoy Biswas; software, M Shalim Uddin, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; validation, Shahabuddin Ahmed, Hemayet Hossain, Khadiza Akter Brishty, Asraful Alam, Md. Amir Hossain, Md. Sazedul Karim Sarker, Aminul Islam, Md. Alauddin, M Shalim Uddin, Md. Masudur Rahman, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; formal analysis, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; investigation, S.A.; resources, Shahabuddin Ahmed, Hemayet Hossain, Khadiza Akter Brishty, Asraful Alam, Md. Amir Hossain, Md. Sazedul Karim Sarker, Aminul Islam, Md. Alauddin, Md. Masudur Rahman, Md. Mahfujur Rahman, Mrityunjoy Biswas; data curation, M. Shalim Uddin, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; writing—original draft preparation, Shahabuddin Ahmed, Hemayet Hossain, Khadiza Akter Brishty, Asraful Alam, Md. Amir Hossain, Md. Sazedul Karim Sarker, Aminul Islam, Md. Alauddin, M Shalim Uddin, Md. Masudur Rahman, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; writing—review and editing, M Shalim Uddin, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; visualization, Shahabuddin Ahmed, Hemayet Hossain, Khadiza Akter Brishty, Asraful Alam, Md. Amir Hossain, Md. Sazedul Karim Sarker, Aminul Islam, Md. Alauddin, M Shalim Uddin, Md. Masudur Rahman, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; supervision, A M Shalim Uddin, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; project administration, M Shalim Uddin, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas; funding acquisition, M Shalim Uddin, Abdulrahman Alasmari, Akbar Hossain, Md. Mahfujur Rahman, Mrityunjoy Biswas. All authors have read and agreed to the published version of the manuscript.	498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523
Funding: This research was funded by Department of Agro Product Processing Technology, Jashore University of Science and Technology, Jashore 7408, Bangladesh.	524 525 526
Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.	527 528 529
Acknowledgments: The authors are grateful to the Laboratory of Agro Product Processing Technology and Nutrition and Food Technology, Department of Jashore University of Science and Technology, Jashore 7408, Bangladesh for their assistance and facilities which were invaluable in this study. Also, the authors would like to thanks to the Poultry Research Center of Bangladesh Livestock Research Institute (BLRI), Dhaka, Bangladesh for their kind support.	530 531 532 533 534 535
Conflicts of Interest: The authors declare no conflicts of interest.	536

References

1. Choi, J.; Kong, B.; Bowker, B.C.; Zhuang, H.; Kim, W.K.; Choi, J.; Kong, B.; Bowker, B.C.; Zhuang, H.; Kim, W.K. Nutritional Strategies to Improve Meat Quality and Composition in the Challenging Conditions of Broiler Production: A Review. *Animals* 2023, Vol. 13, Page 1386 **2023**, 13, 1386, doi:10.3390/ANI13081386.
2. Erenstein, O.; Jaleta, M.; Sonder, K.; Mottaleb, K.; Prasanna, B.M. Global Maize Production, Consumption and Trade: Trends and R&D Implications. *Food Security* 2022 14:5 **2022**, 14, 1295–1319, doi:10.1007/S12571-022-01288-7.
3. Ahiwe, E.U.; Omede, A.A.; Abdallh, M.B.; Iji, P.A. Managing Dietary Energy Intake by Broiler Chickens to Reduce Production Costs and Improve Product Quality. *Animal Husbandry and Nutrition* **2018**, doi:10.5772/INTECHOPEN.76972.
4. Chang’a, E.P.; Abdallh, M.E.; Ahiwe, E.U.; Mbaga, S.; Zhu, Z.Y.; Fru-Nji, F.; Iji, P.A. Replacement Value of Cassava for Maize in Broiler Chicken Diets Supplemented with Enzymes. *Asian-Australas J Anim Sci* **2020**, 33, 1126–1137, doi:10.5713/AJAS.19.0263.
5. Stupak, M.; Vanderschuren, H.; Gruissem, W.; Zhang, P. Biotechnological Approaches to Cassava Protein Improvement. *Trends Food Sci Technol* **2006**, 17, 634–641, doi:10.1016/J.TIFS.2006.06.004.
6. Abdul Kuddus, M.; Chandra Datta, G.; Mahbubul Alam Miah, M.; Kumar Sarker, A.; Md Abdul Hamid, S.; Rahman Sunny, A. Performance Study of Selected Orange Fleshed Sweet Potato Varieties in North Eastern Bangladesh. *International Journal of Environment, Agriculture and Biotechnology* **2020**, 5, doi:10.22161/ijeab.53.21.
7. Alam, M.; Jannat, M.; Datta, N.; Hasan, M.M.; Alam, A.; Zahid, M.A.; Moazzem, M.S.; Molla, M.M.; Biswas, M. The Influence of Microwave-Assisted Osmotic Dehydration in Coconut Meat Preservation Technique. *Applied Food Research* **2024**, 4, 100448, doi:10.1016/J.AFRES.2024.100448.
8. Ahmed, S.; Biswas, M.; Sunny, A.R.; Irin, F.; Hossain, M.F.; Rahman, M.M.; Siddique, M.A.B.; Alauddin, M.; Debnath, M.K.; Hossain, M.P.; et al. Nutritional Evaluation of Cassava Meal Components and Maize in Securing Feed and Food. *Integrative Biomedical Research (Former Journal of Angiotherapy)* **2024**, 8, 1–7, doi:10.25163/ANGIOTHERAPY.839572.

9. Yi, B.; Hu, L.; Mei, W.; Zhou, K.; Wang, H.; Luo, Y.; Wei, X.; Dai, H. Antioxidant Phenolic Compounds of Cassava (*Manihot Esculenta*) from Hainan. *Molecules* **2011**, *16*, 10157–10167, doi:10.3390/MOLECULES161210157.
10. Omede, A.A.; Ahiwe, E.U.; Zhu, Z.Y.; Fru-Nji, F.; Iji, P.A.; Omede, A.A.; Ahiwe, E.U.; Zhu, Z.Y.; Fru-Nji, F.; Iji, P.A. Improving Cassava Quality for Poultry Feeding Through Application of Biotechnology. *Cassava* **2017**, doi:10.5772/INTECHOPEN.72236.
11. Chukwukaelo, A.K.; Aladi, N.O.; Okeudo, N.J.; Obikaonu, H.O.; Ogbuewu, I.P.; Okoli, I.C. Performance and Meat Quality Characteristics of Broilers Fed Fermented Mixture of Grated Cassava Roots and Palm Kernel Cake as Replacement for Maize. *Trop Anim Health Prod* **2018**, *50*, 485–493, doi:10.1007/S11250-017-1457-7/METRICS.
12. Alade, A.A.; Bamgbose, A.M.; Oso, A.O.; Adewumi, B.A.; Jegede, A.V.; Anigbogu, N.M.; Agwunobi, L.N.; Ogunsola, I.A. Effects of Dietary Inclusion of *Zymomonas Mobilis* Degraded Cassava Sifting on Growth Performance, Apparent Nutrient Digestibility, Ileal Digesta Viscosity, and Economy of Feed Conversion of Broiler Chickens. *Trop Anim Health Prod* **2020**, *52*, 1413–1423, doi:10.1007/S11250-019-02146-Z/METRICS.
13. Okrathok, S.; Sirisopapong, M.; Mermillod, P.; Khempaka, S. Modified Dietary Fiber from Cassava Pulp Affects the Cecal Microbial Population, Short-Chain Fatty Acid, and Ammonia Production in Broiler Chickens. *Poult Sci* **2023**, *102*, 102265, doi:10.1016/J.PSJ.2022.102265.
14. Diarra, S.S.; Sandakabatu, D.; Perera, D.; Tabuaciri, P.; Mohammed, U. Growth Performance and Carcass Yield of Broiler Chickens Fed Commercial Finisher and Cassava Copra Meal-Based Diets. *J Appl Anim Res* **2015**, *43*, 352–356, doi:10.1080/09712119.2014.978774.
15. Hassan, A.; Tamburawa, M.; Alponsus, C.; Yusuf, J. Studies on Growth, Organs Weight and Haematological Parameters of Broiler Chicken Fed Graded Level of Sun Dried Cassava Root Meal. *Bayero Journal of Pure and Applied Sciences* **2012**, *5*, 98–102, doi:10.4314/BAJOPAS.V5I1.18.
16. Aerni, P. Mobilizing Science and Technology for Development: The Case of the Cassava Biotechnology Network (CBN) 2006.

17. Akter, M.S.; Uddin, M.T.; Dhar, A.R. Advancing Safe Broiler Farming in Bangladesh: An Investigation of Management Practices, Financial Profitability, and Consumer Perceptions. *Commodities* 2023, Vol. 2, Pages 312–328 **2023**, 2, 312–328, doi:10.3390/COMMODITIES2030018.
18. Hossain, H.; Nuradji, H.; Miah, M.Y.; Islam, M.N.; Siddiqui, M.S.I. Impact of Synbiotic on Growth Performance, Histo-Architectural Modulation of Lymphoid Organ, Hematology, Blood Biochemistry and Humoral Immune Response in Naked Neck Chicken. *Trop Anim Health Prod* **2025**, 57, doi:10.1007/S11250-024-04254-X,.
19. Imranuzzaman, M.; Hossain, H.; Pory, F.S.; Dipsana, K.C.; Haque, M.S.; Akter, S.; Dey, P.R.; Rahman, M.A.; Shovon, M.A.I.; Rahman, M.M.; et al. Phytase Supplementation in Broilers: Influence on Growth Performance and Physiological Health. *Journal of Advanced Biotechnology and Experimental Therapeutics* **2025**, 8, 342–352, doi:10.5455/JABET.2025.28.
20. Rahman, M.; Hossain, H.; Mia, M.; Rahman, M.J.; Al Farabi, A.; Dudayev, Z.; Brishty, K.A.; Afrin, N.; Shovon, M.A.I.; Chowdhury, M.S.R.; et al. Selection of Efficient Broiler Strain for Productive Performances and Immunity under Local Farming System in Bangladesh. *Journal of Advanced Biotechnology and Experimental Therapeutics* **2025**, 8, 218–231, doi:10.5455/JABET.2025.18.
21. Nkukwana, T.T.; Muchenje, V.; Masika, P.J.; Pieterse, E.; Hoffman, L.C.; Dzama, K. Proximate Composition and Variation in Colour, Drip Loss and PH of Breast Meat from Broilers Supplemented with Moringa Oleifera Leaf Meal over Time. *Anim Prod Sci* **2016**, 56, 1208–1216, doi:10.1071/AN14055.
22. Martínez, Y.; Altamirano, E.; Ortega, V.; Paz, P.; Valdivié, M. Effect of Age on the Immune and Visceral Organ Weights and Cecal Traits in Modern Broilers. *Animals* 2021, Vol. 11, Page 845 **2021**, 11, 845, doi:10.3390/ANI11030845.
23. Ogbuewu, I.P.; Mbajorgu, C.A. Dietary Dialium Guineense Stem-Bark Supplementation Improves Growth Performance and Haemato-Biochemical Characteristics of Broiler Chickens. *Heliyon* **2023**, 9, doi:10.1016/j.heliyon.2023.e17341.
24. Biswas, A.K., Mandal, P. Meat Quality Analysis | ScienceDirect. **2019** Available online: <https://www.sciencedirect.com/book/9780128192337/meat-quality-analysis> (accessed on 13 June 2025).

25. Cheng, Y.; Chen, Y.; Li, X.; Yang, W.; Wen, C.; Kang, Y.; Wang, A.; Zhou, Y. Effects of Synbiotic
Supplementation on Growth Performance, Carcass Characteristics, Meat Quality and Muscular An-
tioxidant Capacity and Mineral Contents in Broilers. *J Sci Food Agric* **2017**, *97*, 3699–3705,
doi:10.1002/JSFA.8230.
26. Vargas-Ramella, M.; Pateiro, M.; Rois, D.; Arias, A.; Justo, J.R.; López-Pedrouso, M.; Lorenzo,
J.M.; Franco, D. Effect of Breed and Diet on Carcass Parameters and Meat Quality of Spent Hens.
Annals of Animal Science **2022**, *22*, 477–500, doi:10.2478/AOAS-2021-0036.
27. Sakanaka, S.; Tachibana, Y.; Okada, Y. Preparation and Antioxidant Properties of Extracts of Japa-
nese Persimmon Leaf Tea (Kakinoha-Cha). *Food Chem* **2005**, *89*, 569–575, doi:10.1016/J.FOOD-
CHEM.2004.03.013.
28. Fathima, A.A.; Sanitha, M.; Tripathi, L.; Muiruri, S. Cassava (*Manihot Esculenta*) Dual Use for
Food and Bioenergy: A Review. *Food Energy Secur* **2023**, *12*, e380, doi:10.1002/FES3.380.
29. Otekunrin, O.A. Cassava (*Manihot Esculenta* Crantz): A Global Scientific Footprint—Production,
Trade, and Bibliometric Insights. *Discover Agriculture* **2024**, *2:1* **2024**, *2*, 1–20,
doi:10.1007/S44279-024-00121-3.
30. Akapo, A.O.; Oso, A.O.; Bamgbose, A.M.; Sanwo, K.A.; Jegede, A.V.; Sobayo, R.A.; Idowu, O.M.;
Fan, J.; Li, L.; Olorunsola, R.A. Effect of Feeding Cassava (*Manihot Esculenta* Crantz) Root Meal
on Growth Performance, Hydrocyanide Intake and Haematological Parameters of Broiler Chicks.
Trop Anim Health Prod **2014**, *46*, 1167–1172, doi:10.1007/S11250-014-0622-5,.
31. Nhlane, L.T.; Mnisi, C.M.; Mlambo, V.; Madibana, M.J. Effect of Seaweed-Containing Diets on
Visceral Organ Sizes, Carcass Characteristics, and Meat Quality and Stability of Boschveld Indig-
enous Hens. *Poult Sci* **2021**, *100*, 949–956, doi:10.1016/j.psj.2020.11.038.
32. Abudabos, A.M.; Okab, A.B.; Aljumaah, R.S.; Samara, E.M.; Abdoun, K.A.; Al-Haidary, A.A. Nu-
tritional Value of Green Seaweed (*Ulva Lactuca*) for Broiler Chickens. *Ital J Anim Sci* **2013**, *12*,
177–181, doi:10.4081/IJAS.2013.E28;PAGE:STRING:ARTICLE/CHAPTER.
33. Yang, Y.; Lei, F.; Zhang, Z.; Liu, L.; Li, Q.; Guo, A. Effects of Cassava Root Meal on the Growth
Performance, Apparent Nutrient Digestibility, Organ and Intestinal Indices, and Slaughter Perfor-
mance of Yellow-Feathered Broilers. **2024**, doi:10.21203/RS.3.RS-3984805/V1.

34. Agunbiade, J.A.; Tolorunji, B.O.; Awojobi, H.A. Shrimp Waste Meal Supplementation of Cassava Products Based Diet Fed to Broiler Chickens. *Nigerian Journal of Animal Production* **2004**, *31*, 182–188, doi:10.51791/NJAP.V31I2.1796.
35. Autónoma De Yucatán, U.; Uchegbu, M.; Etuk, M.C.; Omede, E.B.; Okpala, A.A.; Okoli, C.P.; Opara, I.C.; Autónoma, U.; Mérida, Y.; Yucatán, M.; et al. Effect of replacing maize with cassava root meal and maize/sorghum brewers' dried grains on the performance of starter broilers. *Tropical and Subtropical Agroecosystems* **2011**, *14*, 363–367.
36. Okpara, O.; Obakanurhe, O.; Onowhakpor, C.N.; Sorhue, U.G.; Gbayisomore, O.S. Effect of Replacing Maize with Processed Cassava on the Growth Performance and Haematological Characteristics of Broiler Chickens. *Anim Nutr Feed Technol* **2022**, *22*, 155–166, doi:10.5958/0974-181X.2022.00013.0.
37. Wumnokol, D.P.; Y, G.L.; Magaji, S.T.; Damter, S.A. PERFORMANCE OF BROILER CHICKENS FED GRADED LEVEL OF SUN-DRIED CASSAVA ROOT MEAL (SDCRM) BASED DIETS AT STARTER PHASE. *BW Academic Journal* **2023**, *10*, 5–5.
38. Sultana, F.; Ali, M.; Jahan, I. Growth Performance Meat Yield and Profitability of Broiler Chickens Fed Diets Incorporating Cassava Tuber Meal. *Journal of Environmental Science and Natural Resources* **2012**, *5*, 47–53, doi:10.3329/JESNR.V5I1.11552.
39. Abera, A.; Negasi, A.; Mengistu, U. Evaluation of the Carcass Parameters of Growers Fed on Cassava (*Manihot Esculenta* Crantz) Leaf and Root Mixture. **2016**, *6*.
40. Morgan, N.K.; Choct, M. Cassava: Nutrient Composition and Nutritive Value in Poultry Diets. *Animal Nutrition* **2016**, *2*, 253–261, doi:10.1016/J.ANINU.2016.08.010.
41. Adeyemo, G.O.; Longe, O.G. Effects of Cottonseed Cake Based Diets on Performance and Egg Quality Characteristics of Layers. *Pakistan Journal of Nutrition* **2008**, *7*, 597–602, doi:10.3923/PJN.2008.597.602.
42. Namakparvar, R.; Shariatmadari, F.; Hossieni, S.H. Strain and Sex Effects on Ascites Development in Commercial Broiler Chickens. *Iran J Vet Res* **2014**, *15*, 116–121, doi:10.22099/IJVR.2014.2349.
43. Aladi, N.O.; Nwafor, E.J.; Odoemelam, V.U.; Emenalom, O.O.; Okoli, I.C.; Okeudo, N.J. Performance, Carcass, and Organoleptic Scores of Broiler Chickens Fed Diets Containing Wet or Sun-

- Dried Fermented Mixture of Grated Cassava Roots and Palm Kernel Cake as Replacements for Maize. *Trop Anim Health Prod* **2021**, 53, doi:10.1007/S11250-021-02687-2,.
44. Elnour, Z.; Babiker, M.; Habib, A. Effect of Different Levels of Cassava Roots on Growth Performance, Carcass Traits and Meat Quality of Broiler Chickens. *International Journal of Livestock Research* **2020**, 1, doi:10.5455/IJLR.20200627105321.
45. Ukachukwu, S. Chemical Evaluation Of *Mucuna Cochinchinensis* As Alternative Protein Feeds Stuff. *Journal of Applied Chemistry and Agricultural Research* **2008**, 2, doi:10.4314/JACAR.V2I1.41106.
46. Alahmari, L.A. Dietary Fiber Influence on Overall Health, with an Emphasis on CVD, Diabetes, Obesity, Colon Cancer, and Inflammation. *Front Nutr* **2024**, 11, 1510564, doi:10.3389/FNUT.2024.1510564/BIBTEX.
47. Adedokun, O.O. CARCASS CHARACTERISTICS, ORGAN PROPORTION, HAEMATOLOGY, SERUM CHEMISTRY AND DIGESTIBILITY OF BROILER CHICKENS FED UMUCASS 36 CASSAVA ROOT MEAL. *FUDMA JOURNAL OF SCIENCES* **2023**, 7, 87–92, doi:10.33003/FJS-2023-0703-1825.
48. Amos, A.T.; Kareem, D.U.; Amos, A.O.; Idowu, O.M.O. Nutritional Evaluation of Differently Processed Cassava-Soya Blends in the Diets of Broiler Chickens. *Nigerian Journal of Animal Production* **2021**, 48, 111–127, doi:10.51791/NJAP.V48I2.2929.
49. Zálešáková, D.; Novotný, J.; Řiháček, M.; Horáková, L.; Mrkvicová, E.; Šťastník, O.; Pavlata, L. The Blood Biochemical Parameters Intervals and Dynamics in Modern Broiler Chickens. *Vet Anim Sci* **2025**, 29, 100465, doi:10.1016/J.VAS.2025.100465.
50. Ogbuewu, I.P.; Emenalom, O.O.; Okoli, I.C. Alternative Feedstuffs and Their Effects on Blood Chemistry and Haematology of Rabbits and Chickens: A Review. *Comp Clin Path* **2017**, 26, 277–286, doi:10.1007/S00580-015-2210-0/METRICS.
51. Okafor, B.; Kalio, G.; Manilla, H.; Wariboko, O. Haematology and Carcass Visual Appraisal of Broiler Chickens Fed Supplemental Diets of *Aspilia Africana*, *Azadirachta Indica* and *Centrosema Pubescence* Leaf Meals in Humid Tropical Nigeria. *American Journal of Experimental Agriculture* **2015**, 7, 389–394, doi:10.9734/AJEA/2015/16152.

52. Kongpechr, S.; Sukon, P.; Sohsuebngarm, D. The Study of Hematology in Commercial Broiler Chickens of Cobb 500, Ross 308, and Arbor Acres Plus. *Journal of Mahanakorn Veterinary Medicine* **2020**, *15*, 209–221.
53. Coles, B.H.; Krautwald-Junghanns, M.; Orosz, S.E.; Tully, T.N. Essentials of Avian Medicine and Surgery: Third Edition. *Essentials of Avian Medicine and Surgery: Third Edition* **2008**, 1–397, doi:10.1002/9780470692349.
54. Bogosavljević-Bošković, S.; Pavlovski, Z.; Petrović, M.D.; Dasković, V.; Rakonjac, S. Broiler Meat Quality: Proteins and Lipids of Muscle Tissue. *Afr J Biotechnol* **2010**, *9*, 9177–9182.
55. Mir, N.A.; Rafiq, A.; Kumar, F.; Singh, V.; Shukla, V. Determinants of Broiler Chicken Meat Quality and Factors Affecting Them: A Review. *J Food Sci Technol* **2017**, *54*, 2997, doi:10.1007/S13197-017-2789-Z.
56. Hussein, E.O.S.; Suliman, G.M.; Al-Owaimer, A.N.; Ahmed, S.H.; Abudabos, A.M.; Abd El-Hack, M.E.; Taha, A.E.; Saadeldin, I.M.; Swelum, A.A. Effects of Stock, Sex, and Muscle Type on Carcass Characteristics and Meat Quality Attributes of Parent Broiler Breeders and Broiler Chickens. *Poult Sci* **2019**, *98*, 6586–6592, doi:10.3382/ps/pez464.
57. Navid, S.; Hilmi, M.; Sazili, A.Q.; Sheikhlar, A. Effects of Papaya Leaf Meal, Pineapple Skin Meal and Vitamin D3 Supplementation on Meat Quality of Spent Layer Chicken. *Journal of Animal and Veterinary Advances* **2010**, *9*, 2873–2876, doi:10.3923/JAVAA.2010.2873.2876.
58. Barbut, S. The Science of Poultry and Meat Processing. <http://www.poultryandmeatprocessing.com/> **2015**, 1–70.
59. Abubakar, A.; Fitri, C.A.; Koesmara, H.; Mudatsir; Ardatami, S. Analysis of PH and Cooking Losses of Chicken Meat Due to the Use of Different Percentages of Turmeric Flour. *IOP Conf Ser Earth Environ Sci* **2021**, *667*, doi:10.1088/1755-1315/667/1/012042.
60. Bakare, A.G.; Cawaki, P.; Ledua, I.; Bautista-Jimenez, V.; Kour, G.; Sharma, A.C.; Tamani, E. Quality Evaluation of Breast Meat from Chickens Fed Cassava Leaf Meal-Based Diets. *Anim Prod Sci* **2021**, *61*, 613–619, doi:10.1071/AN20031.

61. Fofana Daouda; Ouattara Abdoulaye; Diomande Masse Effect of Cashew Meal (*Anacardium Occi-* 729
dental) on Organ Yields and Organoleptic Characteristics of Broiler Meat in Côte d'Ivoire. *Inter-* 730
national Journal of Science and Technology Research Archive **2023**, 4, 244–254, 731
doi:10.53771/IJSTRA.2023.4.1.0045. 732
62. Warner, R.; Miller, R.; Ha, M.; Wheeler, T.L.; Dunshea, F.; Li, X.; Vaskoska, R.; Purslow, P.; 733
Warner, R.; Miller, R.; et al. Meat Tenderness: Underlying Mechanisms, Instrumental Measurement, 734
and Sensory Assessment. *Meat and Muscle Biology* **2021**, 4, 17–18, doi:10.22175/MMB.10489. 735
63. Lorenzo, I.; Serra-Prat, M.; Carlos Yébenes, J. The Role of Water Homeostasis in Muscle Function 736
and Frailty: A Review. *Nutrients* **2019**, 11, doi:10.3390/NU11081857. 737
64. Howie, J.A.; Tolkamp, B.J.; Avendano, S.; Kyriazakis, I. The Structure of Feeding Behavior in 738
Commercial Broiler Lines Selected for Different Growth Rates. *Poult Sci* **2009**, 88, 1143–1150, 739
doi:10.3382/PS.2008-00441. 740
65. Mayulu, H.; Rahman, A.; Yusuf, R. Consumer Preference of Broiler Meat Attributes in Traditional 741
Markets. *Hasanuddin Journal of Animal Science (HAJAS)* **2019**, 28–36, 742
doi:10.20956/HAJAS.V11I2.9877. 743
744