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Research Paper

# Evaluation of Nutritional Values of Some Meals Containing Soybean Oil

**Tiwar Jagat, Sapko Mahesh**[1]

Plant Developmental Biology and Plant Physiology Institute, University of Chitwan, Nepal

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**Abstract**

The present study investigated dietary inclusion effects of soybean oil at three levels (0%, 2% and 4%) and three sources of commercial bone meals (GBM, PBM and IBM) on the body weight, weight gain, feed consumption, feed efficiency, digestibility coefficient, calcium, phosphorus and ash contents of blood and bone in broiler chickens. Mean weekly feed consumption, average cumulative body weight, and average weekly body weight gain increased significantly ($P < 0.01$) in broilers fed soybean oil-containing diets, with $T_9$ and $T_1$ showing the highest (5058.27 g) and lowest (4117.88 g) mean total feed intakes. Mean cumulative body weight was uppermost (2168.33 g) in $T_6$ while the lowermost value (1930.00 g) was recorded in $T_1$. Likewise, $T_6$ and $T_1$ attained the highest (301.04 g) and lowest (273.77 g) average body weight gain, respectively. Maximum (2.38%) and minimum (1.04%) abdominal fat weight percentages were found in broilers fed a diet containing 4% soybean oil with GBM and those received no soybean oil with IBM, respectively. Yet, soybean oil-containing diet could improve the overall performance of broilers. Dietary inclusion of 2%-4% soybean oil-containing sources of bone meal led to better contents of ash, calcium and phosphorus both in the blood and bone. Therefore, 2%-4% dietary inclusion levels of soybean oil with GBM as the source of bone meal is recommendable as inferred by improved bone calcification and utilization of phosphorus and minerals in the broilers' body.

**Keywords:** Soybean Meal; Bone Meal; Broilers; Performance

**Abbreviations**: GBM=G Bone Meal Source; PBM=P Bone Meal Source; IBM=I Bone Meal Source

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## 1. Introduction

Poultry production as a suitable source of protein has gained ground in meat and egg nourishment among Nepalese people. Maintaining a healthy poultry requires an appropriate nutrition. Essential minerals and lipids play various beneficial roles as major constituents in the body of broilers by making their skeletons rigid and robust. Calcium and phosphorus account for over 70% of mineral content in the chicken' body. As the most frequent bodily mineral, dietary calcium requirements are higher than other nutrients [1]. Ossification depends heavily on concentrations of both calcium and phosphorus in the diet along with vitamin D consumption [2]. A large portion of vital minerals (calcium, phosphorus, etc.) for skeleton formation and maintenance are supplied by bone meal. Calcium and phosphorus are generally estimated together as these two minerals interact frequently. Increasing body weight of young broilers received a particular fattening diet results from increments in various tissues. However, a considerable amount of fat is also deposited in case of feeding a proper fattening diet. In the fattening process, the economic efficiency can be enhanced by means of a good raw material, which can also enrich the chicken meat with protein and fat contents. In addition to energy supply, dietary inclusion of fat

[1] Corresponding author email: sapko.mahesh@gmail.com

boosts the absorption of fat-soluble vitamins, reduces pulverization, improves diet palatability, and elevates the productivity of consumed energy (lesser caloric increment). This further decreases the digesta passageway rate in the gastrointestinal tract leading to enhanced absorption of the whole dietary nutrients.

Concentrations of calcium and phosphorus in the diet along with sufficient vitamin D consumption have a rigorous contribution to bone formation and digestibility of minerals and amino acids. Insufficient calcium and phosphorus contents may result in a poor growth. On the other hand, excessive amounts of both calcium and phosphorus in the diet should be avoided as this may hamper the absorption of other minerals through the intestine. Due to frequent deformations of sternum and rib bones as well as easy breakage of bones, it is crucial to avoid this condition via dietary administration.

Compared to carbohydrates mainly starch as the common energy storage form in plants, animals store energy in fats and oils as the most concentrated forms providing 2.5 times the calorie supplied by carbohydrates and proteins. Fats and oils offer insulation for vital organs, shield them against mechanical shock, preserve optimum body temperature, and also improve diet palatability for all variety of animals. Although taste cannot be measured in case of poultry, it seems that supplementary fat reduces feed dustiness and surmounts problems accompanied by suitability of very fine feed particles. Increasing water loss through the skin and the resultant rise in water consumption come from its rough, flaky surface leading to increased permeability. In addition, poultry present a declined disease resistance, a poorer feed consumption efficiency, and imperfect feathering.

The digestion of dietary fats in insoluble calcium soaps produces fatty acids with problematic assimilation [3]. Absorption of calcium, however, is advantageous to a minor amount of dietary fat, whereas absorption of other fats is interrupted by extra levels of either calcium or phosphorus. For their optimum absorption, therefore, it is desirable to maintain a certain dietary ratio between these two minerals. Fats and oils also contain Vitamin D, which improves both calcium and phosphorus absorption, in particular, when a proper ratio of the two minerals is not present [3]. Animals with deficient C and P show significantly demineralized bones and ash, with reduced bone calcium contents to ca. one-half the normal level. This research, therefore, aimed to examine whether C and P present individual or interaction effects throughout the experiment.

## 2. Materials and Methods

The dietary inclusion effects of soybean oil and sources of bone meal at different levels were examined on broiler chicken. To do this, a total of 270 castrated Vencobb-100 broiler chickens aged 80 days were obtained from a hatchery market and raised in 27 different floor pens of 3.2 m$^2$. There were nine treatments each prepared with interactions of two factors, viz. soybean oil (0%, 2% and 4%) and three commercial bone meal sources (GBM, PBM and IBM). Ten broilers were assigned to individual pens each with three replications in a 3×3 two-factorial completely randomized design. The chickens were fed with two diet types, namely broiler starter (weeks 0 to 4) and finisher (weeks 5 to 7). Isocaloric diets (3000 M.E Kcal/kg) were used, though, starter and finisher diets contained crude protein levels of 20 and 19%, respectively. The required amounts of vitamins, mineral premixes, and mixed chlortetracycline (500 g/t) were also added to strengthen the experimental diets. All treatments were fed *ad libitum* up to 6$^{th}$ weeks of age. Vaccination of the chickens was carried out based on the relevant schedule. Different parameters measured throughout the trial were body weight, weight gain, feed consumption, feed efficiency, carcass characteristics (dressing percentage and sharing of different organs) and calcium, phosphorus and ash contents of blood and bone in the broilers. At completion of the experimental period, each replication in the treatments was subjected to a digestibility trial. Nutrient digestibility was determined by random selection of one bird per treatment and keeping in the cage. Prior to the digestion trial, the broilers were not fed for 24 h, after which they were fed *ad libitum* for 72 h. Feed refusal were recorded and undergone proximate analysis based on the guidelines presented by National Research Council (NRC, 1984) and Association of Official Analytical Chemists (AOAC, 2001). The contents of calcium, phosphorus and ash in the blood and bone of broilers were measured according to AOAC (2001). First, data were entered in Microsoft Excel tables and then analysed statistically in a 3×3 two-factorial completely randomized design (CRD) using MSTAT-C computer software package. Mean values were compared through Least Significant Difference (LSD) at a significance level of 5%.

## 3. Results and Discussion

### *3.1 Digestibility coefficient*

Table 1 shows the digestibility coefficients obtained for CP, CF, EE, NFE and TA contents in the finisher diet of broilers. Highly significant differences ($P < 0.01$) were observed in the digestibility coefficients of CP, NFE, CF, EE and TA between treatments.

The $T_3$ treatment presented a significantly ($P < 0.01$) higher digestibility coefficient of CP in comparison with those of $T_1$ and $T_7$, while the other treatments showed no significant differences. Maximum (85.80%) and minimum (83.20%) CP digestibility coefficients were recorded in $T_3$ and

$T_7$, respectively. Compared to $T_1$, $T_2$, $T_4$ and $T_8$, EE digestibility coefficient increased significantly in $T_3$ ($P < 0.01$). $T_3$ and $T_1$ displayed maximum (86.50%) and minimum (79.00%) digestibility coefficients of EE.

Except for treatments $T_1$ and $T_4$, NFE digestibility coefficient rose significantly ($P < 0.01$) in $T_2$ as opposed to the rest of treatments. The digestibility coefficient of NFE was uppermost in $T_3$ (80.80%) and lowermost in $T_7$ (77.70%). Finally, a highly significant ($P < 0.01$) increase was observed in digestibility coefficient of TA. Maximum (43.00%) and minimum (33.60%) TA digestibility coefficients were detected in $T_1$ and $T_7$, respectively.

Overall, digestibility coefficients of various nutrients were uppermost in $T_3$ as it contained a combination of 4% soybean oil and GBM likely resulting in rising digestibility coefficients of nutrients.

Feeding diets containing soybean oil to the broilers elevated apparent digestibility values of ether extract compared to treatments received soybean oil diet within their first three-week age [5]

### *3.2 Feed consumption*

Table 2 represents average weekly feed consumption of chickens fed with different levels of soybean oil.

According to ANOVA results, soybean oil affected very significantly ($P < 0.01$) the variation of weekly feed consumption of broilers throughout weeks 1-7, with a significant effect ($P < 0.05$) in Week 6 only.

The first-week feed consumption of broilers fed on basal diets with 4%, 2%, and zero levels of soybean oil increased significantly ($P < 0.01$) in order of 92.85 g, 88.97 g, and 87.44 g, respectively. In the same way, feed consumption of broilers rose significantly ($P < 0.01$) in Week 7 with soybean oil inclusions of 4% (1488.16 g), 2% (1319.33 g) and zero (1001.22 g) in the basal diet suggesting the highest feed consumption in 4% soybean oil treatment. As a result, feed intake of chickens elevated with incorporations of 4% and 2% soybean oil in the diet. Our results are in line with previous reports on increased feed consumption in broilers fed soybean oil [6-7].

**Table 1**. Digestibility coefficient of nutrients of broilers fed finisher diets

| Treatments | Digestibility coefficients (%) of | | | | | |
|---|---|---|---|---|---|---|
| | DM | CP | CF | EE | NFE | Ash |
| **$T_1$ = diet without soybean oil + GBM** | 80.50 | $83.30^{b}$ | 63.40 | $79.00^{d}$ | $79.50^{bc}$ | $43.00^{a}$ |
| **$T_2$ = diet with 2% soybean oil + GBM** | 80.10 | $84.60^{ab}$ | 64.00 | $83.50^{c}$ | $80.80^{a}$ | $42.50^{b}$ |
| **$T_3$ = diet with 4% soybean oil + GBM** | 80.50 | $85.80^{a}$ | 63.50 | $86.50^{a}$ | $80.20^{ab}$ | $42.70^{ab}$ |
| **$T_4$ = diet without soybean oil + PBM** | 80.40 | 83.80b | 62.90 | 79.50d | 77.80d | 35.60c |
| **$T_5$ = diet with 2% soybean oil + PBM** | 80.20 | $84.80^{ab}$ | 63.00 | $83.43^{c}$ | $78.20^{d}$ | $33.90^{d}$ |
| **$T_6$ = diet with 4% soybean oil + PBM** | 80.10 | $84.80^{ab}$ | 63.00 | $84.6^{bc}$ | $78.90^{cd}$ | $34.10^{c}$ |
| **$T_7$ = diet without soybean oil + IBM** | 80.50 | $83.20^{b}$ | 64.10 | $79.80^{d}$ | $77.70^{d}$ | $33.60^{d}$ |
| **$T_8$ = diet with 2% soybean oil + IBM** | 80.20 | $84.80^{ab}$ | 64.10 | $83.50^{c}$ | $77.90^{d}$ | $33.80^{d}$ |
| **$T_9$ = diet with 4% soybean oil + IBM** | 80.40 | $85.20^{ab}$ | 64.00 | $85.50^{ab}$ | $78.83^{cd}$ | $34.03^{cd}$ |
| **Mean** | 80.32 | 84.47 | 63.55 | 82.81 | 78.87 | 37.02 |
| **Probability** | Ns | 0.01 | Ns | 0.01 | 0.00 | 0.00 |
| **CV %** | 0.28 | 1.24 | 0.30 | 0.74 | 0.27 | 2.61 |
| **SEm** | 0.05 | 1.08 | 0.37 | 0.37 | 0.44 | 1.33 |
| **LSD value** | - | 2.45 | - | 1.43 | 1.08 | 1.22 |
| **Note:** GBM=G bone meal source, PBM=P bone meal source, IBM=I bone meal source | | | | | | |

**Table 2**. Average weekly feed consumption of broilers fed diets containing various levels of soybean oil

| Treatments | Weeks | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| **$T_1$= diet without soybean oil** | $87.44^{b}$ | $209.82^{c}$ | $349.53^{b}$ | $573.00^{c}$ | $937.48^{b}$ | $981.83^{b}$ | $1001.22^{b}$ |
| **$T_2$ = diet with 2% soybean oil** | $88.97^{ab}$ | $237.61^{b}$ | $365.58^{b}$ | $631.25^{b}$ | $911.41^{b}$ | $1018.37^{a}$ | $1319.33^{a}$ |
| **$T_3$ = diet with 4% soybean oil** | $92.85^{a}$ | $253.21^{a}$ | $401.53^{a}$ | $693.66^{a}$ | $1013.87^{a}$ | $1098.76^{a}$ | $1488.16^{a}$ |
| **Mean** | 89.75 | 233.55 | 372.21 | 632.64 | 954.25 | 1032.99 | 1269.57 |
| **Probability** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 | 0.01 |
| **CV %** | 3.11 | 9.41 | 7.15 | 9.54 | 5.58 | 5.79 | 19.48 |
| **SEm** | 1.10 | 1.60 | 6.64 | 6.36 | 14.17 | 44.51 | 56.07 |
| **LSD value** | 4.51 | 6.51 | 27.04 | 25.89 | 57.70 | 181.2 | 228.3 |

*3.3 Body Weight*

Tables 3 and 4 show mean initial and cumulative body weights of broilers with different soybean oil inclusions.

As indicated by ANOVA results, soybean oil had no significant effect ($P > 0.05$) on the variation of weekly broilers' cumulative body weight in the first week of experiment. The second-week cumulative body weight elevated significantly ($P < 0.01$) in treatments with 4% (319.89 g), 2% (309.22 gm) and zero (295.22 gm) soybean oil additions.

The broilers fed with 4%, 2%, and zero soybean oil supplementation exhibited significant ($P < 0.01$) rises in cumulative body weight in order of 536.88 g, 518.44 g, and 501.77 g in the third week. Likewise, cumulative body weight of broilers rose significantly ($P < 0.01$) with 4% (894.66 g), 2% (855.88 g) and zero (814.11 g) soybean oil inclusions in the fourth week. The fifth-week cumulative body weights of broilers were significantly ($P < 0.01$) high in 4% (1327.77 g), zero (1266.66 g), and 2% (1264.44 g) soybean oil treatments, respectively.

The broilers displayed a significant ($P < 0.01$) cumulative body weight increment (1756.66 g) when fed a diet with 4% soybean oil inclusion in the sixth week. However, treatments containing 2% and zero soybean oil were similar (1672.22 g) concerning broilers' cumulative body weights.

Significant ($P < 0.01$) elevations of broilers' cumulative body weights were recorded in the seventh week with 4% (2157.22 g), 2% (2033.88 g), and zero (1948.88 g) soybean oil treatments.

Inclusion of 4% soybean oil in the basal diet resulted in significant ($P < 0.01$) increases in cumulative body weights of broilers. A variety of lipid sources (beef tallow, soybean oil, canola oil, marine fish oil or a mixture of these oils) were fed to female broilers, of which soybean oil addition significantly raised the birds' live weight [8].

**Table 3**. Mean cumulative body weights of broilers fed diets containing soybean oil at different levels

| Treatments | Weeks | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| **$T_1$= diet without soybean oil** | 116.22 | 295.22$^c$ | 501.77$^c$ | 814.11$^c$ | 1266.66$^b$ | 1672.22$^b$ | 1948.88$^c$ |
| **$T_2$ = diet with 2% soybean oil** | 114.44 | 309.22$^b$ | 518.44$^b$ | 855.88$^b$ | 1264.44$^b$ | 1672.22$^b$ | 2033.88$^b$ |
| **$T_3$ = diet with 4% soybean oil** | 115.55 | 319.22$^a$ | 536.88$^a$ | 894.66$^a$ | 1327.77$^a$ | 1765.66$^a$ | 2157.22$^a$ |
| **Mean** | 115.40 | 307.89 | 519.03 | 854.88 | 1286.29 | 1700.37 | 2046.66 |
| **Probability** | 0.25 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **CV %** | 0.78 | 3.92 | 3.38 | 4.71 | 2.79 | 2.87 | 5.12 |
| **SEm** | 0.52 | 6.96 | 10.14 | 23.26 | 20.75 | 28.15 | 60.48 |
| **LSD value** | --- | 6.46 | 9.19 | 11.19 | 49.75 | 73.44 | 36.18 |

**Table 4**. Mean cumulative body weights of broilers fed diets containing soybean oil at different levels and various bone meal sources

| Treatments | Weeks | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| **$T_1$= diet without soybean oil** | 116.00 | 294.00 | 501.33 | 810.00 | 1263.33 | 1683.33 | 1930.00 |
| **$T_2$ = diet with 2% soybean oil** | 114.33 | 308.00 | 517.33 | 850.00 | 1286.66 | 1666.66 | 2008.33 |
| **$T_3$ = diet with 4% soybean oil** | 115.00 | 318.00 | 532.66 | 893.00 | 1306.66 | 1750.00 | 2156.66 |
| **$T_4$ = diet without soybean oil + PBM** | 117.33 | 296.66 | 502.66 | 813.66 | 1283.33 | 1666.66 | 1966.66 |
| **$T_5$ = diet with 2% soybean oil + PBM** | 114.66 | 311.66 | 522.00 | 857.66 | 1243.33 | 1666.66 | 2030 |
| **$T_6$ = diet with 4% soybean oil + PBM** | 117.00 | 320.66 | 536.66 | 896.00 | 1333.33 | 1766.66 | 2168.33 |
| **$T_7$ = diet without soybean oil + IBM** | 115.33 | 295.00 | 501.33 | 818.66 | 1253.33 | 1666.66 | 1950.00 |
| **$T_8$ = diet with 2% soybean oil + IBM** | 114.33 | 308.00 | 516.00 | 860.00 | 1263.33 | 1683.33 | 2063.33 |
| **$T_9$ = diet with 4% soybean oil + IBM** | 114.66 | 319.00 | 541.33 | 895.00 | 1343.33 | 1753.33 | 2146.66 |

**Table 5**. Mean body weight gain of broilers fed diets containing various soybean oil inclusions

| Treatments | Weeks | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| **$T_1$= diet without soybean oil** | 72.67 | 179.00$^c$ | 206.55 | 312.33$^c$ | 352.55$^c$ | 405.55 | 293.33$^b$ |
| **$T_2$ = diet with 2% soybean oil** | 70.35 | 194.77$^b$ | 209.22 | 337.44$^b$ | 399.66$^b$ | 407.77 | 361.66$^a$ |
| **$T_3$ = diet with 4% soybean oil** | 72.11 | 203.66$^a$ | 217.66 | 357.77$^a$ | 431.77$^a$ | 424.44 | 395.00$^a$ |
| **Mean** | 71.71 | 192.48 | 211.14 | 335.85 | 427.99 | 412.59 | 350.00 |
| **Probability** | 0.13 | 0.01 | 0.06 | 0.01 | 0.01 | --- | 0.01 |
| **CV %** | 1.69 | 6.49 | 2.75 | 6.78 | 6.23 | 2.50 | 14.81 |
| **SEm** | 0.70 | 7.21 | 3.35 | 13.14 | 15.38 | 5.96 | 29.92 |
| **LSD value** | --- | 5.54 | --- | 12.95 | 37.79 | --- | 62.02 |

**Table 6**. Mean feed conversion ratio of broilers fed diets containing various soybean oil inclusions

| Treatments | Weeks | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| **$T_1$= diet without soybean oil** | 1.20b | 1.17c | 1.69b | 1.83b | 2.07b | 2.42b | 3.41c |
| **$T_2$ = diet with 2% soybean oil** | 1.26a | 1.22b | 1.74b | 1.87b | 2.28a | 2.50b | 3.64b |
| **$T_3$ = diet with 4% soybean oil** | 1.28a | 1.24a | 1.84a | 1.93a | 2.35a | 2.59a | 3.76a |
| **Mean** | 1.25 | 1.21 | 1.76 | 1.88 | 2.23 | 2.50 | 3.60 |
| **Probability** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **CV %** | 3.34 | 2.98 | 4.35 | 2.68 | 6.52 | 3.40 | 4.94 |
| **SEm** | 0.01 | 0.01 | 0.03 | 0.02 | 0.05 | 0.03 | 0.06 |
| **LSD value** | 0.04 | 0.01 | 0.04 | 0.04 | 0.14 | 0.08 | 0.11 |

### *3.4 Body weight gain*

Table 5 represents mean weekly body weight gain of broilers received soybean oil diets. Results of ANOVA for the second, fourth, fifth and seventh week revealed highly significant impacts of soybean oil on the variation of broilers' body weight gain ($P < 0.01$) while no significant effects ($P > 0.05$) were observed throughout the first, third and sixth weeks.

The second-week body weight gain of broilers increased significantly ($P < 0.01$) in treatments with 4% (203.66 g), 2% (194.77 g), and zero (179.00 g) soybean oil supplementation. In the fourth week, the broilers exhibited significantly increasing body weight gains of 357.77 g, 337.44 g, and 312.33 g, respectively, when treated with soybean oil inclusions of 4%, 2%, and zero ($P < 0.01$).

Significant ($P < 0.01$) elevations in broilers' body weight gain were noticed by supplementing the basal diet with 4% (431.77 g), 2% (399.66 g) and zero (352.55 gm) levels of soybean oil in the fifth week. In the same way, the seventh-week increments in body weight gain were significant ($P < 0.01$) when the broilers fed with 4% (395.00 g), 2% (361.66 g), and zero (293.33 gm) dietary soybean oil.

The applied soybean oil supplementation led to significant ($P < 0.01$) uppermost body weight gains resulting from the best response of broilers. In a previous study, fat-replaced diets improved body weight and weight gain within 7th weeks of age [9]. Examination of broiler diets with soybean oil levels of 0, 4 and 8% revealed that the birds fed with soybean oil among various lipid levels were similar in weight gain compared to those received no soybean oil, corroborating our observations.

The experimental birds presented the highest body weight gain significantly ($P < 0.05$) as a result of feeding with 4% soybean oil, which was also reported previously [9-10].

### *3.5 Feed conversion ratio (FCR)*

Table 6 shows mean weekly FCR values of broilers received soybean oil-supplemented diets. According to results of ANOVA, soybean oil inclusion levels had a highly significant ($P < 0.01$) impact on the variation of weekly FCR values in broilers throughout the first to the seventh weeks of experimental period. A significantly ($P < 0.01$) superior FCR level was observed in the treatment with zero level (1.20) compared to those of 2% (1.26) and 4% (1.28) soybean oil within the first week. Similarly, FCR was significantly better ($P < 0.01$) in broilers fed a diet with no soybean oil (1.17) as opposed to those of 2% (1.22) and 4% (1.24) soybean oil diets in the second week.

A significantly ($P < 0.01$) better third-week FCR (1.69) was recorded in soybean oil-deficient basal diet in comparison with those of 2% (1.74) and 4% (1.84) soybean oil-fed broilers. Within the fourth week, the broilers fed a diet with no soybean oil had a significantly ($P < 0.01$) better FCR (1.83) as opposed to those received 2% (1.87) and 4% (1.93) soybean oil supplements.

FCR value in the fifth week was significantly ($P < 0.01$) better (2.07) in zero soybean oil treatment than those measured in 2% (2.28) and 4% (2.35) soybean oil treatments. In the same manner, a significantly ($P < 0.01$) better FCR (2.42) was noticed with zero soybean oil diet in comparison with those of 2% (2.50) and 4% (2.59) soybean oil diets within the sixth week.

The broilers exhibited a significantly ($P < 0.01$) better seventh-week FCR (3.41) by feeding on zero soybean oil diet compared to those received 2% (3.64) and 4% (3.76) dietary soybean oil. Accordingly, the diet with zero soybean oil yielded a significantly ($P < 0.01$) better FCR than those of other soybean oil levels. This could have resulted from a greater mean weekly feed intake than mean body weight gain of broilers fed soybean oil-added diets. Diets supplemented with 4% of poultry fat, 4% of soybean oil or a mixture of 2% of soybean oil and 2% of poultry fat could not influence weight gain, feed intake and FCR of broilers fed the above oil sources. Nevertheless, feed intake and weight gain dropped with feeding the mixture to the birds.

### *3.6 Carcass characteristics*

Table 7 represents the broilers' carcass features after feeding with graded levels of soybean oil-supplemented and bone meal diets in different treatments.

The blood weight (2.44%) was maximum in $T_6$ and minimum (2.17%) in $T_1$. Maximum and minimum feather weights were recorded in $T_9$ (5.97%) and $T_4$ (5.12%), respectively. $T_4$ and $T_9$ attained maximum (92.67%) and minimum (91.62%) dressed carcass weights, respectively. The visceral weight was uppermost (15.65%) in $T_6$ and lowermost in $T_1$ (14.50%). The intestine weight maximized (8.11%) in $T_9$ and minimized (7.58%) in $T_1$. The highest (4.92%) and lowest (4.22%) leg weights were measured in $T_4$ and $T_1$, respectively. $T_6$ and $T_8$ had maximum (2.87%) and minimum (2.23%) liver weights. Heart weight was maximal (0.51%) in $T_1$ and minimal (0.44%) in $T_5$. Gizzard weight maximized (3.99%) in $T_6$ and minimized (3.48) in $T_3$. Empty gizzard weight, however, was maximal (2.97%) in $T_9$ and minimal (2.18%) in $T_6$.

The percentage abdominal fat maximized (2.38%) in $T_3$ and minimized (1.04%) in $T_7$. The uppermost percentage of abdominal fat in $T_3$ might have caused by feeding the broilers with 4% soybean oil diet. Similarly, earlier studies observed that inclusion levels of 2% and 4% soybean oil could raise the abdominal fat content [11]. The authors reported no significant differences regarding DM, protein and fat contents in thigh meat, or organoleptic traits of breast meat. However, dietary fat sources affected the composition of abdominal fat. Moreover, soybean oil presented significant increases in typical content of polyunsaturated fatty acids [11]. The dressing percentage, however, was maximal (74.94%) in $T_3$ and minimal (73.11%) in $T_1$.

**Table 7**. Slaughter characteristics of broiler fed diets containing various levels of soybean oil and sources of bone meal

| Treatments | Live wt. (g) | Blood wt. % | Feather wt. % | Dressed carcass wt. % | Visceral wt. % | Abdominal fat wt. % | Dressing percent |
|---|---|---|---|---|---|---|---|
| **$T_1$ = diet without soybean oil + GBM** | 1930.00 | 2.17 | 5.36 | 92.47 | 14.50 | 1.09 | 73.11 |
| **$T_2$ = diet with 2% soybean oil + GBM** | 2008.33 | 2.26 | 5.34 | 92.40 | 15.27 | 1.97 | 74.41 |
| **$T_3$ = diet with 4% soybean oil + GBM** | 2156.66 | 2.42 | 5.49 | 92.09 | 14.94 | 2.38 | 74.94 |
| **$T_4$ = diet without soybean oil + PBM** | 1966.66 | 2.21 | 5.12 | 92.67 | 14.96 | 1.08 | 73.38 |
| **$T_5$ = diet with 2% soybean oil + PBM** | 2030.00 | 2.28 | 5.19 | 92.53 | 15.34 | 1.49 | 73.43 |
| **$T_6$ = diet with 4% soybean oil + PBM** | 2168.33 | 2.44 | 5.26 | 92.30 | 15.65 | 2.34 | 74.86 |
| **$T_7$ = diet without soybean oil + IBM** | 1950.00 | 2.19 | 5.21 | 92.60 | 15.51 | 1.04 | 73.27 |
| **$T_8$ = diet with 2% soybean oil + IBM** | 2063.33 | 2.32 | 5.89 | 91.79 | 14.83 | 1.39 | 73.17 |
| **$T_9$ = diet with 4% soybean oil + IBM** | 2146.66 | 2.41 | 5.97 | 91.62 | 15.19 | 2.36 | 74.85 |
| **Mean** | 2046.66 | 2.30 | 5.43 | 92.27 | 15.13 | 1.68 | 73.93 |
| **Probability** | 92.39 | 0.10 | 0.31 | 0.37 | 0.36 | 0.58 | 1.70 |
| **CV %** | 4.51 | 4.35 | 5.71 | 0.40 | 2.38 | 34.60 | 2.30 |
| **SEm** | 30.80 | 0.03 | 0.10 | 0.12 | 0.12 | 0.19 | 0.57 |

**Table 8**. Interaction effects on ash, calcium and phosphorus content of blood and tibia bone of broilers fed diets supplemented with different levels of soybean oil and sources of bone meal

| Treatments | Blood content | | | Tibia bone content | | |
|---|---|---|---|---|---|---|
| | Ash% | Calcium% | Ash% | Calcium% | Ash% | Calcium% |
| **$T_1$ = diet without soybean oil + GBM** | 5.73 | 20.84 | 5.73 | 20.84 | 5.73 | 20.84 |
| **$T_2$ = diet with 2% soybean oil + GBM** | 5.87 | 20.95 | 5.87 | 20.95 | 5.87 | 20.95 |
| **$T_3$ = diet with 4% soybean oil + GBM** | 5.87 | 21.26 | 5.87 | 21.26 | 5.87 | 21.26 |
| **$T_4$ = diet without soybean oil + PBM** | 5.66 | 18.79 | 5.66 | 18.79 | 5.66 | 18.79 |
| **$T_5$ = diet with 2% soybean oil + PBM** | 5.71 | 18.71 | 5.71 | 18.71 | 5.71 | 18.71 |
| **$T_6$ = diet with 4% soybean oil + PBM** | 5.73 | 18.89 | 5.73 | 18.89 | 5.73 | 18.89 |
| **$T_7$ = diet without soybean oil + IBM** | 5.84 | 19.44 | 5.84 | 19.44 | 5.84 | 19.44 |
| **$T_8$ = diet with 2% soybean oil + IBM** | 5.73 | 19.58 | 5.73 | 19.58 | 5.73 | 19.58 |
| **$T_9$ = diet with 4% soybean oil + IBM** | 5.71 | 19.39 | 5.71 | 19.39 | 5.71 | 19.39 |
| **Mean** | 5.76 | 19.76 | 5.76 | 19.76 | 5.76 | 19.76 |
| **Probability** | - | - | - | - | - | - |
| **CV %** | 1.34 | 5.03 | 1.34 | 5.03 | 1.34 | 5.03 |
| **SEm** | 0.03 | 0.33 | 0.03 | 0.33 | 0.03 | 0.33 |

**Note:** GBM=G bone meal source, PBM=P bone meal source, IBM=I bone meal source

*3.7 Calcium, phosphorus and ash deposition in tibia bone and blood*

Table 8 shows the contents of ash, calcium and phosphorus in the blood and tibia bone of experimental broilers.

Ash contents of blood were uppermost (5.87%) in $T_2$ and $T_3$ and lowermost (5.66%) in $T_4$. The highest and lowest blood calcium percentages were recorded in $T_3$ (21.26%) and $T_5$ (18.71%), respectively, whereas percentages of blood phosphorus maximized (12.57%) in $T_3$ and minimized (10.48%) in $T_4$. Likewise, tibia bone ash was highest (8.13%) in $T_2$ and lowest (7.91%) in $T_5$. The percentage of tibia bone calcium showed a similar trend to that of tibia bone ash. $T_3$ and $T_8$ contained maximum (14.67%) and minimum (12.83%) tibia bone phosphorus, respectively.

According to the results, the calcium and phosphorus contents of blood and tibia bone elevated with addition of GBM-containing soybean oil to the basal diet, which could influence bone calcification and mineralization. Matterson *et al*. (1945) also presented evidence that the interaction effect of soybean oil and bone meal affected concentrations of ash calcium and phosphorus. Sufficient amounts of calcium and phosphorus are recommended to be necessary during the rearing period owing to the constant and fast bone growth rate.

The present study estimated the bioavailability of calcium from a variety of calcium and phosphorus sources to the broilers. It can be concluded that significant differences in broilers' availability to feed grade calcium and phosphorus indicates a positive correlation between both calcium and phosphorus availability in feed grade supplements [13]. The particle size of supplements, however, is a determining factor in calcium utilization of bone meal, oyster shell and limestone by broilers [14].

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