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Research Article

# Effect of Mushroom Flour Inclusion on Biochemical Profile, Hematological Indices and Weight Change of Albino Rats Fed Maize Based *Ogi*

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## Abstract

The goal of the study was to evaluates the effect of mushroom flour addition on the biochemical profile, hematological indices and weight change of albino rat fed maize based *ogi*. Diet was prepared with inclusion of mushroom flour in *ogi* at 0%, 10%, 20% and 30% level respectively with maize-based cerelac as control. Total of 20 animals were randomly divided in 5 groups and were daily fed formulated and control diet for twenty-eight (28) days. Blood samples were collected for clinical nutrition analyses after the feeding period. The result showed improved nutritional profile and rat growth as indicated by proximate composition and weight change result. The addition of mushroom flour in maize *ogi* food had significant ($P<0.05$) effect on total cholesterol (5.07 to 4.67 mmol/L), aspartate amino transferase (8.05 to 8.25 iu/L), alanine amino transfarase (7.00 to 7.15 iu/L), total protein (4.06 to 7.21 g/L) and albumin (2.91 to 3.20 g/L) while the control group had 5.38mmol/L, 8.00 iu/L, 6.06 iu/L, 7.23g/L and 3.14 g/L respectively. Haematological values ranged from 6.21 to 6.53 ($\times10^9$/L), 7.51 to 7.63 ($\times10^{12}$/L), 14.34 to 15.01 (g/L), 43.05 to 45.23%, 98.07 to 104.45 ($\times10^3$/L) while control group had values of 6.81 ($\times10^9$/L), 8.22 ($\times10^{12}$/L), 16.31 (g/L), 49.06%, 106.06 ($\times10^3$/L) for white blood cells, red blood cells, hemoglobin, packed cell volume and platelets respectively. The study established that mushroom flour inclusion in maize-based *ogi* resulted to healthier diet and had no significant effect on organ of the rats as indicated by the haematological and biochemical profile studies.

## Keywords

Mushroom, Biochemical Profile, Haematology, *Ogi*, Maize, Weight Change

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## 1. Introduction

In numerous regions of the world, including Africa and Nigeria, cereals and their products are reliable sources of nutrition. They have been a significant component of diet for thousands of years [1]. They considerably increase energy density in areas of high consumption while providing only a little amount of protein thus resulting to failure in meeting the body requirement for needed nutrients.

Nutrition and health are fundamental components of human life. Optimal nutrition provides the body with the necessary nutrients both macro and micronutrients to function efficiently and this can be achieved through consumption of food that can provide required nutrients to meet the body need for protein and Energy [2].

In Nigeria, infants are frequently fed cereal-based porridges and gruels chiefly among is *ogi*. *Ogi* is a complementary and breakfast food in sub-Saharan Africa traditionally made from maize, sorghum or millet. It is a fermented gruel that is very high in carbohydrate but poor in protein that can be complemented through supplementation with protein rich foods [3]. There are reported research aimed at improving the nutritional value of *ogi*. For instance, Ukeyima *et al*. reported on the quality of formulated food from maize and garden peas for complementary feeding [4], Adeoti and Osundahuns evaluated nutritional properties of maize complementary food supplemented with fermented and germinated Moringa oleifera seed flour [5]. In another report by Omenna *et al.* the quality and sensory properties of co-fermented maize, millet and sorghum/soybean pap-(*ogi*) was evaluated [6]. However, the studies were majorly based on cereal-legume food formulations with little emphasis on potential protein sources like mushroom.

Mushroom have been increasingly known for their health benefits including antioxidants, anti-inflammatory and immunomodulatory effect [7]. With the growing interest in nutritious and functional foods, mushroom flour has emerged as a promising ingredient for enhancing nutritional value and promoting health. Its application in food system can be extended to complementary food owing to good nutritional quality. However, there is general misconception on the toxicity, nutrients availability, utilization of mushroom based complementary food and scarce literature on clinical nutrition parameters of mushroom based complementary foods. For instance, Aishah and WanRosli reported the use of mushroom powder in carbohydrate-based products to enhance nutrient composition [8]. A study by Regula *et al.* also assesses the bioavailability of iron from cereal products enriched with dried shiitake mushrooms [9]. In an Indian study, mushroom powder was successfully incorporated in a Ready to Use Therapeutic Feed (RUTF) formulation with a high degree of efficacy [10]. In a study by Samuel *et al*. the effect of *Pleurotus ostreatus* supplementation on the nutritional and sensory qualities of maize *ogi* was assessed [11]. Ajala and Taiwo also reported on the incorporation of oyster mushroom (*Pleurotus ostreatus*) flour into *ogi* formulations [12]. However, these studies did not address the nutrients utilization and toxicity effect of mushroom supplemented *ogi* on serum biochemical and hematological parameters through animal model (Albino rats).

Albino rats are a widely used animal model for human health research and their biochemical and hematological indices share similarities with those of humans [13]. Therefore, investigating the effect of mushroom flour inclusion on hematological and serum biochemical profile of albino rats can provide valuable insights into its potential effect on human health. The study seeks to explore the impact of mushroom supplementation on the biochemical parameters, hematological profiles, and body weight changes of albino rats.

## 2. Materials and Methods

Maize (*Zea mays*) was obtained from Wadata market, Makurdi and oyster mushroom was obtained from Oracle Farms Makurdi, Benue State, Nigeria. Wistar Albino rats were obtained from school of medical science Benue state University Makurdi, Benue state. Ingredients (vitamin/mineral mix, salt, cray fish meal, vegetable oil, defatted groundnut) for diet formulation were obtained from Modern market, Makurdi Benue state, Nigeria while the non-nutritive fibre (cellulose) was obtained from Mikap Nigeria Limited Benue state, Nigeria.

*Ogi* and mushroom flour were prepared as described by Samuel *et al.* with modification [11]. The maize grains were separated based on good and defected seeds. The good seeds were cleaned and soaked in warm water for 72h. The steeped grains were thoroughly washed and wet-milled into paste using local disc attrition mill before sieving using muslin cloth. The slurry was allowed to settle for 48h during which fermentation occur. The supernatant was decanted and the *ogi* was collected, oven dried, blended using Foshan Geuwa KD-313B blender and stored in air-tight container for further usage.

Healthy and clean oyster mushroom was weighed and dice into small pieces with stainless steel knife. The diced mushroom was blanched, oven dried and blended using Foshan Geuwa KD-313B blender and stored in polyethylene bags for further usage.

### 2.1. Blend and Diet Formulation

Mushroom was incorporated into *ogi* flour at various ratios (Table 1) while diet was formulated based on the formulations and ingredient mix (Table 2).

### 2.2. Analysis of Proximate Composition

Moisture, crude fat, protein (calculated as % N ×6.25), ash, and crude fibre contents were analysed using the standard procedures described by the Association of Official Analytical Chemists [14]. The carbohydrate content of the samples was

estimated by difference.

## 2.3. Feeding Trial Experiment

The feeding experiment was conducted using Wistar albino rats over a period of 28 days following the procedure described by Ikya *et al*. [15]. All experimental procedures involving animal handling and care complied with the guidelines established by the Animal Use and Care Committee (AUCC) of the National Veterinary Research Institute, Vom, Nigeria, which granted ethical approval for the study. A total of twenty (20) Wistar albino rats were randomly assigned to five experimental groups (A, B, C, D, and E), with four animals housed in each cage. The animals in each treatment group were provided with a weighted portion of 55 g of the formulated diet daily while water was supplied *ad libitum* throughout the experimental period. At the end of the 28-day feeding trial, blood samples were randomly collected from the experimental animals for the determination of serum biochemical parameters and hematological indices. Feed intake and body weight measurements were recorded during the study, and weight gain was calculated by comparing the final body weight with the initial body weight. The experiment was arranged using a completely randomized design (CRD).

## 2.4. Weight Change Determination

Body weight was measured at four-day intervals using an analytical balance and both the initial and final weights of the animals were recorded to assess weight changes during the experimental period.

## 2.5. Haematological Analysis

Packed cell volume was analysed using the method of Sarah *et al*. [16]. This technique stopped the blood from clotting, allowing it to spin in a centrifuge and divide into layers because of gravity. Centrifugal force causes the cells to compress and settle. Blood samples collected in anticoagulant-treated tubes were drawn into microhaematocrit capillary tubes, leaving approximately 15 mm of the tube unfilled. One end of each capillary tube was sealed with plasticine and centrifuged at 12,000 rpm for 5 minutes using a microhaematocrit centrifuge. The packed cell volume (PCV) was then determined by placing the centrifuged tubes on a microhaematocrit reader and aligning them until the plasma meniscus corresponded with the 100% calibration mark, after which the PCV value was recorded as a percentage.

Estimation:

PCV value was estimated as the ratio of the height of the cells to the total height of fluid in the tube.

### 2.5.1. Red Blood Cells

Red blood counts were determined as outlined by Ikya *et al.* [15]. All chemicals used were analytical grade. Red blood cell (RBC) counts were determined using an RBC pipette, a Neubauer haemocytometer fitted with a cover slip, a microscope, 70% alcohol, a pipette rotator, and an aspirator connected to a running water source. Blood was drawn into the RBC pipette up to the 0.5 mark, after which Hayem's solution was added to the 101 mark to achieve the required dilution. The contents of the pipette were thoroughly mixed by holding the pipette horizontally and rotating it gently between the thumb and fingers. Subsequently, the diluted blood sample was introduced into the counting chamber by allowing the pipette tip to touch the edge of the haemocytometer at an angle of approximately 45 °. The loaded chamber was placed on the microscope stage and left undisturbed for about two minutes to permit cell settlement. The counting grid was first examined using the 10 × objective lens, after which red blood cells were counted under the 45 × objective lens in five groups of sixteen small squares.

The total red blood cell count was calculated by multiplying the number of cells counted in the 80 designated squares (N) by a factor of 10,000, expressed as:

$$\text{Total RBC count} = N \times 10{,}000$$

where N represents the number of red blood cells enumerated within the 80 counting squares.

### 2.5.2. White Blood Cells

The method outlined by Ikya *et al.* was used [15]. The procedure used for determining the white blood cell (WBC) count was similar to that employed for red blood cell (RBC) enumeration, except that a dilution ratio of 1:20 was adopted for WBC analysis. Glacial acetic acid served as the diluting fluid because of its ability to lyse red blood cells, thereby facilitating accurate counting of white blood cells. The total white blood cell count was calculated by multiplying the number of white blood cells counted in the designated 80 squares (N) by a factor of 10,000, as expressed by the equation:

$$\text{Total WBC count} = N \times 10{,}000$$

where N represents the number of white blood cells counted within the 80 squares of the haemocytometer.

### 2.5.3. Determination of Platelet

Platelet count was determined using the procedure described by Sarah *et al.* [16]. Briefly, blood samples were diluted with 1% ammonium oxalate solution, which lysed the red blood cells to facilitate platelet enumeration. Platelets were then counted within a defined area of an improved Neubauer haemocytometer using the chamber's calibrated grid lines. Identification of platelets was based on their characteristic mauve-pink appearance.

### 2.5.4. Determination of Haemoglobin (Hb) Content

The haemoglobin content (Hb) was determined as outlined by Sarah *et al.* [16]. Haemoglobin concentration was determined using a Sahli haemoglobinometer. Briefly, the graduated tube of the haemoglobinometer was filled with 10 N hydrochloric acid up to the 20 mL mark, after which 0.02 mL of blood was added. The mixture was thoroughly stirred using a glass rod and allowed to stand for 5 minutes to facilitate the conversion of haemoglobin to acid haematin. Additional acid was subsequently added gradually while continuously mixing until the colour of the test solution corresponded with that of the standard comparator. The haemoglobin concentration was then obtained by reading the fluid level in the graduated tube and expressing the result as a percentage.

## 2.6. Serum Biochemical Profile Analysis

### 2.6.1. Serum Total Protein

Method outlined by Ikya *et al.* was used in determination of serum protein [15]. Three test tubes were prepared and designated as standard, blank, and sample tubes. A volume of 2.0 mL of the working reagent was dispensed into each tube. Subsequently, 0.04 mL of the standard solution and the sample were added to their respective tubes, mixed thoroughly, and allowed to incubate at room temperature (25 ℃) for 5 minutes. The spectrophotometer was adjusted to a wavelength of 540 nm and calibrated using the reagent blank. Thereafter, the absorbance values of the standard and sample solutions were measured and recorded.

$$\text{Total Protein (g/dl)} = \frac{Absorbance\ of\ unknown\ X\ Concentration\ of\ standard}{Absorbance\ of\ standard} \quad (1)$$

### 2.6.2. Cholesterol Determination

Cholesterol was determined as outlined by Ikya *et al.* [15]. Cholesterol analysis was carried out directly in cuvettes at room temperature using an enzymatic colorimetric method. The assay involved the enzymatic hydrolysis and oxidation of cholesterol, resulting in the formation of a quinoneimine chromogen in the presence of phenol and peroxidase, with absorbance measured at 500 nm. The reagents employed in the analysis included cholesterol esterase (0.16 U/mL), cholesterol oxidase (0.11 U/mL), 4-aminoantipyrine (5 mmol/L), phenol (25 mmol/L), and peroxidase (5.5 U/mL). For the assay, 1 mL of the working reagent containing these components was dispensed into both the blank and sample test tubes. Subsequently, 0.01 mL of distilled water and 0.01 mL of the blood sample were added to the blank and sample tubes, respectively. The reaction mixtures were incubated at 25 ℃ for 10 minutes, after which the absorbance values were measured at a wavelength of 500 nm.

### 2.6.3. Analysis of Serum Aspartate Aminotransferase (AST)

Aspartate Amino Transferase (AST) was determined as outlined by Ikya *et al.* [15]. AST was measured by monitoring the concentration of 2, 4-dinitrophenylhydrazine. AST/Glutamic oxaloacetictransaminase (GOT), Phosphate buffer pH 7.5 (95mmol/L), aspartate (200mmol/L), α-oxoglutarate (2mmol/L) and Colourreagent, 2,4- dinitrophenylhydrazine (1mmol/L), Standard Pyruvate, Sodium hydroxide (0.4N) were used in determination of AST content of blood samples. In both blank and sample test tubes 500µL of reagent 1 was added and 100ml deionized water. The mixture was incubated exactly for 30 minutes at 37 ℃. About 500µL of reagent 1 was added to both test tubes and mixed and allowed to stand for 20 minutes at 25 ℃. NaOH (0.4N) of 5 ml was added to both test tubes. It was mixed thoroughly, and the photometer analysed the samples after incubation for 5 minutes at 25 ℃. The concentration of AST (U/mL) was calculated from the standard curve.

### 2.6.4. Analysis of Alanine Amino Transferase (ALT)

Alanine Amino Transferase (ALT) was determined as outlined by Ikya *et al.* [15]. Alanine aminotransferase (ALT) activity was determined using glutamic pyruvic transaminase (GPT) assay reagents comprising phosphate buffer (pH 7.5, 95 mmol/L), L-alanine (200 mmol/L), α-oxoglutarate (2 mmol/L), 2,4-dinitrophenylhydrazine (1 mmol/L) as the colour reagent, standard pyruvate, and 0.4 N sodium hydroxide. For the assay, 500 µL of reagent solution was dispensed into both the blank and sample test tubes, followed by the addition of 100 µL of deionized water. The reaction mixtures were incubated at 37 ℃ for exactly 30 minutes. Thereafter, 500 µL of the colour reagent was added to each tube, mixed thoroughly, and allowed to stand at 25 ℃ for 20 minutes. Subsequently, 5 mL of 0.4 N sodium hydroxide was added to each tube, and the contents were mixed thoroughly. Following a further incubation period of 5 minutes at 25 ℃, the absorbance was measured using a photometer. The ALT activity, expressed in U/mL, was determined by reference to a standard calibration curve.

### 2.6.5. Determination of Serum Albumin

Serum albumin concentration was determined using the bromocresol green (BCG) dye-binding method described by Akinnowo et al. [17]. Briefly, 8.0 mL of BCG reagent was dispensed into appropriately labelled test tubes, followed by the addition of 0.1 mL of the serum sample. The contents were thoroughly mixed and incubated in a water bath at 37 ℃ for 15 minutes to allow for colour development. Absorbance was subsequently measured at a wavelength of 640 nm against a reagent blank containing 8.0 mL of BCG solution and 0.1 mL of distilled water. The albumin concentration of each serum sample, expressed as g/100 mL, was calculated using a standard calibration curve.

*Table 1. Ogi/mushroom blend formulation.*

| Sample | Flour (g) | |
|---|---|---|
| | Ogi | Mushroom |
| A | 100 | 0 |
| B | 90 | 10 |
| C | 80 | 20 |
| D | 70 | 30 |

*Table 2. Diet formulation.*

| Diet | | | | | |
|---|---|---|---|---|---|
| Ingredients (%) | A (100:0) | B (90:10) | C (80:20) | D (70:30) | E (Control) |
| *Ogi* flour | 80 | 72 | 64 | 56 | - |
| M. flour | 0 | 8 | 16 | 24 | - |
| Cray fish | 3 | 3 | 3 | 3 | - |
| Vit/min. Mix | 1 | 1 | 1 | 1 | - |
| V.oil | 5 | 5 | 5 | 5 | - |
| Salt | 4 | 4 | 4 | 4 | - |
| Sugar | 2 | 2 | 2 | 2 | - |
| Cellulose | 5 | 5 | 5 | 5 | - |
| Cerelac | - | - | - | - | 100 |
| Total | 100 | 100 | 100 | 100 | 100 |

Key: M. flour = mushroom flour, V. oil = Vegetable oil

### 2.7. Methods of Statistical Analysis

The data obtained from the study were analysed using the Statistical Package for the Social Sciences (SPSS) version 20.0. Analysis of variance (ANOVA) was employed to evaluate significant differences among treatment means and the results were expressed as mean values accompanied by their corresponding standard deviations (mean ±SD). Duncan multiple range test was used for mean separation.

## 3. Results and Discussion

### 3.1. Effect of Mushroom Inclusion on the Proximate Composition of Maize Based *ogi*

The proximate composition of maize based *ogi* is shown in Table 3. Significant ($p < 0.05$) variations were observed among the samples for moisture, protein, fibre crude fat, ash and carbohydrate content. Moisture content of the formulated samples ranged from 7.95 to 8.71% with a corresponding lower value (5.95%) for the control. The result agreed with the report of Ajala and Taiwo who reported moisture content ranged of 9.08% to 10.42% in *ogi* supplemented with oyster mushroom [12]. The moisture content of food gives an indication of its safety and microbial stability [18]. Moisture content reported by this study is within the safe moisture content of 10% recommended by protein advisory group [18]. The protein content of the samples differed significantly ($p < 0.05$) and ranged from 7.63 to 15%. The protein content increased with increase in level of mushroom inclusion in maize *ogi*. Ajala and Taiwo also reported increase (8.9% to 13.29%) in protein content of *ogi* supplemented with mushroom flour [12]. The formulation with 30% mushroom inclusion compares favorably to the control sample and falls within the 15% range

that the World Health Organization recommends for complementary foods [19].

Fat content ranged from 3.82 to 4.91%. The result agreed with the 4.8 to 9.42% reported by Ikujenlola and Fashakin for complementary diets produced from quality protein maize-soy blends [20]. The control sample (cerelac) had significantly (P<0.05) higher value of fats as compared to the formulated sample. This might be due to supplementation of the commercial weaning product with fat source. High fat is nutritionally advantageous; however, it can reduce the shelf life and stability of the food product during storage as reported by Taglieri [21]. Fibre content of the formulated and control samples was within the recommended value of less than 5% reported by Reddy *et al.* [22]. Values ranged from 1.11 to 2.11 for formulated samples. The result agreed with the report of Ajala and Taiwo who reported higher values ranging from 3.13% to 3.90% [12]. Particular attention is given to maintaining low fibre levels in weaning foods because the digestive systems of infants are often not sufficiently developed to effectively process high-fibre diets. Excessive dietary fibre intake has been reported to interfere with the digestion and absorption of proteins and essential minerals in humans [23].

The result for ash composition of formulated samples increased with increase in level of mushroom inclusion in *ogi*. The result showed consistency with the report of Ajala and Taiwo whose values ranged from 1.56% to 1.90% in their work on enrichment of *ogi* with mushroom flour. Control sample (cerelac) was significantly higher in ash content; however, among the formulated samples, the formulation with 30% mushroom inclusion had significantly (P<0.05) higher ash content [12]. The ash content of a food product serves as an important indicator of its mineral composition and is also widely used as a quality parameter for assessing the presence of contamination or adulteration [18].

Carbohydrate is a major source of energy thus contributing energy to the body. The result of carbohydrate content indicates value range of 68.52 to 77.42% in a decreasing trend with mushroom flour inclusion at different levels. The carbohydrate content of the formulated samples showed consistency with 69.64% to 72.51% reported by Ajala and Taiwo [12]. The finding also agreed with the report of Akinrinola *et al.* [24] whose values ranged from 70.77 to 89.60% in their work on supplementation of *ogi* with okra seeds. The carbohydrate content reported by this study is within the 41.13 to 73.79g/100 g recommended standard by Codex Alimentarius commission as reported by Pisa *et al.* [25].

***Table 3.*** *Effect of mushroom inclusion on proximate composition of maize based ogi.*

| Sample | % | | | | | |
|---|---|---|---|---|---|---|
| | **Moisture** | **Protein** | **Fat** | **Fibre** | **Ash** | **Carbohydrate** |
| A | $7.95^{c}$ ±0.78 | $7.63^{e}$ ±0.01 | $4.91^{b}$ ±0.01 | $1.11^{c}$ ±0.01 | $1.13^{e}$ ±0.01 | $77.42^{a}$ ±0.11 |
| B | $8.12^{bc}$ ±0.01 | $10.04^{d}$ ±0.01 | $4.66^{c}$ ±0.06 | $1.32^{b}$ ±0.01 | $1.22^{d}$ ±0.01 | $74.72^{b}$ ±0.01 |
| C | $8.23^{b}$ ±0.01 | $13.32^{c}$ ±0.01 | $4.01^{d}$ ±0.01 | $1.46^{b}$ ±0.01 | $1.31^{c}$ ±0.01 | $71.67^{c}$ ±0.03 |
| D | $8.71^{a}$ ±0.13 | $15.32^{b}$ ±0.03 | $3.82^{c}$ ±0.01 | $2.11^{a}$ ±0.13 | $1.43^{b}$ ±0.01 | $68.52^{d}$ ±0.45 |
| E | $5.95^{d}$ ±0.07 | $15.73^{a}$ ±0.01 | $10.40^{a}$ ±0.01 | $2.12^{a}$ ±0.02 | $3.14^{a}$ ±0.01 | $62.63^{e}$ ±0.01 |
| LSD | 0.02 | 0.04 | 0.08 | 0.16 | 0.02 | 0.53 |

All values are duplicate means ± standard deviation. Different superscripts between columns depict significant difference (p≤ 0.05). Key: A = 100% *Ogi* + 0% mushroom, B = 90% *Ogi* + 10% mushroom, C =80% *Ogi* + 20% mushroom, D =70% *Ogi* + 30 mushroom and E = commercial weaning food (maize based Ceralac).

## 3.2. Mean Weekly Feed Consumption and Weight Change of Rats Fed Formulated Diet

The body weight of experimental rats noticeably increased with inclusion of mushroom flour in *ogi* indicating that the diet support growth (Table 4). The average feed consumption pattern showed significant (P<0.05) decreased with mushroom inclusion in the diet probably due to non-palatability of diet with increased level of mushroom flour in the diet. The group fed control diet consumed the highest food. Umar *et al.* reported high feed consumption by group fed control and high protein food [26]. The weight gain increased significantly (P<0.05) with mushroom flour inclusion in the diet. Mean weight of rats increased weekly and ranged from 7.51 to 40.50g at the last week of feeding experiment. The weight

change was probably impacted by the type of protein, its constituents and the quantity of diet consumed. It was observed that the weight gain of the group fed formulated diet was lower than those fed the control diet (cerelac). According to Ikya *et al.* weight gain is a measure of nutritive value of food and index of diet to support growth [15]. Among the formulated diet, diet A (100% *ogi*) with least protein supported best weight gain while the diet with 10% inclusion supported the least weight. This could be due to obesity. Duwaerts and Maher reported that high carbohydrate in diet suppresses release of fatty acids from adipose tissues and directs fatty acids towards the adipose storage resulting to obesity and this can account for the high weight in diet A (100% *ogi*) [27].

***Table 4.*** *Mean weekly feed consumption and weight change of rats fed formulated diet.*

| Diet | Mean weekly feed intake (g) | Weight changes (g) Week 1 | Week 2 | Week 3 | Week 4 |
|---|---|---|---|---|---|
| A | $53.10^{a}$ ±0.14 | $13.18^{a}$ ±0.10 | $15.05^{b}$ ±0.01 | $16.18^{b}$ ±0.10 | $17.01^{b}$ ±0.01 |
| B | $47.12^{c}$ ±0.16 | $7.23^{b}$ ±0.03 | $7.30^{d}$ ±0.01 | $7.36^{e}$ ±0.01 | $7.51^{e}$ ±0.01 |
| C | $43.74^{d}$ ±0.20 | $7.35^{b}$ ±0.01 | $12.05^{c}$ ±0.01 | $13.05^{c}$ ±0.07 | $15.10^{c}$ ±0.14 |
| D | $33.58^{e}$ ±0.25 | $6.75^{c}$ ±0.01 | $7.24^{e}$ ±0.01 | $7.81^{d}$ ±0.01 | $8.15^{d}$ ±0.07 |
| E | $51.50^{b}$ ±0.07 | $7.26^{b}$ ±0.01 | $24.25^{a}$ ±0.35 | $35.05^{a}$ ±0.07 | $40.50^{a}$ ±0.71 |
| LSD | 0.93 | 0.13 | 0.42 | 0.17 | 0.83 |

All values are duplicate means ±standard deviation. Different superscripts between columns depict significant difference ($p \leq 0.05$). Key: A = 100% *Ogi* + 0% mushroom, B = 90% *Ogi* + 10% mushroom, C =80% *Ogi* + 20% mushroom, D =70% *Ogi* + 30 mushroom and E = commercial weaning food (maize based Ceralac).

### 3.3. Effect of Mushroom Inclusion in Maize Based *ogi* Diet on Serum Biochemical Profile of Wistar Albino Rat

The blood chemistry of experimental animals is used to ascertain the nutritional and toxicity status of diet. The chemistry of serum is routinely used for detection of organ diseases in domestic mammals and the amount of available protein in the diets [28]. Serum biochemical parameters determine were within the safe level for laboratory rats. The serum biochemical parameters are presented in Table 5.

The cholesterol values of group fed formulated diet ranged from 4.63 to 5.07 mmol/L and lower than the group fed control diet. The values reported by this study are more than 0.94 to 0.97 mmol/L reported by Ikya *et al.* [15] but within the reference level of 11.1mmol/L for laboratory rats [28].

The serum activities of Alanineaminotransferase (ALT), Aspartate aminotransferase (AST) is usually used as indices in assessing the liver physiological status. AST and ALT values of the group fed formulated diets ranged from 8.05 to 8.25 iu/L and 7.00 to 7.15 iu/L. The study reported lower values for group fed control diet. However, all the AST and ALT values reported by this study are within the reference range of less than of 50 to 150 iu/L [29]. Ikya *et al.* reported values range of 1.60 iu/L to 1.61 iu/L in his assessment of clinical nutritional parameters of rats fed rice meal [15]. Level of AST and ALT in the blood is caused by increased conditions of liver cell damage and death. The findings of this study indicate that the incorporation of mushroom flour had no adverse effect on the liver function of the experimental rats.

The serum total protein and albumin of the group fed control diet were significantly ($P<0.05$) higher than the group fed formulated diet although no significant difference ($P<0.05$) in albumin value of the group fed on diet B, C and D. The serum protein of group fed diet D (70% *ogi* + 30 mushroom flour) compares favourably well with group fed control diet, same was observed in albumin values of group fed 20% (C) and 30% (D) mushroom inclusion. Serum protein and albumin values are indicators of protein quality in food and index of the nutrition and health status of animals [30].

***Table 5.*** *Effect of mushroom inclusion in maize based ogi diet on serum biochemical profile of rat.*

| Diet | TC (mmol/L) | AST (iu/L) | ALT (iu/L) | TP (g/L) | ALB (g/L) |
|---|---|---|---|---|---|
| A | $5.07^{b}$ ±0.78 | $8.05^{b}$ ±0.35 | $7.00^{c}$ ±0.01 | $4.06^{c}$ ±0.09 | $2.91^{b}$ ±0.01 |
| B | $4.93^{c}$ ±0.92 | $8.06^{b}$ ±0.64 | $7.07^{b}$ ±0.06 | $4.71^{c}$ ±0.01 | $3.06^{ab}$ ±0.08 |
| C | $4.88^{d}$ ±0.70 | $8.23^{a}$ ±0.01 | $7.13^{a}$ ±0.21 | $6.11^{b}$ ±0.71 | $3.15^{a}$ ±0.07 |
| D | $4.67^{e}$ ±0.70 | $8.25^{a}$ ±0.01 | $7.15^{a}$ ±0.01 | $7.21^{a}$ ±0.01 | $3.20^{a}$ ±0.14 |
| E | $5.38^{a}$ ±0.07 | $8.00^{c}$ ±0.01 | $6.06^{d}$ ±0.07 | $7.23^{a}$ ±0.01 | $3.14^{a}$ ±0.06 |
| LSD | 0.04 | 0.10 | 0.04 | 0.83 | 0.22 |

All values are duplicate means ±standard deviation. Different superscripts between columns depict significant difference ($p \leq 0.05$). Key: A = 100% *Ogi* + 0% mushroom, B = 90% *Ogi* + 10% mushroom, C =80% *Ogi* + 20% mushroom, D =70% *Ogi* + 30 mushroom and E = commercial weaning food (maize based Ceralac). TC = Total cholesterol, AST = aspartate amino transfarase, ALT = Alanine amino transfarase, TP = Total protein, ALB = Albumin

## 3.4. Effect of Mushroom Inclusion in Maize Based *ogi* Diet on Haematology of Rat

Haematological parameters are important indicators used to assess the physiological condition and overall health status of animals and livestock populations. According to Adejuwon *et al.* haematological indices provide valuable baseline data for evaluating nutritional deficiencies, physiological variations, and the health status of farm animals, particularly those reared under traditional husbandry systems in Nigeria [31].

The values for blood count ranged from 6.21 ($\times10^{9}$/L) to 6.53 ($\times10^{9}$/L), 7.51 ($\times10^{12}$/L to 7.63 ($\times10^{12}$/L), 14.34 (g/L) to 15.01 (g/L), 43.05 (%) to 45.23 (%) and 98.07 ($\times10^{3}$/L) to 104.45 ($\times10^{3}$/L) for white blood cells, red blood cells, haemoglobin content, packed cell volume and platelets respectively (Table 6). The hematological parameter values of the formulated diet were significantly ($p<0.05$) lower than their corresponding control values. This could be due to difference in nutritional composition of the food. The primary role of white blood cells and their differential components is to protect the body against infections by engulfing and destroying invading microorganisms through phagocytosis, as well as by producing, transporting, and distributing antibodies involved in immune responses. All the values obtained were within the range of $5\times10^{9}$ to $9\times10^{9}$ /L as specified by Andrew *et al.* [32]**.** According to Osaro *et al.* red blood cells are involved in the transport of oxygen and carbon dioxide in the body [33]. The values reported are lower than those reported by Ikya *et al.* whose values ranged from 9.01 to 9.07 ($\times10^{12}$/L) in his clinical nutrition work on rice meal [15]. The Hemoglobin concentration and haematocrit are values that show the degree of anemia. The Haemoglobin concentration and haematocrit are values. White blood cells and their various subtypes play crucial roles in the body's defense mechanisms by combating infectious agents, eliminating foreign materials through phagocytic activity, and facilitating immune responses through the production and transport of antibodies. The result shows similarity to those reported by Adeoti and Osundahunsi with values ranging from 13.10 – 13.49 g/dl [5]. As reported by Osaro *et al.* packed cell volume (PCV) plays a vital role in the transport of oxygen and absorbed nutrients throughout the body [33]. Therefore, an elevated PCV value indicates enhanced transport capacity and may be associated with the development of primary or secondary polycythaemia. All the values showed high percentage when compared to the reference value of 24-34% recommended for healthy rat [34]. This finding agreed with the report of Umar *et al.* whose values ranged from 35.40 to 45.86% in his work on millet and maize based complementary weaning food [26]. Blood Platelets play a critical role in the blood coagulation process. A reduced platelet count may impair clot formation, thereby prolonging bleeding time and increasing the risk of excessive blood loss following injury. The platelet values obtained in the present study are consistent with those reported by Umar et al. who recorded platelet counts ranging from 97 to 350 × 10 ³/L in their investigation of millet- and maize-based complementary weaning foods [26].

***Table 6.*** *Effect of mushroom inclusion in maize based ogi diet on haematology of rat.*

| Diet | WBC ($\times10^{9}$/L) | RBC ($\times10^{12}$/L) | Hb (g/L) | PCV (%) | PLT ($\times10^{3}$/L) |
|---|---|---|---|---|---|
| A | $6.21^{d}$ ±0.01 | $7.51^{c}$ ±0.01 | $14.34^{d}$ ±0.21 | $43.05^{e}$ ±0.07 | $98.07^{e}$ ±0.08 |

| Diet | WBC ($\times10^9$/L) | RBC ($\times10^{12}$/L) | Hb (g/L) | PCV (%) | PLT ($\times10^3$/L) |
|---|---|---|---|---|---|
| B | $6.29^c$ ±0.11 | $7.53^c$ ±0.01 | $14.35^d$ ±0.01 | $44.00^d$ ±0.01 | $98.90^d$ ±0.01 |
| C | $6.52^b$ ±0.07 | $7.62^b$ ±0.01 | $14.71^c$ ±0.01 | $45.02^c$ ±0.06 | $101.02^c$ ±0.04 |
| D | $6.53^b$ ±0.01 | $7.63^b$ ±0.01 | $15.01^b$ ±0.01 | $45.23^b$ ±0.01 | $104.45^b$ ±0.14 |
| E | $6.81^a$ ±0.01 | $8.22^a$ ±0.01 | $16.31^a$ ±0.01 | $49.06^a$ ±0.07 | $106.06^a$ ±0.07 |
| LSD | 0.03 | 0.03 | 0.04 | 0.05 | 0.09 |

All values are duplicate means ±standard deviation. Different superscripts between columns depict significant difference ($p \leq 0.05$). Key: A = 100% *Ogi* + 0% mushroom, B = 90% *Ogi* + 10% mushroom, C =80% *Ogi* + 20% mushroom, D =70% *Ogi* + 30 mushroom and E = commercial weaning food (maize based Ceralac). WBC = white blood cells, RBC = Red blood cells, Hb = Haemogobin content, PCV = Packed cell volume and PLT = Platelets.

## 4. Conclusions

The inclusion of mushroom in maize-based *ogi* had impact on the biochemical profile, hematological indices and weight change of albino rats. The significant improvements in hematological indices suggest that mushroom inclusion in *ogi* enhanced the overall health and well-being of the rats. The significant improvement in serum protein and safe level of cholesterol, Alanineaminotransferase (ALT) and Aspartate aminotransferase (AST) indicates the nutrients potentials and safety of the product. In addition, the significant weight gain observed in the experimental groups indicates improved nutritional adequacy of the mushroom-supplemented *ogi*. These findings suggest that mushroom inclusion in maize-based *ogi* may be a valuable strategy for enhancing nutritional quality and potential health benefits of this staple food, particularly in regions where *ogi* is a mainstay of the diet.

## Abbreviations

ALB Albumin
ALT Alanine Amino Transfarase
AST Aspartate Amino Transferase
RBC Red Blood Cells
Hb Haemogobin Content
PCV Packed Cell Volume
PLT Platelets
TP Total Protein
TC Total Cholesterol
WBC White Blood Cells

## Author Contributions

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## Conflicts of Interest

The authors declare that there are no conflicts of interest.

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