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Research Article

# Effects of Replacing Soybean Meal with Cowpea Meal on Growth Performance and Carcass Characteristics of Sasso Chickens

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## Abstract

Soybean meal is a primary protein source in the poultry feed industry due to its high protein content and good amino acid profile. However, limited supply and high import costs in Tanzania make the cost of commercial feeds high. This study evaluated the effects of replacing soybean meal with cowpea meal on Sasso chickens' growth performance and meat characteristics. Five diets were formulated such that cowpea meal replaced soybean meal by 0 % ($T_1$), 25 % ($T_2$), 50 % ($T_3$), 75 % ($T_4$), and 100% ($T_5$). A total of 150 one-month-old Sasso chickens with weights ranging from 603.33 ± 10.04 to 618.79 ± 15.30 g were randomly assigned to the five dietary treatments and reared for nine weeks. The amount of feed provided and the refusals were recorded daily and body weight was measured once per week. At the end of the experiment, feed intake, weight gain and feed conversion ratio (FCR) were calculated. In addition, a total of 30 chickens, six chickens per treatment, were randomly selected and slaughtered to determine carcass characteristics. The chickens under $T_5$ had higher ($P \leq 0.001$) average feed intake (120.76 ±1.43 g/d), final body weight (2624.56 ±62 g), weight gain (1824.37 ±42.43 g), daily weight gain (31.91 ±0.90 g/d), slaughter body weight (2592.53 ±133.73 g) and carcass weight (1988.80 ±137.00 g) than those on the other treatments. The chickens on $T_1$ had the lowest values for the same parameters. The FCR ranged from 3.77 ±0.04 in $T_3$ to 4.37 ±0.06 in $T_2$. However, the meat of the chickens in $T_1$ had higher crude protein (21.59 ±0.71 %) and lower fat contents (10.24 ±1.19 %) than those in $T_5$ ($P \leq 0.05$) (18.59 ±0.82 % CP and 16.60 ±1.06 % fat). The study concludes that cowpea meal can completely replace soybean meal as an alternative plant protein source in poultry diets.

## Keywords

Cowpea Meal, Daily Weight Gain, Feed Intake, Soybean Meal, Meat Quality, Weight Gain

## 1. Introduction

Poultry production plays an important role in global agriculture in developing countries, contributing to livelihood improvement and food and nutrition security. The economic contributions are through the generation of additional income for the family from the sale of eggs, meat, live chickens, and sometimes manure [1-3]. Moreover, poultry production is the main source of high-quality protein for both rural and urban households [4]. The main obstacle limiting the growth of the

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chicken industry in Tanzania is poor nutrition. Feed is an important component and input in chicken production and contributes about 70 – 80 % of total expenses [5].

Protein is the most important component in the chicken diet, contributing significantly to growth, development and general productivity of chickens. Chickens grow and produce well when fed diets with a balanced nutrient profile, particularly protein and amino acids [6]. However, protein sources, especially animal protein sources, are the most expensive ingredients in chicken diets. Studies have shown that more profit from chicken production enterprises can be realised by minimising feed cost, which accounts for 70–80% of the total cost. [5]. In Tanzania, the cost of chicken feeds has risen due to the increase in the cost of protein sources, especially fishmeal and soybean meal thus, their use in poultry feeds increases feed cost. Commercial chicken production relies heavily on the consistent supply of fishmeal as a high-quality protein source in poultry feeds. The fishmeal shortage and the associated high prices have posed significant challenges to commercial chicken farming. To improve production and increase the efficiency of commercial chicken enterprises, efforts are needed to develop cheaper protein sources that are locally available. Soybean meal is used in poultry feeds as an alternative to fishmeal due to its high content of protein and essential amino acids such as methionine, lysine and tryptophan, which are crucial for optimum growth of chicken [7]. However, the rising cost of soybeans and limited availability in Tanzania made it less desirable as a viable alternative protein source. The increasing demand, high cost, and environmental constraints of soybeans have led to the search for alternative sources of protein that are cheaper, locally available, and have comparable nutritional value to soybeans [8]. Cowpea has emerged as a promising legume among these alternatives due to its high protein content, high digestibility, and adaptability to various agro-climatic conditions [8].

Cowpea (Vigna unguiculata) is a herbaceous, short-term, annual legume plant grown in many tropical and subtropical countries [9]. Cowpeas utilize soil moisture efficiently and are more drought-tolerant than other legume crops, such as groundnuts, soybeans, and sunflowers, as annual rainfall between 400 and 750 mm can yield satisfactory cowpeas [10]. Cowpea grains are inexpensive, readily available, and possess a favorable amino acid profile that supports poultry growth [11, 12]. Previous studies have shown that incorporating cowpea into poultry feeds reduces the cost per kg of feed and improves broiler chicken growth parameters, thus promoting the sustainability of chicken farming [13, 14]. Depending on the specific variety, these seeds possess a lower level of anti-nutritional factors (such as trypsin and chymotrypsin inhibitors) in comparison to soybeans and common beans, which leads to fewer issues in poultry nutrition. [11] According to earlier research, these seeds are a good source of dietary protein when fed to chickens in their raw state [15]. The nutrition profile of cowpeas can vary due to several factors, including environmental factors like climate conditions, soil types. Also, different cultivars and processing techniques may affect cowpea composition [16]. However, the effects of replacing soybean meal with cowpea meal on poultry growth performance, carcass characteristics, and meat quality have not been well investigated in Tanzania. Therefore, this study assessed the impact of substituting soybean meal with cowpea meal on Sasso chickens' growth performance and carcass characteristics. The study provides insight into the potential of cowpea as a cost-effective protein source that can be used without compromising chicken growth performance and meat quality. This study hypothesised that cowpeas can replace soybean meal without affecting chickens' growth performance, carcass characteristics, and meat quality.

## 2. Materials and Methods

### 2.1. Study Location

The study was conducted at the lower farm of the Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA) in Morogoro Municipality. SUA is located at 6°52′′ S and 37°38′59′′ E at an altitude of 660 m above sea level. The annual rainfall of the area is between 500 and 1800 mm, and ambient temperatures range from 27 to 31 ℃, with a minimum night temperature of 14 ℃ in the coolest months.

### 2.2. Experimental Design and Treatments

A completely randomized design was adopted. The treatments were five experimental diets. The diets were formulated to be iso-calorific and contained 13.3 – 13.5 MJ/kg DM of metabolizable energy and 18.3 – 23.2% crude protein. The raw cowpea was used in this study. The five diets were formulated such that raw cowpea meal replaced fat-extracted soybean meal by 0% ($T_1$) (control diet), 25% ($T_2$), 50% ($T_3$), 75% ($T_4$) and 100 % ($T_5$) as shown in Table 1. The cowpeas used in formulating diets for this study were sourced from agricultural plots irrigated by nutrient-rich water from the fish tanks, forming an integrated farming system. The farming system comprised cowpeas-chickens-fish integration whereby chickens provided manure to fertilize both cowpea plots and fish tanks, while cowpea grains served as a protein source in both chicken and fish diets and the water in the fish tank was used to irrigate the cowpea plots.

### 2.3. Chicken Breed and Their Management

The Sasso chickens were used in this experiment. One week before the arrival of chicks, the chicken house was cleaned, disinfected and set up with the appropriate brooding equipment to provide the chicks with a warm and comfortable environment. The chicken house had 15 compartments, which were used to rear the chickens. A total of 150 Sasso chicks were brooded for one month using a commercial starter crumble diet and the chicks were fed *ad libitum* for the four weeks of the brooding period. The birds were vaccinated against Newcastle disease, Gumboro and fowlpox disease as per recommendations of the manufacturers. Water was provided *ad libitum* throughout the experimental period. After brooding period, the chicks had an average body weight of 609.62 g and were randomly allocated to 15 compartments in the chicken house, 10 chickens per room. Then the rooms were randomly assigned to five dietary treatments ($T_1$, $T_2$, $T_3$, $T_4$ and $T_5$), thus, in total 30 chickens were allocated to each treatment. Each treatment was replicated three times, and each replicate had 10 chickens. The chickens were fed twice per day at 08:00 am and 04:00 pm and reared for nine weeks (63 days) of the experimental period.

*Table 1. Proportions of feed ingredients in the experimental diets.*

| | Treatments | | | | |
|---|---|---|---|---|---|
| **Ingredients** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** |
| Maize meal (%) | 30 | 30 | 30 | 30 | 30 |
| Hominy meal (%) | 28 | 28 | 28 | 28 | 28 |
| Sunflower seed cake (%) | 5 | 5 | 5 | 5 | 5 |
| Soybean meal (%) | 30 | 22.5 | 15 | 7.5 | 0 |
| Cowpea meal (%) | 0 | 7.5 | 15 | 22.5 | 30 |
| Fish meal (%) | 5 | 5 | 5 | 5 | 5 |
| Mineral premix (%) | 2 | 2 | 2 | 2 | 2 |
| Total (%) | 100 | 100 | 100 | 100 | 100 |
| Estimated CP (%) | 23.2 | 22.5 | 21.1 | 19.5 | 18.3 |
| Estimated ME (MJ/kg DM) | 13.3 | 13.5 | 13.5 | 13.5 | 13.5 |

Note: In $T_1$ soybean meal (SBM) replaced with 0% cowpea meal (CPM), in $T_2$ SBM replaced with 25% CPM, in $T_3$ SBM replaced with 50% CPM, in $T_4$ SBM replaced with 75% CPM and in $T_5$ SBM replaced with 100% CPM.

## 2.4. Data Collection

### 2.4.1. Chemical Composition of the Experimental Diets

The ingredients used to formulate the experimental diets and the formulated diets were analyzed for chemical composition using the proximate analysis scheme according to [17]. Metabolizable energy content of the formulated diets was calculated using the following formula [18].

$$\text{ME (kcal/kg DM)} = 3951 + 54.4\ \text{EE} - 88.7\ \text{CF} - 40.8\ \text{Ash}.$$

### 2.4.2. Feed Intake

The amount of feed provided to the chickens in each replicate was measured before feeding. Refusals were collected and measured in the morning before providing the feed for each day. The amount of feed eaten by each chicken was determined using the following formula:

$$\text{Feed intake} = \frac{\text{Total weigt of feed given} - \text{Total weight of refusal}}{\text{Number of chickens}}$$

### 2.4.3. Body Weight

The body weight of each chicken was weighed using a digital weighing balance before the start of the experiment to get the initial body weight and then once a week during the experimental period of nine weeks. The chickens were weighed at 07:00 – 08:00 am before feeding. At the end of the experiment, body weight gain, growth rate (Daily body weight gain) and feed conversion ratio (FCR) were calculated by using the following formulae:

$$\text{Body weigth gain} = \text{final weight} - \text{Initia weight}$$

$$\text{Growth rate} = \frac{\text{Final weight} - \text{initial weight}}{\text{Number of days of experimental period}}$$

$$\text{Feed conversion ratio} = \frac{\text{Feed intake}}{\text{Body weight gain}}$$

### 2.4.4. Carcass Characteristics

At the end of nine weeks of the experiment, a total of 30 chickens, six chickens per treatment, were randomly selected and slaughtered. Before slaughter, the chickens were fasted for 12 hours and then weighed to determine their slaughter body weights. After five minutes of bleeding, the slaughtered chickens were manually de-feathered and weighed after being de-feathered, and the feather weight was determined as the difference between body weight before and after de-feathering. Then the carcasses were eviscerated to remove the internal organs (liver, kidney, gastrointestinal tract, and gizzard). Carcass weight and weights of gastrointestinal parts, breasts, drumsticks, thighs, liver, heart, and spleen were recorded. Dressing percentage and Hepatosomatic index were computed by using the following formulae:

$$\text{Dressing Percentage (DP)} = \frac{\text{Weight of the carcass}}{\text{Live body weight}} \text{X100}$$

$$\text{Hepatosomatic index (HIS)} = \frac{\text{Weight of the Liver}}{\text{body weight}} \text{X100}$$

### 2.4.5. Meat Physical Characteristics

The physical characteristics of chicken meat studied include pH, temperature, color, cooking loss and tenderness. The pH of each bird's breast was determined using a spear-end digital portable pH meter (Knick Portamess® 910, Germany) at 45 minutes, 6 hours, and 12 hours post-slaughter. The pH meter was calibrated before by using a standard pH buffer to ensure accurate readings and the probe was properly cleaned to avoid cross-contamination between samples. The temperature of each bird's breast was determined using a digital thermometer with the probe at 45 minutes, 6 hours, and 12 hours post-slaughter. The colour of the meat was determined by taking measurements from the internal surface of the breast using a portable colorimeter (MINOLTA CR 200b colorimeter, Osaka, Japan) based on the CIELAB system, which gives the meat's colour in terms of its relative lightness (L*), relative redness (a*), and relative yellowness (b*).

Cooking loss was determined according to [19]. A meat sample of approximately 150 g for breast, 110 g for thigh and 86 g for drumstick was weighed and each sample was sealed in a polyethylene plastic bag to prevent direct contact with water during cooking. Then the meat samples were cooked in a water bath set at a constant temperature of 70 ℃ for one hour. After cooking, samples were carefully removed from the water bath, cooled under running cold water for two hours and then removed from the polyethylene plastic bag. The excess water from the surface of the meat was removed by patting the surface with clean paper and then reweighing to obtain the difference. Cooking loss was calculated using the following formula.

$$\text{Cooking loss } \% = \frac{\text{Weight of meat sample before cooking} - \text{Weight of meat sample after cooking}}{\text{Weight of meat sample before cooking}} \text{x}100$$

To determine meat tenderness, a strip measuring approximately 2 × 2 × 1 cm was cut parallel to muscle fibre from the breast, thigh, and drumstick cuts. Then, the Shear force of these strips was determined using the Warner Bratzler shear blade attached to the Zwick/Roell (Z2.5, Germany) instrument, with the shear force value expressed in Newton (N).

### 2.4.6. Carcass Composition

The proportions of bone, fat and lean contents in the carcasses were determined from the half carcass of each chicken. Visible fat around muscles, under the skin and within the body cavity was separated from muscle tissue, and the bones were separated from muscle tissue and then weighed. The following formulae were used to calculate the lean-to-fat and lean-to-bone ratio:

$$\text{Lean to Fat } = \frac{\text{Total weight of the lean}}{\text{Weight of fat}}$$

$$\text{Lean to bone ratio} = \frac{\text{Total weight of the lean}}{\text{Weight of bone}}$$

### 2.4.7. Meat Chemical Composition

The analysis of chemical composition of the carcass involved mixing the muscle and fat portions, grinding each sample using a meat grinder equipped with a 5 mm plate, and then freezing it at -4 ℃ until chemical composition analysis. The chemical composition of minced meat was analysed using a wet proximate analysis scheme to determine the dry matter, ash, crude protein and fat contents. The dry matter (DM) content of fresh meat was determined by drying the meat sample in an oven set at 105 ℃ for 24 hours [20]. The ash content of meat was determined by incinerating the samples in a muffle furnace at 550 ℃ for three hours [21]. Crude protein (CP) content was determined using the Kjeldahl method [22]. Ether extract (EE) was determined by the Soxhlet extraction method [17].

## 2.5. Statistical Analysis

Before data analysis, normality of the data was assessed by the Shapiro-Wilk test. Data on final body weight, daily weight gain, total weight gain, and shear force value of the breast and drumstick were log-transformed to reduce skewness. Data were subjected to one-way analysis of variance to test the effect of diet on final weight, average weight gain, daily weight gain, carcass characteristics, and meat quality of chickens. Initial weight was used as a covariate in the model for analysis of growth performance data, and the significance of the differences between the pairs of means was assessed using the Tukey test ($P < 0.05$), and values were presented as the mean ± standard error (SE). The statistical analysis was run using R statistical analysis software version 4.3.2 (2023).

# 3. Results

## 3.1. Chemical Composition and Nutritive Value of Experimental Diets

Soybean meal used in the present study had higher crude protein (CP) (45.17%) and slightly lower metabolizable energy (13.98 MJ/kg DM) than cowpea meal, which contained 26.56% CP and metabolizable energy of 14.86 MJ/kg DM. The chemical compositions of the experimental diets are presented in Table 2. Dry matter contents of the diets did not differ significantly among the treatments, the values were between 97.74 ± 0.13 % ($T_1$) and 98.92 ± 0.01 % ($T_3$). There was a significant difference ($P = 0.001$) in ash content among the treatments. The diet in $T_4$ had the highest value (11.65 ± 0.04 %) while that in $T_1$ had the lowest (9.18 ± 0.20 %) ash content. The diet in $T_1$ had the highest value of CP (24.30 + 0.12 %) compared to the diets in other treatments, whereas the diet in $T_5$ had the lowest value (20.68 ± 0.03%). The diet in $T_2$ had the highest crude fiber (4.46 ± 0.03%) while that in $T_4$ (2.39 ± 0.38%) had the lowest value. The highest fat content was found in $T_{4,}$ while the lowest was observed in $T_1$. The metabolizable energy value was higher ($P = 0.035$) in $T_4$ (13.76 ± 0.07 MJ/kg DM) than in other treatments' diets.

## 3.2. Growth Performance and Feed Utilization of Sasso Chickens

Growth performance parameters of chickens fed diets containing different levels of soybean and cowpea meals are shown in Table 3. The diet had a significant effect on average final body weight (AFBW), average total weight gain (ATWG), and average daily weight gain (ADWG). The chickens in $T_5$ had higher ($P \leq 0.001$) AFBW (2624.56 ± 62 g), ATWG (1824.37 ± 42.43 g) and ADWG (31.91 ± 0.90 g/d) than those on other treatments. The results in Table 3 show that the values of ATWG and ADWG increased with the increase in the percentage of cowpea meal in the diets. Similarly, the diet significantly influenced feed intake and FCR. The chickens in $T_5$ showed the highest average daily feed intake while those in $T_3$ had the lowest. On the other hand, the chickens in $T_4$ and $T_2$ showed a higher value of Feed conversion ratio (FCR) while those in $T_1$, $T_3$ and $T_5$ had lower values ($P \leq 0.001$).

The growth performance trends of the chickens under different treatments are presented in Figure 1. The chickens in all treatments had almost similar average body weight at the beginning of the experiment. From week seven onward, the chickens on $T_5$ increased in body weight more rapidly than those in other treatments. The chickens in $T_1$, $T_2$, $T_3$, and $T_4$ showed a gradual increase in body weight with similar growth patterns but did not attain the same body weight as those in $T_5$. However, the chickens on $T_4$ showed slightly higher growth performance from week 8 compared to those on $T_1$, $T_2$ and $T_3$.

*Table 2. Chemical composition (Mean ± SE) of experimental diets used in different treatments.*

| Parameters | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | *P*-value |
| No of samples | 2 | 2 | 2 | 2 | 2 | |
| DM % | 97.74 ± 0.13 | 98.28 ± 0.13 | 98.92 ± 0.01 | 98.67 ± 0.02 | 98.56 ± 0.44 | 0.229 |
| ASH % | 9.18 ± 0.20$^b$ | 11.37 ± 0.02$^a$ | 10.51 ± 0.25$^{ab}$ | 11.65 ± 0.04$^a$ | 11.12 ± 0.60$^a$ | 0.001 |
| CP % | 24.30 ± 0.12$^a$ | 23.50 ± 0.02$^{ab}$ | 23.29 ± 0.30$^{ab}$ | 22.57 ± 0.07$^b$ | 20.68 ± 0.03$^c$ | 0.000 |
| CF % | 3.52 ± 0.21$^{ab}$ | 4.46 ± 0.03$^a$ | 4.26 ± 0.07$^a$ | 2.39 ± 0.38$^b$ | 4.42 ± 0.27$^a$ | 0.003 |
| EE % | 5.87 ± 0.06$^b$ | 7.30 ± 0.37$^{ab}$ | 7.20 ± 0.06$^{ab}$ | 7.54 ± 0.23$^a$ | 6.48 ± 0.41$^{ab}$ | 0.043 |
| ME (MJ/kg DM) | 13.34 ± 0.05 | 13.34 ± 0.05 | 13.66 ± 0.03 | 13.76 ± 0.07 | 13.29 ± 0.09 | 0.035 |

Note: $^{a, b, c}$ Means with different superscripts within a row differ significantly at $P \leq 0.01$
DM = Dry matter, CP = Crude protein, CF = Crude fibre, EE = Ether extracts

*Table 3. Effects of replacing soybean meal with cowpea meal on growth performance and feed utilization of Sasso chickens (Mean ± SE).*

| Parameters | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | *P*-value |
| Initial weight (g) | 605.72 ±15.65 | 618.79 ± 15.30 | 603.33±10.04 | 606.72 ± 14.26 | 614.41 ± 15.02 | 0.931 |
| AFBW (g) | 2136.34 ± 53.07$^b$ | 2154.64 ± 60.49$^b$ | 2159 ± 51.76$^b$ | 2234.83 ± 55.66$^b$ | 2624.56 ± 62$^a$ | 0.000 |
| ATWG (g) | 1469.58 ± 67$^b$ | 1455.14 ± 29.45$^b$ | 1474.68 ±28.90$^b$ | 1532.20 ± 32.06$^b$ | 1824.37 ± 42.43$^a$ | 0.000 |
| ADWG (g/d) | 24.30 ± 0.71$^b$ | 24.38 ± 0.87$^b$ | 24.70 ± 0.78$^b$ | 25.84 ± 0.76$^b$ | 31.91 ± 0.90$^a$ | 0.000 |
| ADFI (g/d) | 91.40 ± 0.73$^c$ | 102.67 ± 0.90 $^b$ | 90.40 ± 0.75$^c$ | 101.89 ± 0.84$^b$ | 120.76 ± 1.43$^a$ | 0.000 |
| FCR | 3.85 ± 0.04$^c$ | 4.37 ± 0.06$^a$ | 3.77 ± 0.04$^c$ | 4.04 ± 0.04$^b$ | 3.80 ± 0.04$^c$ | 0.000 |

Note: $^{a, b, c}$ Means with different superscripts within a row differ significantly at $P \leq 0.01$
AFBW = Average final body weight, ATWG = Average total weight gain, ADWG = Average daily weight gain, ADFI = Average daily feed intake, FCR = Feed conversion ratio

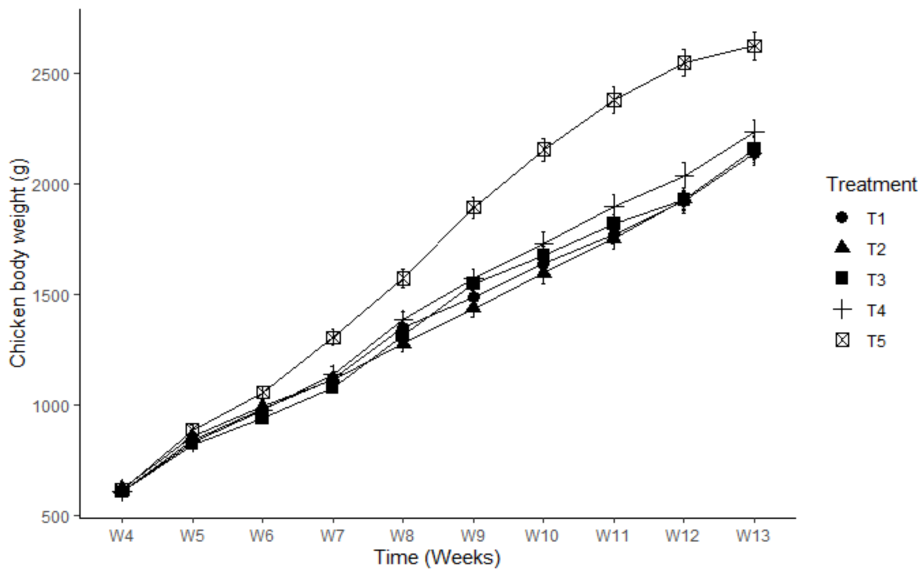


*Figure 1. Comparison of growth performance of Sasso chickens fed diets containing different levels of soybean and cowpea meals.*

Note: T1= Diet with 100% soybean meal (SBM) and 0% cowpea meal (CPM), T2 = Diet with 75% SBM and 25% CPM, T3 = Diet with 50% SBM and 50% CPM), T4 = Diet with 25% SBM and 75% CPM, T5 = Diet with 0% SBM and 100% CPM.

## 3.3. Carcass Characteristics of Sasso Chickens

The Carcass characteristics of Sasso chickens subjected to different treatments are presented in Table 4. We observed significant differences ($P$ = 0.01) in slaughter body weight and carcass weight. The chickens in $T_5$ had the highest slaughter body weight (2592.53 ± 133.73 g) and carcass weight (1988.80 ±137.00 g) while those in $T_1$ had the lowest slaughter body weight (1727.9 ±210.08 g) and carcass weight (1277.38 ± 157.93 g) values. On the other hand, dressing percentage and non-carcass components (head, feathers, GIT, legs, liver, heart, and spleen) did not differ significantly ($P$ > 0.05) among the treatments. This indicates that the diet did not significantly influence non-carcass components. The chickens in $T_5$ had the highest breast weight (202.32 ±10.03 g) while those in $T_1$ (137.82 ±20.84 g) had the lowest value ($P$ < 0.05). Thigh weight followed the same trends as the breast among the chickens on different treatments.

*Table 4. Effects of replacing soybean meal with cowpea meal on carcass characteristics of Sasso chicken meat.*

| Parameters | Treatments | | | | | P-Value |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | |
| Slaughter Body Weight (g) | 1727.9 ±210.1$^{b}$ | 2082.8 ±94.1$^{ab}$ | 1917.4 ±172.2$^{b}$ | 2013.7 ±114.6$^{ab}$ | 2592.53 ±133.7$^{a}$ | 0.007 |
| Non-carcass | 423.6 ±54.1 | 459.5 ±16.3 | 458.9 ±31.3 | 452.2 ±17.9 | 544.7 ±27.0 | 0.129 |
| Carcass weight (g) | 1277.3 ±157.9$^{b}$ | 1587.8 ±86.8$^{ab}$ | 1412.9 ±142.3$^{b}$ | 1515.8 ±103.3$^{ab}$ | 1988.8 ±137.0$^{a}$ | 0.008 |
| Dressing % | 73.8 ±1.2 | 76.1 ±0.9 | 73.3 ±1.10 | 75.1 ±1.1 | 76.4 ±1.8 | 0.36 |
| Breast (g) | 137.8 ±20.8$^{b}$ | 159.7 ±12.3$^{ab}$ | 138.2 ±20.3$^{b}$ | 155.3 ±10.1$^{ab}$ | 202.3 ±10.0$^{a}$ | 0.043 |
| Thigh (g) | 68.9 ±10.4$^{b}$ | 79.7±6.7$^{ab}$ | 74.7 ±7.8$^{b}$ | 76.8 ±6.5$^{a}$ | 110.8 ±6.7$^{a}$ | 0.007 |
| Drumstick (g) | 62.3 ±9.5 | 67.8 ±5.3 | 63.4 ±8.7 | 65.5 ±2.8 | 86.4 ±14.6 | 0.347 |
| Lean % | 64.5 ±1.1 | 64.1 ±1.5 | 63.1 ±2.3 | 61.4 ±1.8 | 62.9 ±1.6 | 0.732 |
| Bone % | 23.4 ±1.9 | 20.4 ±1.2 | 22.2 ±2.3 | 20.5 ±0.6 | 18.8 ±0.7 | 0.258 |
| Fat % | 4.2 ±1.0 | 4.5 ±0.6 | 4.5 ±0.7 | 5.2 ±0.5 | 7.2 ±0.5 | 0.179 |
| Lean to bone ratio | 2.8 ±0.2 | 3.2 ±0.3 | 3.1 ±0.5 | 3.0 ±0.13 | 3.4 ±0.3 | 0.747 |

| Parameters | Treatments | | | | | P-Value |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | |
| Lean to fat ratio | 20.7 ±5.2 | 16.2 ±3.0 | 15.5 ±2.2 | 12.3 ±1.3 | 10.6 ±1.9 | 0.189 |
| Hepatosomatic Index | 1.6 ±0.1 | 1.4 ±0.1 | 1.6 ±0.1 | 1.60 ±0.1 | 1.24 ±0.3 | 0.298 |

## 3.4. Meat Physical Characteristics

The results of the meat's physical characteristics are presented in Table 5. There were no significant differences ($P > 0.05$) in meat tenderness, cooking loss of different parts (breast, thigh, and drumstick), meat colour, and pH among the chickens under different treatments. The initial meat temperatures (45 min post slaughter) were significantly different ($P = 0.000$) among treatments, but the subsequent meat temperatures (6 and 12 hrs after slaughter) did not differ ($P > 0.05$) among the treatments.

***Table 5.*** *The meat physical characteristics of Sasso chickens when soybean meal was replaced with cowpea meal at different levels.*

| Parameters | Treatments | | | | | P-Value |
|---|---|---|---|---|---|---|
| | T1 | $T_2$ | $T_3$ | $T_4$ | $T_5$ | |
| Tenderness/shear force value (N) | | | | | | |
| Breast | 17.77 ±0.86 | 19.39 ±1.60 | 16.96 ±0.68 | 21.22 ±1.95 | 16.07 ±0.61 | 0.119 |
| Drumstick | 18.46 ±0.99 | 18.17 ±1.22 | 17.14 ±1.05 | 17.79 ±1.30 | 17.15 ±1.07 | 0.868 |
| Thigh | 17.52 ±1.14 | 15.58 ±0.79 | 18.20 ±0.64 | 18.46 ±1.07 | 18.18 ±0.71 | 0.105 |
| Cooking loss (%) | | | | | | |
| Breast | 13.15 ±0.72 | 12.78 ±1.87 | 15.08 ±1.58 | 13.02 ±0.96 | 14.43 ±1.32 | 0.702 |
| Thigh | 20.19 ±1.26 | 18.69 ±0.76 | 21.04 ±0.95 | 18.83 ±1.56 | 17.91 ±1.26 | 0.88 |
| Drumstick | 13.67 ±2.79 | 12.96 ±2.76 | 13.02 ±1.93 | 15.35 ±1.60 | 15.74 ±2.67 | 0.37 |
| Color | | | | | | |
| L* | 60.56 ±2.67 | 66.39 ±4.32 | 60.08 ±4.34 | 62.27 ±5.20 | 56.64 ±2.65 | 0.535 |
| a* | -2.25 ±0.35 | -3.02 ±0.57 | -2.22 ±0.49 | -2.71 ±0.64 | -2.30 ±0.28 | 0.721 |
| b* | 2.72 ±0.88 | 2.51 ±1.25 | 1.94 ±0.77 | 2.15 ±1.23 | 1.21 ±0.48 | 0.831 |
| pH | | | | | | |
| 45 min | 6.03 ±0.03 | 5.95 ±0.06 | 5.93 ±0.07 | 5.90 ±0.07 | 5.93 ±0.05 | 0.563 |
| 6 h | 5.58 ±0.08 | 5.50 ±0.09 | 5.53 ±0.03 | 5.50 ±0.07 | 5.47 ±0.08 | 0.836 |
| 12 h | 5.58 ±0.08 | 5.48 ±0.08 | 5.50 ±0.04 | 5.45 ±0.11 | 5.42 ±0.07 | 0.179 |
| Temperature | | | | | | |
| 45 min | 33.15 ±0.60$^{c}$ | 34.22 ±0.68$^{bc}$ | 36.60 ±0.70$^{ab}$ | 37.00 ±0.85$^{a}$ | 36.82 ±0.3$^{ab}$ | 0.000 |
| 6 h | 20.90 ±0.63 | 21.12 ±0.73 | 20.32 ±0.75 | 19.18 ±0.68 | 20.53 ±0.29 | 0.248 |
| 12 h | 15.90 ±0.51 | 16.32 ±0.53 | 16.67 ±0.91 | 15.00 ±0.34 | 17.12 ±0.64 | 0.646 |

## 3.5. Chemical Composition of Sasso Chicken Meat

Chemical composition of the meat from chickens under different treatments are shown in Table 6. Dry matter and ash contents of meat did not differ significantly ($P > 0.05$) among the chickens subjected to different treatments, but there were significant differences ($P \leq 0.05$) in meat CP and ether EE contents among the chickens under different treatments. The meat of the chickens under $T_1$ had highest CP content (21.59 ±0.71 %) and lowest EE content (10.24 ±1.19 %) while those in $T_5$ ($P \leq 0.05$) and $T_4$ had the lowest CP content (18.59 ±0.82%) and highest EE content (20.79 ±0.83), respectively.

*Table 6. Chemical composition of Sasso chicken meat when soybean meal was replaced with cowpea meal.*

| | | | Treatments | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** | ***P*-value** |
| DM (%) | 45.08 ±1.60 | 45.03 ±2.13 | 42.63 ±2.64 | 45.68 ±2.7 | 48.89 ±4.10 | 0.625 |
| ASH (%) | 2.89 ±0.48 | 2.47 ±0.16 | 2.30 ±0.08 | 1.71 ±0.25 | 2.39 ±0.44 | 0.175 |
| CP (%) | 21.59 ±0.71[a] | 20.76 ±0.49[ab] | 20.75 ±0.57[ab] | 19.17 ±0.74[ab] | 18.59 ±0.82[b] | 0.025 |
| EE (%) | 10.24 ±1.19[c] | 16.23 ±1.07[b] | 11.78 ±1.10[c] | 20.79 ±0.83[a] | 16.60 ±1.06[ab] | 0.000 |

## 4. Discussion

### 4.1. Chemical Composition and Nutritive Value of Experimental Diets

The nutritional value of cowpea grains used matches those reported by [23, 24] but are lower than that reported by [25], who found 20.91% CP content in cowpeas. The inconsistency in the nutritive value of cowpea may be due to different cultivars and post-harvest handling, as reported by [26], who assessed the variation of CP content in different cultivars of cowpea. In this study, the cowpea had lower levels of CP, EE, and CF contents compared to soybean. A similar result was reported by [24]. However, [27] found that cowpea and soybean have similar amino acid profiles needed to meet chicken requirements. The protein and energy contents of the diets used in the present study are comparable to those fed to broiler chicken [28]. Despite lower protein content, the cowpea-based diet still meets the Sasso chicken requirements for growth and development, which require 18 – 23% CP. Also, a cowpea-based diet can provide sufficient energy to meet Sasso chicken requirements [29]. Additionally, the fibre content in cowpeas might support gut health and digestion, hence making this diet more suitable for chickens [11]

### 4.2. Growth Performance and Feed Utilization of Sasso Chickens

In the present study, final body weight, total weight gain and average daily gain were found to increase as cowpea levels in the diets increased. This result was slightly unexpected as it was hypothesized that replacing soybean meal with cowpea meal would have no significant effect on growth performance since the diets were formulated to contain almost comparable energy content. Surprisingly, in this study, the diets with higher inclusion levels of cowpeas outperformed the soybean-based diet. This can be explained by the fact that, while cowpea have low protein content, they contain important nutritional components such as natural oil and fibres which enhance gastrointestinal health and promote efficient nutrient absorption and utilization as reported by [11]. Additionally, the fat content in cowpea can be used as an energy source which promotes growth to compensate for the lower protein content. The results in this study are similar to those reported by [25] who included 30% cowpea in the broiler diet. Furthermore, the higher growth performance of Sasso chicken in $T_5$ is in agreement with the results obtained by [30], who replaced soybean with unprocessed cowpea meal up to 20% in broiler diets. The better growth performance observed in chickens fed diets with high inclusion levels of cowpea can be attributed to the fact that cowpea meal is more digestible and energy rich and this enhances nutrient absorption and utilization as reported by [31]. Furthermore, cowpea contain beneficial compounds such as antioxidants that enhance chicken health and lead to better growth performance [7].

The final body weight observed in this study is higher compared to that reported by [24] in Sasso chickens. This discrepancy could be attributed to differences in initial body weight at the commencement of the experiments and nutritional profile of the diets, variation in feed ingredients used which affect nutrient availability. Also, it can be due to the difference in environmental conditions as this could affect chicken response to feed. In this study higher feed intake was observed in chickens fed diets with high inclusion levels of cowpea. A similar trend was observed by [25, 32], who observed an increase in feed intake as the level of cowpea increased in the diet. This may be due to the high digestibility of cowpea as previously reported by [31]. This enhanced nutrient absorption likely contributed to the increase in feed intake as cowpea level increased in the diet. Additionally, Cowpea contain soluble and insoluble fibres that can improve gut health, which enhances nutrient digestion and absorption, thus enabling the animal to eat effectively and regularly [33]. Improvement in feed intake likely contributed to better growth rate, as animals with higher feed intake are expected to gain more weight.

The feed conversion ratio reflects feed utilization efficiency. The FCR obtained in this study were relatively lower compared to that reported by [34] who reported 4.8 kg of feed intake used to gain one kg of body weight for Sasso chicken fed standard commercial broiler diet with ingredient such as corn and soybean meal, in contrast to this study where cowpea were used as protein source in place of soybean meal. Also, [35] reported a higher feed conversion ratio ranging from 8.68 to 9.97 for Sasso chickens fed a locally formulated diet composed of local grain and a protein source like soybean. This discrepancy might be due to a difference in the age of chickens (13 vs 20 weeks old) as well as the types of feed ingredients used. Older chicken generally has a lower metabolic rate and different nutrients influence the conversion of feed into body mass. In this study, it was found that FCR improved as the cowpea level increased in the diet, indicating that a high level of cowpea meal leads to better feed efficiency in chickens. This supports the idea that cowpea enhance nutrient utilization and lead to increased feed intake as reported by [30] in a broiler diet containing cowpea. The lower FCR in the current study indicates better feed efficiency when cowpea meal was increased in the diet up to 30%. The improved feed efficiency and growth performance of chickens fed a diet containing a high level of cowpea meal might be attributed to the good nutrient profile of cowpea, as it improves gut health, which helps in extracting nutrients from the feed more efficiently, as reported by [11]. This indicates that cowpeas not only contributed to higher feed intake but also improved feed utilisation efficiency and hence, better growth performance of Sasso chickens.

## 4.3. Carcass Characteristics of Sasso Chickens

For carcass characteristics, the chickens in $T_{5,}$ in which cowpea meal completely replaced soybean meal, exhibited higher slaughter body weight and carcass weight than those in $T_{1,}$ which were fed a diet in which soybean meal was not replaced by cowpea meal. This is consistent with the findings reported by [36], who found higher slaughter body weight of Sasso chickens fed a diet containing haricot bean in replacement of soybean. The improvement in slaughter body weight and carcass weight aligns with the observed higher body weight gain and daily weight gain, indicating that the better growth performance was reflected in higher meat yield for the chickens fed the diet based on cowpea meal instead of soybean meal. However, non-carcass weight and the dressing percentage did not differ among the chickens fed different diets containing varying cowpea levels, indicating that the replacement of soybean meal with cowpea meal did not alter other carcass characteristics apart from slaughter and carcass weights. The slightly higher dressing percentage obtained from the chickens fed the diet containing cowpea meal in place of soybean meal in this study aligns with the findings of [25], who incorporated cowpea up to 30% in broiler chicken. Generally, the dressing percentages obtained in this study were higher compared to the dressing percentage of 64.00 - 72.67% reported by [37] for Sasso chickens fed a diet made with locally available feed ingredients. This difference might be due to the different nutritional levels of the feed ingredients used in both studies.

Higher weights of breast, thigh and drumstick were observed in the chickens fed the diet containing cowpea meal ($T_5$) than those fed the diet containing soybean meal ($T_1$). Therefore, these body parts followed the same trend as the body weight gain and slaughter weight, indicating a good relationship between growth performance and meat yield. The percentages of lean, bone, and fat in the carcasses did not differ significantly among the treatments, indicating that cowpeas can replace soybean meal without causing any negative effect on meat quality, as reported by [25]. Moreover, treatment had no significant effects on the hepatosomatic index of chickens. This indicates that the inclusion of cowpeas in the chicken diet does not affect the normal function, physiological, and biochemical health status of the liver [38]

## 4.4. Meat Physical Characteristics

Meat quality parameters such as meat tenderness, cooking loss, colour and pH were not significantly different among the meat samples of chickens fed different diets, implying that the meat physical characteristics are not affected by the replacement of soybean meal with cowpea meal. The values of meat tenderness obtained in this study are in agreement with [39] who reported similar values in the breast of Sasso chickens. The same author reported lower cooking loss in breast meat. The meat pH observed in this study is comparable to that obtained by [40, 41] in chicken meat with pH of 5.66 ± 0.04, but slightly lower than that found by [42] in chicken breast meat. The observed variation might be explained by the fact that muscles differ in their metabolism, which affects the rate of acidification after slaughter. Therefore, inclusion of cowpeas in the diet of Sasso chickens led to improved growth performance, better feed conversion ratio and higher meat yield without compromising meat quality. Increased digestibility and gut health enhanced nutrient absorption for the diets containing higher levels of cowpea and this played a key role in the improvement of feed utilization and growth performance.

## 4.5. Chemical Composition of Sasso Chicken Meat

Concerning meat quality, high fat content was observed in the meat obtained from Sasso chickens fed a diet containing cowpea meal. This is likely due to the breed's ability to store fat, especially when provided with a diet which have high metabolizable energy. In contrast to the present study, a study by [43] reported low fat content in Sasso chickens. The possible explanation for this might be due to differences in the diet used in the two studies. However, the increased fat content in the meat of the chickens fed cowpea meal-based diets might be due to the high metabolizable energy of the cowpea used in this study. This was further reflected by high dry matter content on the meat from chickens in $T_5$ diet, probably due to lower moisture content associated with increased fat deposition. The meat samples in the present study had lower moisture content and protein content compared to those of [44], who found a moisture content of 72% and protein content of 22%. The high meat fat content obtained across different treatments explains the higher meat temperature observed 45 minutes post-slaughter, as fat content affects metabolic heat production and thermal conductivity [45]. Chicken meat in $T_5$ exhibited high fat content, which is consistent with the observed higher meat temperature for the chickens in $T_5$ compared to those in $T_{1,}$ which had low meat fat content, as fat has lower conductivity, thus slowing down the rate at which heat is dissipated from the muscles. Also, fat acts as an insulator that reduces the efficiency of heat transfer from muscles to the surroundings; hence, meat with high fat content retained more heat post-slaughter and this resulted in high meat temperature. Furthermore, a decline in chicken meat temperature from 45 minutes to 12 hours displayed similar trends as reported by [46].

## 5. Conclusion

Results of this study revealed that complete replacement of soybean meal with cowpea meal significantly increases growth performance, slaughter weight, carcass weight and feed utilization efficiency of chickens. Also, the study revealed that the replacement of soybean meal with cowpea meal at different levels does not affect chicken meat quality parameters. Therefore, cowpea can replace soybean in the chicken's diet as a plant protein source. However, it is important to note that the effects of cowpea meal may vary depending on factors such as processing methods, cowpea cultivars and environmental conditions. Also, this has several practical implications because cowpea is often more cost-effective than soybean, especially in regions where they are locally produced and stand as an environmentally sustainable option.

## 6. Recommendations

1. Poultry farmers and feed manufacturers should consider replacing soybean meal with cowpea meal as a source of protein in chicken diets, considering local availability and cost and its potential for improving the growth performance of chickens.

2. Further research is recommended to explore the economic viability of replacing soybeans with cowpeas and assess the effect of higher inclusion levels of cowpeas in chickens' diets for different breeds.

## Abbreviations

| | |
|---|---|
| ADWG | Average Daily Weight Gain |
| AFBW | Average Final Body Weight |
| ATWG | Average Total Weight Gain |
| CP | Crude Protein |
| CPM | Cowpea Meal |
| DM | Dry Matter |
| DP | Dressing Percentage |
| EE | Ether Extract |
| FCR | Feed Conversion Ratio |
| GIT | Gastrointestinal Track |
| HIS | Hepatosomatic Index |
| Kg | Kilogram |
| ME | Metabolizable Energy |
| MJ | Megajoule |
| SBM | Soybean Meal |
| SUA | Sokoine University of Agriculture |

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## Author Contributions

This work was carried out by collaboration among all authors. Martha E. Israel designed the study, prepared the material, collected the data, performed the statistical analysis, and wrote the first draft of the manuscript. Authors Sebastian W. Chenyambuga and Renalda N. Munubi guided Martha E. Israel in study designing, material preparation, data collection, and statistical analysis, read and improved the previous version of the manuscript. All authors read and approved the final manuscript.

## Statement of Ethical Clearance

Procedures for the care and use of animals were followed. The study was approved by the ethical committee of the Directorate of Postgraduate Studies, Research, Technology Transfer and Consultancy at Sokoine University of Agriculture with reference number: DPRTC/R/186/37.

## Data Availability Statement

The datasets generated and/or analysed during the current study are not publicly available to protect the integrity of future publications and analyses. However, they are available from the corresponding author upon reasonable request.

## Conflicts of Interest

The authors declare no conflicts of interest

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