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# Biological and Economic Efficiency of Partial Dietary Substitution of Soybean (*Glycine max*) Meal with Cowpea (*Vigna unguiculata*) Meal in Broiler Production

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## Abstract

This manuscript explores the biological and economic efficiency of partial dietary substitution of soybean (*Glycine max*) meal with cowpea (*Vigna unguiculata*) meal in broiler production. As a result of the shortage of soybean in Zimbabwe due to droughts, inadequate irrigation infrastructure, high input costs, and price controls, the authors identified an alternative to soybean meal in cowpea meal due to its availability and similar amino acid profile to soybean meal. The experiment was carried out at Cold Storage Company in Kadoma. A total of 150 unsexed day-old broiler chicks (Cobb 500) were used. All the birds were brooded in one pen during the first two weeks of age and fed with standard broiler starter mash from National Foods PVT LTD for adaptation. The birds were randomly allocated into five equal groups, each with three replicates and 10 birds per replicate at three weeks of age. Five experimental diets: T1 (100% soybean meal + 0% cowpeas meal), T2 (75% soybean meal + 25% cowpeas meal), T3 (50% soybean meal + 50% cowpeas meal), T4 (25% soybean meal + 75% cowpeas meal) and T5 (0% soybean meal + 100% cowpeas meal) were formulated to be iso-caloric and iso-nitrogenous to meet nutrient requirements of broilers according to NRC (2001). Ration formulation using maize, soybean and cowpea meal as ingredients for broiler starter (21% Crude Protein) and broiler finisher (19% Crude Protein) was done using the Pearson Square Method. Feed intake (g) and weight gain (g) were recorded weekly. Feed Conversion Ratio (FCR) and bioeconomic efficiency were calculated weekly. The experiment lasted for five weeks. The results showed that total Dry Matter Intake for Treatment 1 was the highest (3285 g), and Dry Matter Intakes for Treatments 2, 3 and 4 (3284 g, 3284 g and 3284 g) were not significantly different ($P > 0.05$) and Dry Matter Intake for Treatment 5 was the lowest (3282 g). Weight gains for Treatments 1 and 2 (2089 g and 2089 g) were not different (P > 0.05), Treatments 3 and 4 (2098 g and 2103 g) were not different (P > 0.05) and Treatment 5 had the lowest gain of 1990 g. Feed Conversion Ratio for Treatments 1 and 2 (1.572 and 1.572) was not significantly different (P > 0.05), Treatments 3 and 4 (1.565 and 1.562) were not different (P > 0.05) and Treatment 5 had the highest FCR (1.64). The bioeconomic efficiency results were significantly different (P < 0.05) for Treatments 1, 2, 3, 4 and 5 (42.16, 41.93, 41.46, 41.13 and 42.66, respectively). Based on the analyses and results, the authors concluded that cowpea meal prepared from boiled cowpea grain can be used to replace soybean meal in broiler diets at 50% and 75% inclusion, respectively. This study is unique and interesting and suitable for acceptance in this journal because it seeks to provide an alternative to feeds for the ever-growing broiler industry in Zimbabwe and the rest of the world.

## Keywords

Anti-Nutritional Factors, FCR, Feed Intake, Growth Performance

## 1. Introduction

The broiler industry in Zimbabwe has been growing tremendously over the past two decades [1]. Zengeni (2017) [2] reported that in the year 2009, Zimbabwe sold 18 million day-old broiler chicks and in 2018, it sold 90.8 million day-old broiler chicks. Bumhira and Madzimure (2022) [1] recommended that this growth of the broiler industry should also be complemented by an increase in the quantity of broiler feed manufactured in order to feed the continuously increasing number of broilers being reared. Dietary protein is a crucial nutrient in broiler diets since it contributes close to 75% of the total cost of making broiler feed [2]. Soybean meal is the major supplier of dietary protein to poultry diets with the remaining small portion being contributed by animal protein [3] [4]. Animal protein is being banned by some countries across the world since it is associated with zoonotic diseases such as salmonellosis and is also likely to be banned in Zimbabwe for use as a feed ingredient in broiler diets [5]. This leaves soybean meal as the only source of protein in broiler diets [6]. However, there is a shortage of soybean in Zimbabwe due to recurrent droughts, inadequate irrigation infrastructure, high input costs, price controls and lack of bankable land tenure [7]. This scarcity of soybean is causing the price of soybean meal for stockfeed manufacture to skyrocket and make broiler production unviable [2].

There is a need to look for other alternative plant sources of protein to soybean meal, which are locally available, cheap and drought tolerant [8]. Cowpea meal is the best alternative since it is comparatively similar to soybean meal in terms of amino acid profile even though it is lower in methionine and cysteine [8]. However, cowpea meal utilisation in broiler diets is limited due to the presence of anti-nutritional factors, namely phytates, lectin, tannins and protease inhibitors [9]. Nalle *et al.* (2010) [5] and Abbas and Ahmad (2018) [10] reported that anti-nutritional factors in grain legumes reduce the digestibility, absorption and utilisation of nutrients contained in broiler diets. Anti-nutritional factors' effects on monogastric animals range from retarded growth to death [11]. Nalle *et al.* (2010) [5] state that tannins bind to protein and reduce protein digestibility while trypsin inhibitors on the other hand prevent the release of trypsin enzymes from the pancreas into the ileum. Trypsin enzymes digest protein [1].

Dehulling, roasting, boiling and pressure cooking are familiar processing techniques that were being used to remove anti-nutritional factors from grain legumes to make them palatable and improve nutrient digestibility [8]. Dehulling only removes tannins located on the testa but not protease inhibitors located within the cotyledons. Therefore, there is a need to investigate the effect of boiled cowpea on broiler performance and economic efficiency.

## 2. Materials and Methods

This experiment was carried out at Cold Storage Company in the Kadoma district of Mashonaland West province, Zimbabwe.

### 2.1. Cowpea Grain Preparation

Cowpea grains were bought from a local market in Kadoma. Some cowpea grains were left untreated (raw) and some were soaked for 24 hours in tap water, boiled at 120˚C for 30 minutes, removed from water and allowed to dry in the sun for 5 days. Boiling was done to remove tannins which are usually located on the seed coat and also to remove trypsin inhibitors which are located in the seed cotyledons. An elevated temperature of 120˚C destroyed both tannins and trypsin inhibitors. Tannins were also partly removed as a result of leaching by boiling water. Both the raw and treated cowpea grains were separately ground into flour using a hammer mill.

### 2.2. Experimental Diets

**Table 1** and **Table 2** show five experimental diets that were formulated to meet broilers' nutrient requirements as recommended by National Research Council (2014) [13]. Diet T1 (control) contained 100% soybean meal + 0% cowpea meal, Diet T2 contained 75% soybean meal + 25% cowpea meal, Diet T3 contained 50% soybean meal + 50% cowpea meal, Diet T4 contained 25% soybean meal + 75% cowpea meal and Diet T5 contained 0% soybean meal + 100% cowpea meal (negative control). The experimental diets were formulated to be iso-caloric and iso-nitrogenous.

### 2.3. Chemical Analyses of Feed Ingredients

**Table 3** shows representative samples (50 g per each feedstuff) that were analysed for proximate composition at University of Zimbabwe's agriculture laboratory

**Table 1.** Broiler starter mash.

| Ingredient | Treatment | | | | |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 |
| **Maize** | 64 | 58.62 | 50.29 | 39.92 | 21.50 |
| **SBM** | 32.8 | 28.64 | 22.85 | 14.22 | 0 |
| **CWP** | 0 | 9.55 | 22.85 | 42.66 | 75.30 |
| **Vit-min mix** | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| **Total** | **100** | **100** | **100** | **100** | **100** |

SBM: Soybean Meal; CWP: Cowpea Meal; Vit-min mix: Vitamin-mineral premix.

**Table 2.** Broiler finisher mash.

| Ingredient | Treatment | | | | |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 |
| **Maize** | 69.38 | 64.88 | 58.6 | 49.25 | 33.84 |
| **SBM** | 27.40 | 23.94 | 19.1 | 11.89 | 0 |
| **CWP** | 0 | 7.98 | 19.1 | 35.66 | 62.96 |
| **Vit-min mix** | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| **Total** | **100** | **100** | **100** | **100** | **100** |

**Table 3.** Chemical composition of soybean meal, cowpea meal and maize.

| Ingredient | DM | CP | EE | CF | ASH | ME kcl/kg DM |
|---|---|---|---|---|---|---|
| **Maize** | 90 | 8.8 | 2.9 | 4.67 | 8.5 | 3340 |
| **Soybean meal** | 95 | 44.80 | 2.65 | 5.3 | 6.65 | 4062.9 |
| **Cowpea meal** | 90.5 | 23.31 | 1.54 | 5.33 | 2 | 3562 |

using standard methods of analysis as described by Association of official Analytical Chemistry (AOAC) (1990) [12].

## 2.4. Birds and Management

A total of 150 (Cobb 500) one day-old unsexed broiler chicks were used in this experiment. The birds were reared in a deep litter house and the experiment lasted 5 weeks. Feed and water were provided *ad libitum*. The chicks were fed the control diet during the first two weeks of age as adaptation period and thereafter fed with experimental diets. Variation in feeding was limited to a single factor (graded levels of cowpea meal) of treatment diets. The birds were vaccinated against Infectious Bursal Disease (IBD) and Newcastle disease as outlined by Kpomasse *et al.* (2021) [14]. Mortalities were recorded daily. Feed intake and weight gain were recorded weekly while FCR and bioeconomic efficiency were calculated weekly.

### 2.5. Experimental Design

At the beginning of third week of age, the broiler birds were randomly allocated into five dietary groups which were replicated three times with 10 birds per replicate and 30 birds per treatment. On day 15 of age, the birds were fed rations with different graded levels of cowpea meal that is 0% cowpea meal, 25% cowpea meal, 50% cowpea meal, 75% cowpea meal and 100% cowpea meal.

### 2.6. Statistical Analyses

The Statistical Analysis System (SAS) Version 9.3 (SAS, 2010) was used to analyse the growth trial data. Data on growth performance were subjected to PROC MIXED of SAS for repeated measures analysis. All the means were separated using the adjusted Turkey's method for comparisons of means.

## 3. Results

**Dry Matter (DM)** refers to the material remaining after removal of water from a feed.

**Crude Protein (CP)** is a measure of the amount of protein in a feed which is determined as the amount of nitrogen multiplied by 6.25 [1].

**Crude Fibre (CF)** is defined as a measure of the amount of indigestible cellulose, pentosans and lignin in feeds [1].

**Ether Extracts (EE)** refers to the amount of lipids or oil in a feed [5].

### Mortalities

A mortality rate of 2% was recorded for each of the five experimental groups up to the end of the experiment.

## 4. Discussions

### 4.1. Dry Matter Intake Grams (g)

The feed intake results in **Table 4** show that the overall feed consumed by birds from Treatments 2, 3 and 4 were not significantly different ($P > 0.05$). Highest feed intake was recorded in Treatment 1 and lowest feed intake in Treatment 5. This was in agreement with [15]. Scott *et al.* (1982) [16] reported that birds were expected to consume similar amount of feed when fed on diets containing approximately equal energy and protein. The high feed intake in Treatment 1 can be attributed to the better palatability of soybean meal than cowpea meal and on the other hand lowest feed intake obtained in Treatment 5 was because cowpea meal had fine feed particles making it difficult for the birds to eat (it choked the birds). The other reason might be the presence of residual anti-nutritional factors in cowpea meal. Chakam *et al.* (2010) [17] reported that thermal treatment of cowpea grains reduced phytate levels but failed to destroy tannins. The reduced

**Table 4.** Weekly feed intake (g).

| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Week 1 | 164$^{a}$ | 164$^{a}$ | 164$^{a}$ | 164$^{a}$ | 164$^{a}$ |
| Week 2 | 400$^{a}$ | 400$^{a}$ | 400$^{a}$ | 400$^{a}$ | 400$^{a}$ |
| Week 3 | 559$^{a}$ | 559$^{a}$ | 559$^{a}$ | 559$^{a}$ | 559$^{a}$ |
| Week 4 | 994$^{a}$ | 993.7$^{a}$ | 993.6$^{a}$ | 993.69$^{a}$ | 993.67$^{a}$ |
| Week 5 | 1169.91$^{a}$ | 1167.39$^{b}$ | 1167.58$^{bc}$ | 1167.26$^{bcd}$ | 1165.81$^{c}$ |

*Values with different superscript letters in the same row are significantly different at 0.05 level of significance as analysed by Tukey's test and this applies to **Tables 4-8**.

feed intake in diets containing cowpea meal were similar to results obtained by Thomas (2013) [3] who reported that despite cowpea meal having protein with high digestibility, cowpea grain seed coats' have high levels of crude fibre (Non-starch Polysacharrides) that possibly reduce its palatability. This was the case with the study of Eljack *et al.* (2009) [15] in which feed intake was found to be lower whenever cowpea inclusion rate was increased in the diets.

### 4.2. Weight Gain (g)

The overall weight gain (**Table 5**) by birds in Treatments 1 and 2 were not significantly different. The weight gains for Treatments 3 and 4 were not significantly different ($P > 0.05$). The lowest weight gain was recorded in Treatment 5. The weight gains obtained in this study were in agreement with those obtained by Eljack *et al.* (2009) [15] who obtained overall weight gain ranging from 1683.29 - 2152.02 g. These were higher than weight gains obtained by Chakam *et al.* (2010) [17] and Defang *et al.* (2008) [18] who reported 1287.85 - 1536.13 g and 1094.93 - 1362.49 g, respectively. Birds in Treatment 5 weighed less than birds from other Treatments because they consumed the lowest amount of feed when compared to the other treatments. Birds from Treatments 3 and 4 performed better than other treatments because protein digestibility of cowpea meal is higher than any other legume [19]. Defang *et al.* (2008) [18] recorded that cowpeas has a protein digestibility of 77.9%. Similar results were reported by Eljack *et al.* (2010) [15].

### 4.3. Feed Conversion Ratio (FCR)

Overall Feed Conversion Ratio (FCR) results in **Table 6** show that FCR results at 5 weeks for Treatments 1 and 2 had no significant difference ($P > 0.05$). Treatments 3 and 4 were not significantly different ($P > 0.05$). Treatment 5 had the highest FCR. Treatments 3 and 4 had better FCRs because combining different sources of protein in poultry feeds produced a diet with a balanced amino acid profile [18]. They consumed less feed which they converted into more meat (1.56 kg feed/kg meat). This was in agreement to results obtained by Eljack *et al.* (2009) [15] who obtained an FCR range of 1.5 - 2.2.

Table 5. Cumulative weight gain (g).

| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Week 1 | 167[a] | 167[a] | 167[a] | 167[a] | 167[a] |
| Week 2 | 500.69[a] | 500.7[a] | 500.67[a] | 500.65[a] | 500.60[a] |
| Week 3 | 894[a] | 894[a] | 893.97[a] | 893.9[a] | 893.87[a] |
| Week 4 | 1430[a] | 1429.92[a] | 1431[b] | 1431[bc] | 1429[d] |
| Week 5 | 2088.67[a] | 2089[a] | 2097.67[b] | 2102.67[bc] | 1990[d] |

Table 6. Cumulative FCR.

| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Week 1 | 0.98[a] | 0.98[a] | 0.98[a] | 0.98[a] | 0.98[a] |
| Week 2 | 1.13[a] | 1.13[a] | 1.3[a] | 1.13[a] | 1.13[a] |
| Week 3 | 1.26[a] | 1.26[a] | 1.26[a] | 1.26[a] | 1.26[a] |
| Week4 | 1.48[a] | 1.48[a] | 1.479[b] | 1.479[bc] | 1.48[a] |
| Week 5 | 1.57[a] | 1.57[a] | 1.56[b] | 1.56[bc] | 1.65[d] |

## 4.4. Total Feed Cost per Treatment

The cost effectiveness of experimental diets is shown in Table 7. Total feed cost for Treatments 1, 2, 3, 4 and 5 were significantly different (P < 0.05). This was in agreement with results obtained by Embaye *et al.* (2018) [11] who obtained total feed cost/kg weight gain of US$2.51 - US$3.36. The amount of cowpea meal in broiler diets and total feed cost per treatment were inversely proportional. Total feed cost per treatment gradually decreased with increasing addition of cowpea meal to the treatment diets. The gradual decrease of the cost of feed in treatments containing cowpea meal was due to the low cost of cowpea grain (US$0.33/kg) when compared to US$0.66/kg of soybean meal in Zimbabwe.

## 4.5. Bioeconomic Efficiency

Bioeconomic efficiencies (Table 8) from the five treatments were significantly different (P < 0.05) with the lowest level obtained in Treatment 4 followed by Treatments 3, 2, 1 and 5. As a result, Treatments 3 (50% soybean meal + 50% cowpea meal) and 4 (25% soybean meal + 75% cowpea meal) with higher weight gains, average feed consumption, average FCR, average feed cost/kg and lowest bioeconomic efficiencies could be recommended to be used in raising broilers at 21% CP broiler starter and 19% CP broiler finisher.

The mortality rate was not significantly different (P > 0.05) among all the five experimental groups. This clearly shows that the mortalities were not as a result of differences in cowpea inclusion level in the experimental diets but it can be attributed to other causes that maybe hatchery related.

**Table 7.** Feed cost per treatment (US$).

| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Week 1 | 1.47$^a$ | 1.47$^a$ | 1.47$^a$ | 1.47$^a$ | 1.47$^a$ |
| Week 2 | 5.07$^a$ | 5.07$^a$ | 5.07$^a$ | 5.07$^a$ | 5.07$^a$ |
| Week 3 | 10.02$^a$ | 10.02$^a$ | 10.02$^a$ | 9.90$^b$ | 9.81$^c$ |
| Week 4 | 17.76$^a$ | 17.67$^a$ | 17.61$^a$ | 17.49$^b$ | 17.28$^c$ |
| Week 5 | 26.82$^a$ | 26.67$^b$ | 26.58$^c$ | 26.37$^d$ | 26.01$^e$ |

**Table 8.** Bioeconomic efficiency.

| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Week 1 | 1.44$^a$ | 1.44$^a$ | 1.44$^a$ | 1.44$^a$ | 1.44$^a$ |
| Week 2 | 5.73$^a$ | 5.73$^a$ | 5.73$^a$ | 5.73$^a$ | 5.73$^a$ |
| Week 3 | 12.63$^a$ | 12.63$^a$ | 12.63$^a$ | 12.47$^b$ | 12.36$^c$ |
| Week 4 | 26.28$^a$ | 25.15$^b$ | 26.05$^c$ | 26.87$^d$ | 25.57$^e$ |
| Week 5 | 42.11$^a$ | 41.87$^b$ | 41.46$^c$ | 41.14$^d$ | 42.92$^e$ |

## 5. Conclusion

This study was conducted to evaluate the biological and economic efficiency of partial dietary substitution of soybean meal with cowpea meal in broiler production. It can be concluded that cowpea meal prepared from boiled cowpea grain can be used to replace soybean meal in broiler diets at 50% and 75% inclusion levels without any adverse effect on the performance of broilers, so as to increase the economic efficiency of broiler production.

## 6. Recommendations

Based on the results of this study, farmers are recommended to:

1) Use Treatments 3 (50% soybean meal + 50% cowpea meal) and 4 (25% soybean meal + 75% cowpea meal) with higher weight gains, average feed consumption, average FCR, average feed cost/kg and lowest bioeconomic efficiencies in raising broilers at 21% CP broiler starter and 19% CP broiler finisher.

2) Grow a lot of cowpeas in order to improve the productivity and economic efficiency of the poultry industry in Zimbabwe.

3) Do further research on the processing of cowpea grains in order to destroy all anti-nutritional factors that limit the proper utilization of protein in this feedstuff by broilers.

4) There is also the need to increase the number of birds in the experiment to reduce experimental error and increase efficiency.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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