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Haematology, serum lipid levels, and antioxidant properties of broiler chickens fed diets containing fermented cassava peels

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Abstract: This study investigated the haematological, serum lipid, and antioxidant status of broiler chickens fed diets containing *Saccharomyces cerevisiae* fermented cassava peels. The objective was to evaluate the nutritional and physiological impacts of this unconventional feed ingredient. Ninety (90) one-day-old Cobb 500 broilers were randomly assigned to three dietary treatments (0%, 25%, and 50% maize replacement) in a completely randomized design. Fermented cassava peels were prepared using *S. cerevisiae* and incorporated into starter and finisher diets as a maize replacement. On day 42, blood samples were collected for haematological and biochemical analyses, and muscle samples were collected for antioxidant analyses. Results showed significant reductions ($P < 0.05$) in WBC, RBC, HGB, and HCT at higher replacement levels, while MCV, MCH, and MCHC remained unaffected. Serum lipid profiles improved with increased HDL and reduced LDL, total cholesterol, and triglycerides. Liver enzymes (ALT, AST) decreased, indicating no hepatic stress. Antioxidant enzyme activities (SOD, GST, and catalase) were significantly elevated in muscle tissues, especially at 50% replacement. *S. cerevisiae*-fermented cassava peels enhanced antioxidant status and lipid metabolism without compromising liver or kidney function, though high inclusion levels may affect haematological indices. Optimizing fermentation and inclusion rates is essential for safe and effective use in broiler nutrition.

Keywords: fermentation; blood profile; cassava peels; broiler chickens

INTRODUCTION

Broiler chickens are a vital component of the poultry industry, providing a significant source of protein for human consumption (Alagawany et al., 2018). However, nutrition is the most expensive factor in broiler production, taking approximately 70% of production budgets (Sugiharto and Ranjitkar, 2019). Recent studies have highlighted the potential of unconventional feed ingredients, such as cassava peels, which are often considered agricultural waste (Narasimha and Raghavendra, 2018). These peels contain various nutrients that can benefit poultry if properly processed, and fermentation using micro-fungi has been recog-

nized for its ability to improve the nutritional profile of feed ingredients.

Microbial fermentation enhances the digestibility and bioavailability of nutrients, thereby improving growth performance and health outcomes in poultry (Chang et al., 2022). One promising approach to repurposing cassava peels is micro-fungi fermentation. This biological process involves using fungi such as *Aspergillus niger*, *Saccharomyces cerevisiae*, and *Rhizopus oryzae* to break down complex organic matter into simpler, more beneficial compounds (Egbune et al., 2023). Specifically, the use of these micro-fungi to ferment cassava peels may augment their nutritional value and offer an alterna-

tive energy source in broiler diets (Akinmola-dun and Olaniyan, 2020). Using *Saccharomyces cerevisiae*, a widely recognized probiotic yeast, has emerged as an effective biotechnological approach to enhance the nutritional profile of cassava peels (Shareef and Al-Dabbagh, 2009). Moreover, *S. cerevisiae* has been shown to exert immune-modulatory and antioxidant effects, which may translate into improved haematological and biochemical parameters in broilers.

Haematological indices and serum lipids are critical indicators of the overall health and nutritional status of broiler chickens. These parameters can reflect the physiological responses to dietary interventions, and can be used to assess the effectiveness of alternative feed ingredients (Musa and Adebayo, 2021). Reports have shown that blood components (biochemical and haematological) are influenced by the quantity and quality of feed, including feed additives offered to the animals (Olafedehan et al., 2010). For a feedstuff to be considered safe for animal health, its effects on blood parameters must be studied to understand its nutritional potential and safety based on its acceptability (Attia et al., 2017). Antioxidant markers reveal the bird's ability to counteract oxidative stress, a common challenge in intensive poultry systems (Oke et al., 2024). Therefore, this study explores the innovative use of *S. cerevisiae*-fermented cassava peels as a partial maize replacement in broiler diets, evaluating its impact on haematological indices, serum lipid profiles, and antioxidant status. This approach aligns with circular economy principles by valorizing waste, reducing feed costs, and promoting sustainable poultry production.

MATERIALS AND METHODS

Experimental sites

The study was conducted at the Poultry Unit of the Research and Teaching Farm, Federal University of Technology, Akure, Nigeria (FUTA). This site is situated between latitude 7° 15' north of the equator and longitude 5° 12' east of the Greenwich Meridian, within the humid tropi-

cal rainforest region. The climatic conditions in Akure align with the southwest region of Nigeria, characterized by an average annual rainfall of approximately 1300 to 1650 mm and daily temperatures ranging from 27°C to 38°C (Daniel, 2015).

Cassava tubers and peels / microorganisms

A pure fungal strain of *Saccharomyces cerevisiae* was sourced from the microbiology laboratory at the Federal University of Technology, Akure. Fresh cassava tubers were also collected from the vicinity of the university. Following thorough washing with fresh water, the cassava tubers were peeled and milled. The peels were then dried and ground using a hammer mill at the university's feed mill, while the tubers were milled into pulp, and the wastewater was extracted for microorganism inoculation.

Sample preparation

The whole cassava roots were washed, peeled, and milled. The pulp was inoculated with fungal inoculum and nutrient solution (750 mL of nutrient solution containing 8.0 g of urea, 1.3 g of KH_2PO_4 , 11 g of MgSO_4 , and 2.0 g of citric acid). The mixtures were allowed to ferment for five days, after which the wastewater was collected through pressing. The resulting material was then processed into flour and garri. Additionally, cassava peels obtained from both the processing and external sources were washed, dried, and ground. The ground cassava peels were spread in fermenter trays to an average thickness of approximately 2 cm. They were subsequently fermented using the wastewater from the pulp, nutrient solution, and *S. cerevisiae* inoculum. The fermentation lasted for seven days before it was concluded, and subsequent analysis was conducted. Fermented cassava peel meal used in the experiment was abbreviated as FCPM.

Experimental dietary layouts

A total of 90 one-day-old unsexed Cobb 500 broilers were obtained from a Hatchery and were randomly allocated to three treatment groups. Each treatment group was replicated thrice, with each replicate consisting of ten chicks. The ex-

perimental design followed a (1 x 3) augmented factorial arrangement in a completely randomized design. Treatment 1 (T1), a diet without fermented cassava peel meal, served as the control diet; Treatment 2 (T2) and Treatment 3 (T3) re-

placed 25% and 50% of the maize with fermented cassava peel meal in the diet, respectively.

The experimental diets were formulated for both starter (1 - 21 days) and finisher (22 - 42 days) phases, with the chickens fed ad libitum.

Table 1. The experimental feed formulation (Starter phase 1 - 21 days)

Ingredients (%)	T1	T2	T3
MFCP	0.00	12.55	25.10
Maize	50.20	37.65	25.10
Soybean meal	35.60	35.60	35.60
Wheat offal	1.50	1.50	1.50
Fish meal	3.50	3.50	3.50
Soya oil	3.50	3.50	3.50
Limestone	1.10	1.10	1.10
Bone meal	1.60	1.60	1.60
Methionine	0.20	0.20	0.20
Lysine	0.10	0.10	0.10
Salt	0.20	0.20	0.20
Premix	0.50	0.50	0.50
Total	100.00	100.00	100.00
Crude protein (%)	23.01	22.98	23.11
ME (Kcal/kg)	3130.69	3129.34	3131.33

MFCP=microbe-fermented cassava peels, T1=control diet (0% FCPM), T2=25% maize replacement with FCPM, T3=50% maize replacement with FCPM, ME=Metabolizable energy

Source: Authors' own elaboration

Table 2. Composition (%) of the broiler Finisher diet

Ingredients (%)	T1	T2	T3
MFCP	0.00	13.17	26.35
Maize	52.70	39.53	26.35
Soyabean meal	28.90	28.90	28.90
Wheat offal	1.50	1.50	1.50
Fish meal	3.00	3.00	3.00
Soya oil	3.50	3.50	3.50
Limestone	1.00	1.00	1.00
Bone meal	1.40	1.40	1.40
Methionine	0.20	0.20	0.20
Lysine	0.10	0.10	0.10
Salt	0.20	0.20	0.20
Premix	0.50	0.50	0.50
Total	100.00	100.00	100.00
Crude protein (%)	20.00	19.96	20.07
ME (Kcal/kg)	3170.93	3168.15	3170.67

MFCP=microbe-fermented cassava peels, T1=control diet (0% FCPM), T2=25% maize replacement with FCPM, T3=50% maize replacement with FCPM, ME=Metabolizable energy

Source: Authors' own elaboration

Details of the experimental starter and finisher diets are presented in Tables 1 and 2, respectively.

Haematological and serum lipid analysis

At day 42 of the experiment, blood samples were collected from one bird randomly selected from each replicate per treatment for the evaluation of haematological and serum parameters. Blood collection was carried out by using a sterile needle to puncture the right jugular vein, and blood was drawn into the syringe. The blood samples were collected into labelled sterile bottles containing EDTA (ethylenediaminetetraacetic acid) powder as an anticoagulant. These samples were used in the laboratory to determine haematological parameters such as Red Blood Cell (RBC), White Blood Cell (WBC), Haemoglobin, Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), and Mean Corpuscular Haemoglobin Concentration (MCHC) were all determined according to Ukorebi and John (2023) and Jain (1989). Also, blood samples were collected into another labelled sterile bottle without anticoagulant to analyze serum biochemical constituents such as total protein, albumin, globulin, creatinine, total cholesterol, HDL, LDL, Urea, Uric acid and triglycerides, using enzymatic methods (Ukorebi and John, 2023; Friedewald et al., 1972).

Antioxidants analysis

At day 42 of the experiment, muscle samples were collected from one bird randomly selected from each replicate per treatment for the evaluation of antioxidant markers. Muscle collection was carried out using a knife to cut a piece of the muscle samples (approximately 4 cm distal part of the muscle), which were collected no later than 10 min after death. The tissues were cut into small pieces (10 × 5 mm), immediately frozen in liquid nitrogen, and then stored at –80 °C (Arctico ULUF 450-2M, Denmark). A 100 mg portion of each muscle was homogenized (Ultra-Turrax T25, Janke and Kunkel GmbH & Co. KG, Germany) in 0.8 mL ice-cold sucrose buffer containing 0.05 M Tris-HCl and 1 mM EDTA (pH 7.4).

Determination of catalase activity

The activity of catalase in the tissue homogenates was assayed according to a procedure that was based on the method of Clairborne (1995). The method was based on catalase decomposing hydrogen peroxide to form water. Typically, clean-sterilized test tubes containing 1.25 mL of 10 mM sodium phosphate buffer (pH 7.0) were pipetted with 1 mL of 0.2 M H₂O₂, 0.5 mL of tissue aliquot (0.1 mL of 1000 mg/kg (w/v) homogenate and 0.4 mL of distilled water). The reaction was terminated at varying times (15, 30, 45, and 60 s) by the addition of 1 mL of 5% dichromate-glacial acetic acid (1:3). The reaction mixture was heated at 100°C for 10 min and allowed to cool down in running water. The absorbance was read at 570 nm against the reagent blank (prepared by replacing the tissue homogenates with distilled water). The catalase activity was calculated.

Determination of glutathione-s-transferase activity (GST)

Using 1-chloro-2,4-dinitrobenzene (CDNB) as a substrate, the GST activity was measured using the method of Habig and Jakoby (1981), with little modification. 1.0 mL of phosphate buffer, pH 6.5, was added along with CDNB and distilled water. At 37°C, the mixture was incubated for 5 min. Then, 100 uL of tissue supernatant and 100 uL of GSH (300 mM) were added. After that, the absorbance was measured at 340 nm.

Determination of glutathione level

The reduced glutathione (GSH) content of the tissue homogenates was assayed according to the procedure based on the method of Moron et al. (1979).

Determination of superoxide dismutase (SOD) activity

Superoxide dismutase activity in the tissue homogenates was determined according to the method of Misra and Fridovich (1972). About 40 µL of homogenate was pipetted into clean-sterilized test tubes containing 160 µL of distilled water to make a 1:4 (5-fold) dilution, followed by

the addition of 2.5 mL of 0.05 M carbonate buffer (pH 10.2). The reaction was initiated by the addition of 300 μ L of 0.3 mM adrenaline (freshly prepared), and quickly mixed by inversion. The absorbance was read at 480 nm for 150 sec at 30-sec intervals against the reagent blank (prepared by replacing the homogenate with distilled water). The SOD activity was expressed as a percentage

inhibition of adrenaline oxidation. 1 unit of SOD activity was defined as the amount of SOD necessary to cause 50% inhibition of the oxidation of adrenaline.

Statistical analysis

Data were analyzed using Ordinary one-way ANOVA with GraphPad Prism software (version

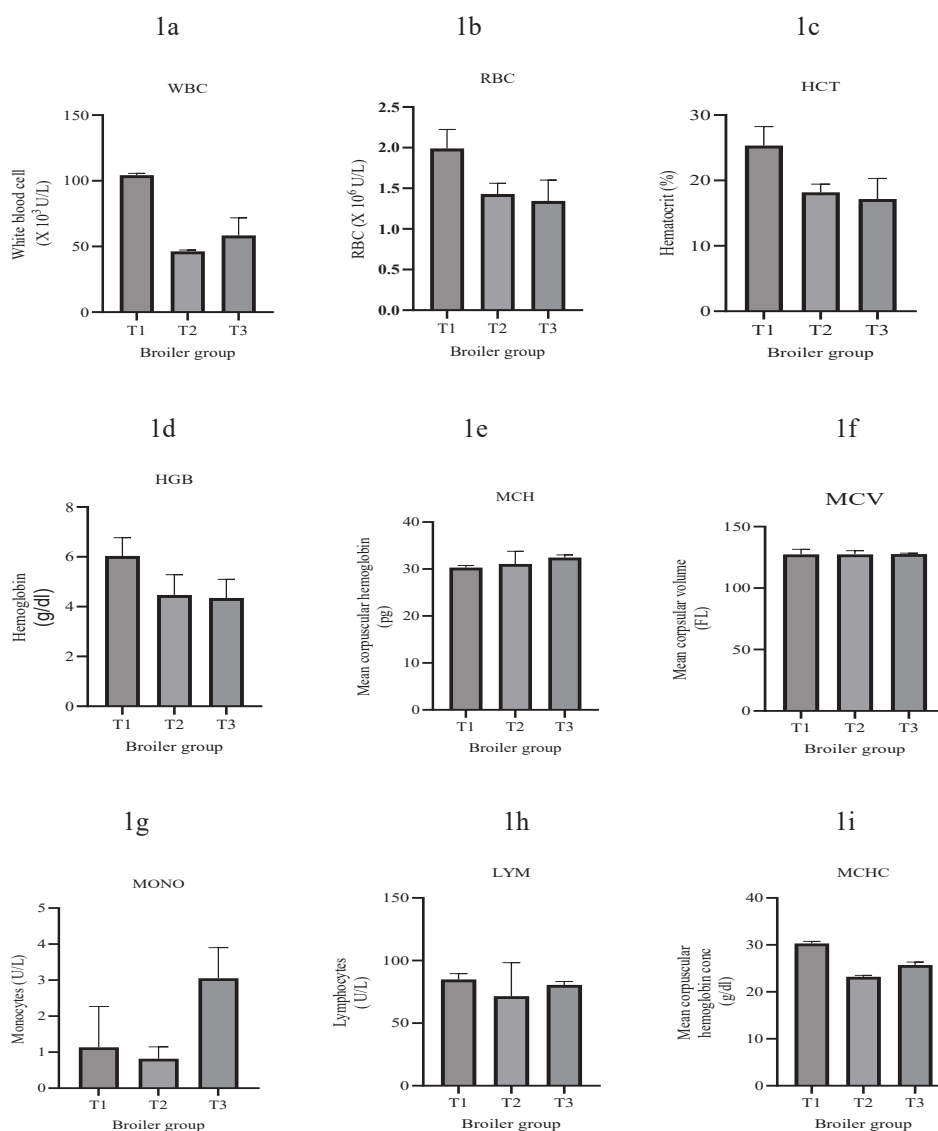


Figure 1. Hematology indices of broiler chicken fed *Saccharomyces cerevisiae* fermented cassava peels (a) White blood cells, (b) Red blood cells, (c) Hematocrit, (d) Hemoglobin, (e) Mean corpuscular Hemoglobin (f) Mean corpuscular volume (g) Monocytes (h) Lymphocytes (i) mean corpuscular hemoglobin concentration

Bars are significantly different from normal (* $p<0.05$; ** $p<0.01$; *** $p<0.001$; **** $p<0.0001$). Control: Feed without cassava peel; B: Feed with 25% cassava peel; C: Feed with 50% cassava peel.

Source: Authors' own elaboration

10). Differences among treatment means were determined using Dunnett's multiple comparisons, and the results are reported as mean $\pm$ SEM and considered significantly different at $p < 0.05$, $p < 0.001$, and $p < 0.01$.

RESULTS AND DISCUSSION

The results of the haematological indices of broiler chickens fed *Saccharomyces cerevisiae*-fermented cassava peels were analyzed and are shown in Figure 1. Increasing replacement levels of fermented cassava peels (from 0% to 50%) resulted in significant reductions in WBC (Figure 1a), RBC (Figure 1b), HGB (Figure 1d), and HCT (Figure 1c), values ($P < 0.05$). MCV, (1f) MCH, (1e) and MCHC (1i) values showed no significant differences across replacement levels, indicating that erythrocyte size remained consistent

regardless of diet. However, lymphocyte counts (LYMP) (1h) decreased with higher replacement levels, while monocyte counts (MONO) (1g) increased significantly at 50% replacement.

The results of the serum lipids of birds fed *Saccharomyces cerevisiae*-fermented cassava peels diets are shown in the charts below. It shows that increasing the replacement level in the diet had a substantial impact on serum lipid profiles, kidney and liver function markers in broiler chickens. Replacement levels of 25% and 50% resulted in greater levels of high-density lipoprotein (Figure 2d) compared to the control. Meanwhile, higher cassava peel replacement levels showed a drop in TRIG (Figure 2b), low-density lipoprotein, and total cholesterol levels compared to the control ($P < 0.001$). Similarly, there was a drop in total bilirubin (BIL) (Figure 4c) at 50% replacement. Creatinine (Figure 3a) and urea levels (Figure 3b) were unaffected by replacement levels ($p > 0.05$).

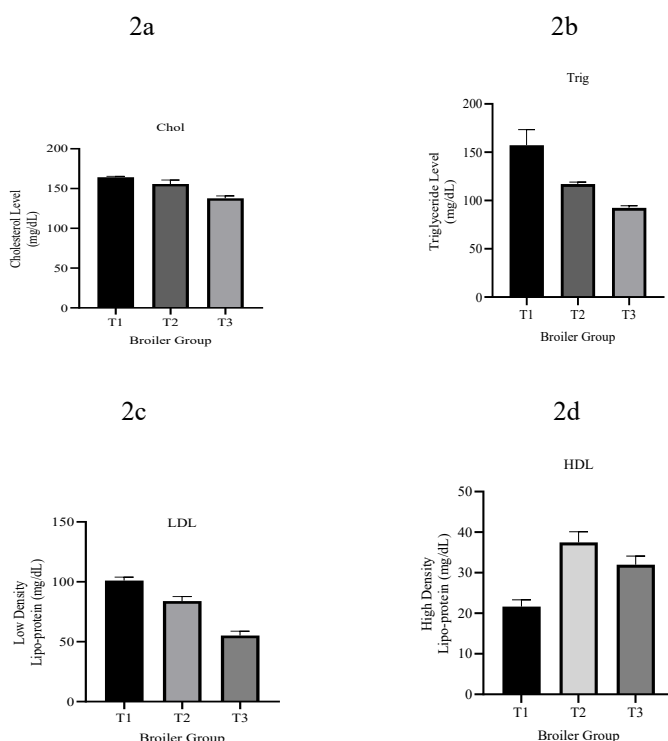


Figure 2. Serum lipid of broiler chicken fed *Saccharomyces cerevisiae* fermented cassava peels replacement diets (a) Cholesterol, (b) Triglycerides, (c) Low-density lipoprotein, (d) High-density lipoprotein

Bars are significantly different from normal (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$). Control: Feed without cassava peel; B: Feed with 25% cassava peel; C: Feed with 50% cassava peel.

Source: Authors' own elaboration

However, alanine aminotransferase (ALT) (Figure 4a) and aspartate aminotransferase (AST) (Figure 4b), important liver enzymes, were dramatically reduced at higher replacement levels ($p < 0.01$), indicating that the diet did not impose hepatic stress.

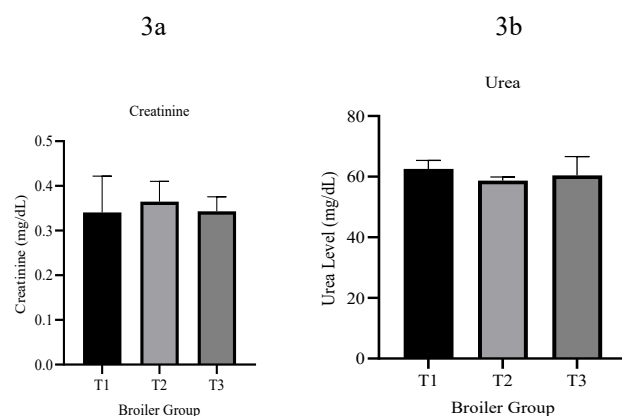


Figure 3. Kidney function markers of broiler chicken fed *Saccharomyces cerevisiae* fermented cassava peels replacement diets. (a) Creatinine, (b) Urea in the blood of broiler chickens

Bars are not significantly different from normal (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$). Control: Feed without cassava peel; B: Feed with 25% cassava peel; C: Feed with 50% cassava peel.

Source: Authors' own elaboration

The effect of the *Saccharomyces cerevisiae* fermented cassava-replaced diets on the activities of antioxidant indices, such as reduced glutathione (GSH), glutathione-S-transferase (GST), superoxide dismutase (SOD), and catalase in the tissue analysis (breast, thigh, and drumstick) of broiler chicken following exposure to the diets for 6 weeks was studied. As depicted in Figure 5a, b, and c below, diets replaced with the *Saccharomyces cerevisiae* fermented cassava peels exhibited significantly ($p < 0.05$) higher GST (5 a(iv), b(iv), c (iv) and SOD (5 a(iii), b(iii), c(iii)) activities when compared with those of the control group, which were fed the normal diet. Furthermore, the level of replacement (25% and 50%) did not affect this increase in SOD and GST activity, especially the diets with 50% replacement, which caused an increase in the tissue SOD activity after the 6 weeks of treatment. Furthermore, the tissue catalase activity 5 a (ii), b (ii), c (ii) in the broiler chickens revealed that the replaced diets also caused a marked increase in the tissue catalase activity in the birds fed the diets with 50% replacement compared to those of the control group. Regarding the non-enzymatic antioxidant, reduced glutathione (GSH) (5 a(i), b(i), c(i)) levels were also elevated in the breast, thigh, and drumstick tissues of birds fed fermented cassava peel replacement diets, with the 50% replacement level showing the greatest increase compared to

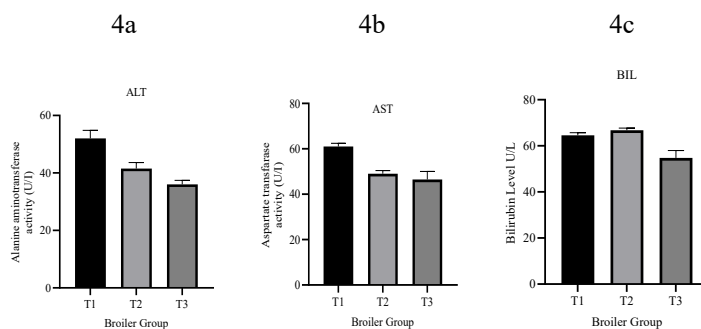
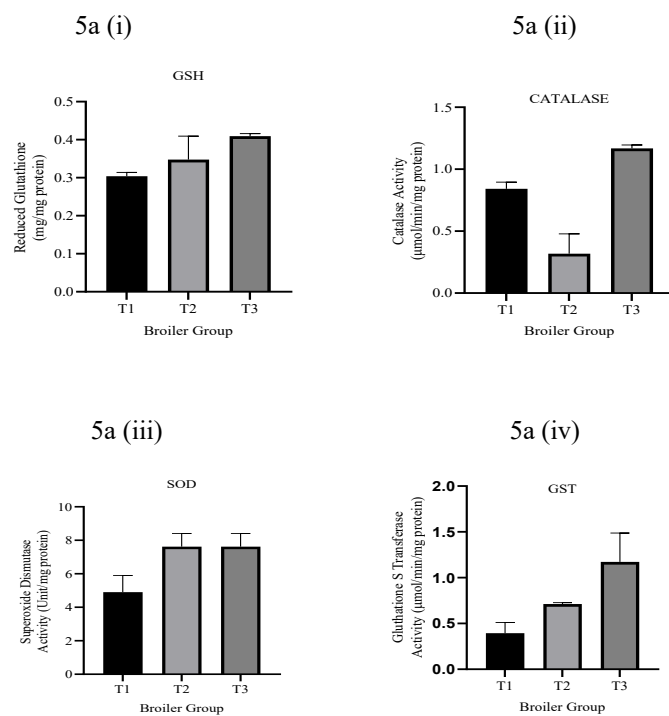


Figure 4. Liver function markers of broiler chicken fed *Saccharomyces cerevisiae* fermented cassava peels replacement diets (a) Alanine aminotransferase, (b) Aspartate aminotransferase, (c) Bilirubin in the blood of broiler chicken

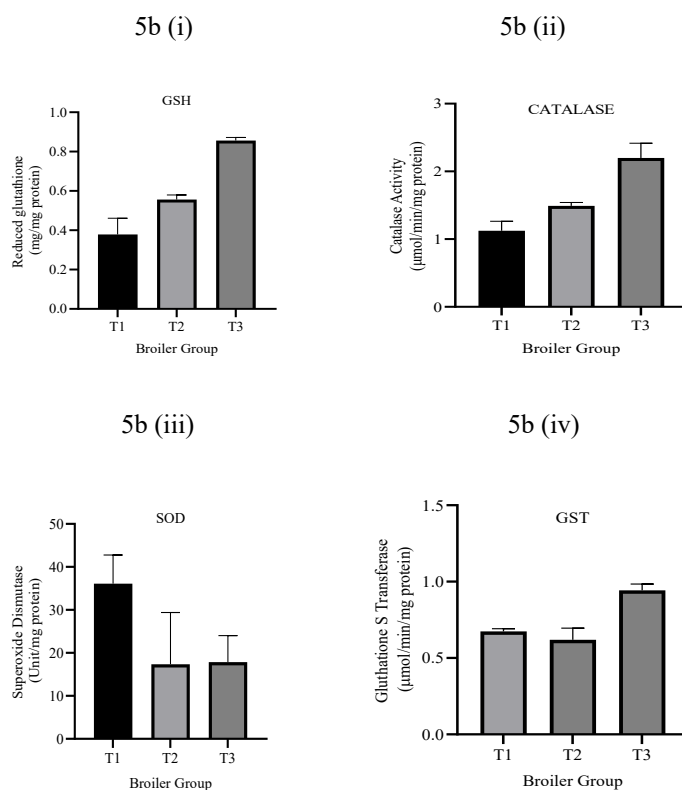
Bars are significantly different from normal (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$). Control: Feed without cassava peel; B: Feed with 25% cassava peel; C: Feed with 50% cassava peel.

Source: Authors' own elaboration

5a. Breast



5b. Thigh



5c. Drumstick

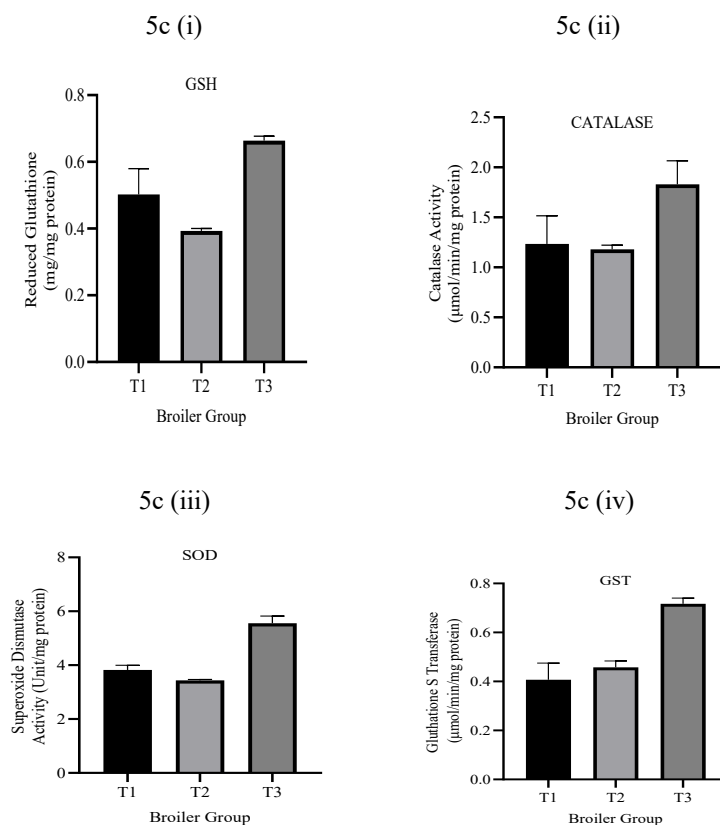


Figure 5. Antioxidant status of broiler chicken (a) Breast, (b) Thigh, (c) Drumstick fed *Saccharomyces cerevisiae* fermented cassava peels replacement diets (i) Reduced Glutathione, (ii) Catalase, (iii) Superoxide dismutase, (iv) Glutathione S-transferase in the meat of Broiler Chicken

Bars are significantly different from normal (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$). Control: Feed without cassava peel; B: Feed with 25% cassava peel; C: Feed with 50% cassava peel.

Source: Authors' own elaboration

the control group ($p < 0.05$), indicating enhanced non-enzymatic antioxidant defense.

According to Oboh and Oladunmoye (2007), fermentation, particularly with microfungi such as *Aspergillus niger*, *Rhizopus oryzae*, and *Saccharomyces cerevisiae*, has been shown to improve the protein content and digestibility of cassava peels. This not only enhances the nutritional profile, but also reduces the levels of cyanogenic glycosides, which are toxic compounds naturally present in cassava (Jayanegara et al., 2025). The inclusion of fermented cassava peels in broiler diets has been associated with improved growth performance, feed efficiency, and meat quality,

making it a viable alternative to traditional feed ingredients (Sugiharto, 2019).

Meanwhile, blood, which is an active transport medium in higher animals, especially in vertebrates, is explained to be a medium that constantly bathes all the organs and tissues of the body, enabling exchange of materials between the internal and external environment of the organs and tissues (Mallanagoud, 2023). The normal ranges of hematological parameters in chickens are Hb: 7.0 - 13.0 g/dl, RBC: 3.0 - 3.5 $\times 10^6/\mu\text{l}$, and WBC: 9.0 - 31.0 ($10^3/\mu\text{l}$) (Jain, 1989). Others are MCV: 90.0 - 140.0 fl, MCH: 33.0 - 47.0 pg/cell, and MCHC: 26.0 - 35.0 (g/dl) (Ukorebi and John,

2023; Bounous and Stedman, 2000). It has been established that haematological parameters are useful in monitoring feed toxicity, especially with feed constituents that affect the blood (Isaac et al., 2013). Nutrients absorbed after the digestion of food/feed are carried by the blood to the different cells and tissues of the body. If such nutrients are toxic, the physiology of the animal subject will be affected (Ukorebi, 2022). The results of this study demonstrated that increasing the replacement levels of micro-fungi-fermented cassava peels in broiler diets (25% and 50%) significantly reduced haematological indices such as WBC, RBC, HGB, and HCT. The observed reduction in WBC count, alongside decreased RBC, HGB, and HCT, indicates potential adverse effects on hematopoiesis and oxygen-carrying capacity, and these parameters decreased in the presence of anti-nutritional factors (Predescu et al., 2024). This indicates potential adverse effects of higher replacement levels on hematopoiesis and oxygen-carrying capacity, possibly due to residual anti-nutritional factors such as cyanogenic glycosides in cassava peels (Olafadehan et al., 2011). Jiwuba et al. (2021) also reported similar trends in reductions in RBC and HGB in sheep and goats fed cassava peel diets. Similarly, Eruvbetine et al. (2015) reported reductions in haematological indices of broiler chickens fed fermented cassava peel meal, corroborating the present findings. Meanwhile, the serum lipid results revealed that increasing the replacement level of micro-fungi-fermented cassava peels significantly influenced serum lipid metabolism, kidney function, and liver enzymes in broiler chickens. The significant decrease in low-density lipoprotein (LDL) at 25% and 50% replacement levels ($p < 0.001$), suggests that higher fermented cassava peel replacement may reduce the transport of harmful lipoproteins in circulation. The concurrent increase in high-density lipoprotein (HDL) ($p < 0.001$) implies that the diet may also enhance reverse cholesterol transport, which is beneficial for cardiovascular health. The observed reduction in total cholesterol (CHOL) and triglycerides (TRIG) at higher replacement levels ($p < 0.001$) aligns with findings by Tolulope et al. (2024), who reported improved lipid me-

tabolism in broilers fed fermented cassava peels due to microbial degradation of lipogenic precursors. This suggests that fermentation effectively reduces lipid accumulation, likely by hydrolyzing residual cyanogenic glycosides, which are known to interfere with lipid metabolism. Adesehinwa et al. (2016) reported similar trends in pigs, where dietary cassava peel inclusion led to lower triglyceride levels, indicating a potential hypolipidemic effect. Renal function markers, including creatinine (CREAT) and urea (UREA), were not significantly affected by replacement levels ($p > 0.05$), indicating that the diet did not impose nephrotoxicity. This finding is in agreement with the results of Adeosun et al. (2024), who found no adverse effects on kidney function in rabbits fed processed cassava peels, implying that replacing maize with sundried cassava peel up to 50% will not negatively affect the serum biochemistry of rabbits. However, the increased uric acid (URIC) at 50% replacement could indicate protein catabolism or metabolic stress, warranting further research. Amaefule et al. (2015) reported a similar trend, where excessive cassava peel inclusion in poultry diets led to increased uric acid levels, potentially due to residual anti-nutritional factors affecting protein utilization.

The significant reduction in alanine aminotransferase (ALT) and aspartate aminotransferase (AST) at higher replacement levels indicates the absence of significant liver damage during the study period. It should be noted that lower ALT and AST levels do not necessarily indicate a healthier liver per se, but rather confirm that the diet did not induce hepatic injury under the experimental conditions. This aligns with the findings of Unigwe et al. (2018), who reported lower liver enzyme activity in pigs fed fermented cassava diets, suggesting hepatoprotective effects of microbial fermentation. However, studies by Oboh and Akindahunsi (2005) reported elevated ALT and AST in rats fed fermented cassava flour, reinforcing the importance of microbial fermentation in reducing cassava-induced hepatic stress. The investigation of antioxidant indices such as glutathione-S-transferase (GST), superoxide dismutase (SOD), reduced glutathione (GSH), and

catalase in the breast, thigh, and drumstick tissues of broiler chickens fed a diet replaced with *Saccharomyces cerevisiae* fermented cassava peels shows significant increases in antioxidant enzyme activity across all tissue types. These results indicate that higher levels of dietary fermented cassava peels influence the activities of these key antioxidant enzymes after six weeks of rearing. Specifically, GST, catalase, and GSH activity were elevated. However, it should be noted that increased antioxidant enzyme activity can reflect two possibilities: either a decrease in oxidative stress leading to upregulated defense capacity, or an adaptive response to increased oxidative stress whereby the body compensates by elevating enzyme production. To definitively confirm improved antioxidant status, further measurement of oxidative damage markers such as malondialdehyde (MDA), reactive oxygen species (ROS), or thiobarbituric acid reactive substances (TBARS) would be needed in future studies. These findings nonetheless suggest that the replacement of fermented feed ingredients influences the antioxidant enzyme profile in poultry, with potential implications for improving overall health. The increased GST activity observed in the breast, thigh, and drumstick tissues aligns with previous research highlighting the role of dietary antioxidants in enhancing detoxification pathways in poultry. Additionally, Galal et al. (2015) reported that phytochemicals from plants are known to induce GST activity, which plays a crucial role in detoxification and protection against oxidative stress, potentially contributing to cancer prevention. Similarly, Sugiharto et al. (2020) also reported that feeding fermented cassava pulp improved immune responses and the antioxidant status of broiler chickens, suggesting that dietary interventions aimed at increasing antioxidant enzyme activity contribute to better growth performance and meat quality in broilers. In terms of SOD activity, the results indicate a systemic enhancement across breast and drumstick tissues, which is crucial for the detoxification of superoxide radicals and hydrogen peroxide, respectively. These enzymes are essential in protecting cells from

oxidative damage, which can arise from high metabolic demands in poultry. The findings are consistent with research by Salami et al. (2015), who noted that an antioxidant-rich diet led to significant increases in SOD and catalase activities, thereby improving oxidative stress management in broilers. However, contrasting studies have suggested that not all fermented feed types yield the same benefits. Ibukun (2012) reported that fermentation caused a reduction in the level of total phenolic compounds in raw sesame seeds from 0.026 mg/g to 0.01 mg/g after seven days of fermentation, establishing that raw sesame seeds exhibited better antioxidant ability than the fermented samples, regardless of fermentation duration. Overall, the comprehensive evaluation of antioxidant enzyme activities in broiler tissues highlights the potential of microfungi-fermented cassava peels as a valuable dietary supplement.

CONCLUSION

This study demonstrates the potential of *Saccharomyces cerevisiae*-fermented cassava peels as a sustainable feed ingredient in broiler production. Regarding haematological indices, replacing maize with fermented cassava peel meal at high proportions (25% and 50%) led to significant decreases in RBC, WBC, HGB, and HCT, indicating anemia at elevated inclusion levels, which warrants careful consideration when determining safe inclusion rates in practical poultry nutrition. With respect to serum lipid levels, the reduction observed in broilers fed fermented cassava peel meal indicates improved lipid metabolism and the absence of significant hepatic damage during the study period. The antioxidant properties showed elevated activities of SOD, CAT, and GST, alongside increased GSH levels, indicating a modulation of the antioxidant defense system in broilers fed fermented cassava peel meal-based diets.

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Writing-review and editing: Akinlolu Oluwafemi Ayeni, Stephen Adeniyi Adefegha, Funmilayo Temidayo Azeez, Olajide Raymond Ojo.

Project administration: Olufemi Adesanya Adu, Ganiyu Oboh, Stephen Adeniyi Adefegha, Funmilayo Temidayo Azeez.

All authors have read and agreed to the published version of the manuscript.

Data availability statement

The data presented in this study are available on request from the corresponding author.

Ethical statement

The study was conducted with the approval of the institutional ethics committee for the care and use of animals for research at the host institution. Ethics Reference No.: FUTA/ETH/23/121.

Conflict of interest

All authors declare no conflict of interest.

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