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Augmentation of Soybean Oil Cake as a Replacement for Vegetable Oil in Broiler Diets

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ABSTRACT

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A research investigation was carried out to assess the effects of incorporating soybean oil cake as a substitute for vegetable oils in the diets of commercial broiler chickens. This experimental investigation involved 250 commercial chicks housed in a deep litter environment under standard management conditions for a period of 0 to 35 days. Six different dietary treatment groups were established: T1, the basal diet (BD) with 100% vegetable oil (rice bran oil, RBO); T2, T3, T4, and T5, where RBO was gradually substituted with 25%, 50%, 75%, and 100% soybean oil cake (SOC), respectively. By the end of the fifth week, results indicated that T3 and T4 exhibited significantly ($P<0.05$) higher weight gains (1890.90g and 1845.34g) compared to T1, T2, and T5. Regarding carcass quality, the 75% SOC supplementation (T4) had a significant ($P<0.05$) effect on eviscerated and ready-to-cook weights compared to other treatment groups. Sero-biochemical analysis revealed significant ($P<0.05$) variations in serum protein, albumin, and albumin: globulin ratios among the treatment groups, with the highest levels observed in the T4 group. Histomorphology examination of the jejunum showed a significant ($P<0.01$) difference in both intestinal villi height and villi height: crypt depth ratio among the treatment groups, with T5 demonstrating the highest intestinal villi height (1334.55 µm). However, crypt depth did not vary significantly among the treatment groups. The study clearly indicates that soybean oil cake can effectively replace vegetable oils in broiler diets. It is recommended that agro-industrial byproducts like soybean oil cake be included in broiler diets up to 75% as a replacement for vegetable oil to enhance production and gut health for sustainable production.

Keywords: Soya oil cake, non-conventional feed, histomorphology.

INTRODUCTION

The increasing socioeconomic status of people worldwide, coupled with a rising population, has led to a substantial demand for high-quality food necessary for a healthy life (Mottet and Tempio, 2017). This surge particularly emphasizes the need for protein-rich foods. Animal by-products such as meat, milk, and eggs are rich sources of high-quality protein and other essential nutrients. Over the past five decades, poultry meat has exhibited the highest absolute and relatively faster growth rate among all species of meat producers worldwide (Windhorst, 2017). Projections suggest that poultry meat will remain the leading contributor to growth in total meat production, attributed to its affordability relative to red meats, convenience, potential health advantages, and widespread cultural acceptance (Baldi, Soglia, and Petracci, 2020a). Therefore, the poultry sector is crucial for ensuring food security for the expanding global population, offering both considerable opportunities and challenges (Mottet and Tempio, 2017). In poultry production, feed costs constitute at least 70% of total expenses, making them a critical focus for cost management (Dinani *et al.*, 2020). The cost of feed is crucial, with metabolizable energy being one of the most expensive components, followed by protein and phosphorus. Consequently, the composition of poultry feed has been adjusted to cope with higher prices. Typically, broiler chickens are fed with ad libitum to meet their energy needs and achieve target weights rapidly, but timed feeding has recently been recommended for economic reasons.

The rising prices and limited availability of animal-based feed sources have prompted a necessary shift towards plant-based alternatives to manage costs while meeting nutritional needs (Alagawany *et al.*, 2015). For intensive poultry farming, feed is the most critical input, and the availability of low-cost, high-quality feed is essential for the industry's growth. To ensure maximum performance and good health, poultry require a consistent supply of energy, protein, essential amino acids, minerals, vitamins, and water. Practical poultry diets are formulated from a mix of ingredients, including cereal grains, cereal by-products, fats, plant protein sources, vitamin and mineral supplements, crystalline amino acids, and feed additives. The increasing costs and decreasing supplies of traditional feedstuffs, partly due to food-feed competition and population growth, are anticipated to impact the future expansion of poultry production. Public apprehensions regarding the strain on finite natural resources, biodiversity depletion, antimicrobial resistance propagation, and the environmental impact of livestock farming have strengthened the ideologies of 'sustainable intensification' and 'achieving higher productivity with reduced inputs' as approaches for nourishing forthcoming

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generations (Tixier-Boichard, 2020). This scenario highlights the pressing necessity to embrace a wider array of alternative feeds, including insect meals, food waste, and agro-industrial byproducts, while also minimizing the utilization of human-edible components in poultry diets. The utilization of most alternative feedstuffs remains limited due to nutritional, technical, and socio-economic constraints. Additionally, many feed resources are either underutilized or wasted. Addressing these challenges and enhancing the efficiency of feed resource utilization is imperative for the sustainable growth of the poultry industry.

The growing demand for animal protein calls for sustainable alternative feed resources and poultry breeds that can convert non-conventional feed resources into usable protein for human consumption. Incorporating unconventional feed ingredients is a viable strategy to attain food and nutritional security (Mnisi *et al.*, 2023). Energy-rich fats or oils are available from cereal sources such as rice bran oil, palm oil, and sunflower oil. Incorporating traditional feed components like maize, soybean meal, and fish meal into poultry feed has significantly increased costs. With the current shortage and rising costs of conventional feed ingredients, scientists advocate using agro-industrial by-products as unconventional feedstuff. These by-products are cheaper and available in large quantities in agro-based economies, benefiting poultry farmers. For instance, cassava pulp, a by-product of the tapioca industry, is abundant in most tropical countries. Because of its exceptionally high energy content at 2484 kcal/kg, this by-product has been effectively employed as a partial substitute for maize in poultry diets (Khempaka *et al.*, 2009). Similarly, copra meal, a residue from oil extraction from the coconut endosperm, contains 4247-5872 kcal/kg gross energy and high levels of protein (15-25%) and carbohydrates (60%), making it a potential poultry feed ingredient (Arun *et al.*, 2020).

With this background, the present experiment was planned to execute using soya oil cake (Fig. 1) an agro-industrial by-product from soya oil refineries, into broiler diets. Soya oil cake is an unconventional feedstuff, which is the agro-industrial byproduct produced by the hydrogenation of soya oil along with a catalyst, cheaper than the other traditional energy sources comparatively to oil. Soya oil cake has a semi-solid consistency, a long shelf life, high gross energy level (9405 kcal/kg), less than 0.5% moisture, and less than 2% free fatty acid (as oleic acid) compared to other vegetable oils. Having high gross energy level with lesser free fatty acid level, the present study was planned to execute its potential on broiler diets, whose energy requirements are higher. This study aims to determine the efficacy of using soya oil cake as a feed ingredient in broiler production.

MATERIALS AND METHODS

Experimental birds and diets

The biological experiment was conducted in broiler house at the Department of Poultry Science, Veterinary College and Research Institute, Namakkal, Tamil Nadu. The experiment was carried out with two hundred- and fifty-day-old, commercial broiler (Ven Cobb-400) chicks belonging to single hatch. The chicks were wing banded, weighed, and randomly allotted into five treatment groups with five replicates of 10 chicks in each replicate with each replicate having an equal number of male and female chicks. The birds were reared under intensive deep litter system for a duration of 0-35days with standard conditions. Ad libitum feed and water were provided for the birds during the study. The whole experimental period was divided into three phases *viz.* pre-starter (1 to 12 days), starter (13 to 24 days) and finisher (25 to 35 days). The elaborated details of the treatment group are described in Table 1.

Fig. 1: Represents the image of Soya Oil Cake

Table 1: Experimental group

Treatment	Description
T1	Basal diet+100% supplemented with Rice bran oil
T2	Basal diet+25% Rice bran oil replaced with soya oil cake
T3	Basal diet+50% Rice bran oil replaced with soya oil cake
T4	Basal diet+75% Rice bran oil replaced with soya oil cake
T5	Basal diet+100% supplemented with soya oil cake

To compare the effects of rice bran oil and soya oil cake, soya oil cake was incorporated into the feed by formulating isonitrogenous and isocaloric broiler diets. The basal broiler feed was formulated according to the Ven Cobb 400 standard, and the experimental diets were prepared by adding feed additives as per the experimental design. The ingredients and nutrient composition of the experimental diet, presented in Table 2.

Table 2: Ingredients and nutrient composition (%) of experimental broiler pre starter, starter, and finisher ration (on as such basis) of control diet

Sl.No.	Ingredients	Pre starter	Starter	Finisher
1.	Maize	52.59	56.04	61.51
2.	Soya	40.27	35.2	29.59
3.	Rice bran oil (RBO)	3.03	4.5	4.91
4.	Soya oil cake (SOC)	0	0	0
5.	Calcite	1.45	1.63	1.56
6.	Di Calcium phosphate	1.2	0.9	0.92
7.	Sodium chloride	0.37	0.33	0.29
8.	Lysine	0.2	0.18	0.18
9.	Methionine	0.3	0.27	0.25
10.	Threonine	0.02	0.04	0.04
11.	Phytase	0.01	0.01	0.02
12.	Vitamin premix	0.05	0.05	0.04
13.	Trace mineral mixture	0.15	0.15	0.15
14.	Choline chloride	0.1	0.1	0.1
15.	Toxin binder	0.05	0.05	0.05
16.	Liver tonic	0.1	0.08	0.1
17.	Coccidiostat	0.05	0.05	0.05
18.	Antioxidant	0.02	0.02	0.02
19.	Emulsifier	0.05	0.05	0.05
	Total	100	100.0	100.0
Nutrient composition* (on dry matter basis)				
1.	Crude Protein (%)	23	21	20
2.	ME Kcal/ kg	3000	3100	3250
3.	Crude Fibre (%)	3.5	3.5	3.01
4.	Lysine (%)	1.25	1.1	1
5.	Methionine (%)	0.6	0.55	0.5
6.	Calcium (%)	1.0	1.0	1.0
7.	Total Phosphorus	0.6	0.6	0.6

*Calculated values

[1]One gram of Vitamin AB_2D_3K supplement contained 82500 IU of Vitamin-A, 50 mg of Vitamin-B_2, 12000 IU of Vitamin-D_3 and 10 mg of Vitamin-K.

[2]One gram of B-complex supplement contained 8 mg of Vitamin-B_1, 16 mg of Vitamin-B_6, 80 mcg of Vitamin-B_{12}, 80 mg of Vitamin-E, 120 mg of Niacin, 8 mg of Folic acid, 80 mg of Calcium -D-pantothenate and 86 mg of Calcium.

[3]One gram of Trace mineral mixture contained 54 mg of Manganese, 52 mg of Zinc, 20 mg of Iron, 2 mg of Iodine and 1 mg of Cobalt.

Proximate analysis

The proximate analysis was conducted (Table 3) to determine its nutritional composition of soya oil cake, including moisture, crude protein, crude fat, crude fibre, and ash content. Moisture content was measured using the oven-drying method at 105°C for 24 hours. Crude protein was analysed using the Kjeldahl method, and crude fat was determined via Soxhlet extraction. Crude fibre content was assessed through sequential acid and alkali digestion, and ash content was measured by incinerating the sample in a muffle furnace at 550°C for 5 hours. These analytical procedures followed the standard methods outlined by the Association of Official Analytical Chemists (AOAC, 2000). The gross energy of the soya oil cake was determined using a bomb calorimeter following AOAC (2000) guidelines, while free fatty acid content was analysed via solvent extraction and titration with standard sodium hydroxide solution, ensuring accurate assessment of nutritional quality.

Table 3: Proximate Analysis of Soya oil Cake

Sl.No	Proximate Principle	Value
1	Moisture	1.16 %
2	Crude Protein	BDL of 1%
3	Crude Fiber	BDL of 1%
4	Ether Extract	99.00 %
5	Total Ash	0.22 %
6	Acid insoluble Ash (Sand & Silica)	BDL of 1%
7	Calcium	0.20 %
8	Phosphorus	BDL of 1%
9	Salt	BDL of 1%
10	Gross Energy	9404 Kcal/kg
11	Free Fatty Acid	1.96 %

Production Parameters

Body weight gain and Feed conversion ratio: Weekly weight gain (g) and FCR were calculated using standard formulas for the treatment groups in the present study. Mortality was recorded at occurrence.

Carcass characteristics

At the conclusion of the 35-day experiment, two birds (one male and one female) from each replicate, totalling ten birds per treatment group, were randomly selected. These birds were fasted for approximately 12 hours to clear the digestive tract, during which they were provided with ad-libitum access to drinking water ensured that the birds remained hydrated and minimized stress. Subsequently, the birds were humanely slaughtered. Different carcass quality traits as influenced by the different dietary regimen were judged in these slaughtered birds.

Intestinal histomorphology

During the slaughter process, jejunal intestinal samples were collected in 10% buffered formalin for histological examination. The jejunum was identified by locating Meckel's diverticulum, and samples were taken 1.5 to 2 cm anterior to it. The tissues were then dehydrated using a graded series of ethanol concentrations and embedded in paraffin wax. Serial sections of 5 µm thickness were cut from the jejunum samples using a microtome. Four cross-sections of the jejunum per bird were stained with Mayer's Haematoxylin and Eosin (H&E) from Hi-Media Manufacturers Ltd. Morphometric analyses were observed under light microscopy. The histological sections were examined at a low magnification (10x), and parameters such as villus height, crypt depth and villus height-to-crypt depth ratio were measured using ImageJ 1.50i software. For each cross-section, measurements were taken from ten villi and ten crypts per bird. Crypt depth was determined by measuring the distance between the basolateral membrane and the base of individual villi (Baurhoo *et al.*, 2007).

Assessment of serum biochemical profile

On 35th day of experiment, blood samples were collected from the treatment groups to extract their serum. The blood was collected with red capped serum vials, further centrifuged at 3000 rpm for 10 minutes to obtain serum which was transferred into sterilized plastic eppendroff vials, and then stored at -20°C for further use. In this present serum profile and lipid profiles were done in detail using commercial kits available from Coral Clinical Systems (Tulip Diagnostics Pvt. Ltd., Goa), readings were measured using spectrophotometer. The study employed various methods to determine serum biomarkers. Total protein estimation was performed using the Biuret method (Mann, 1906), while the Bromocresol Green method was employed for albumin assessment (Doumas *et al.*, 1971). Globulin estimation was derived using the formula: Globulin (g/dl)= Total Proteins (g/dl) – Albumin (g/dl), whereas the Albumin/Globulin Ratio (A/G Ratio) was calculated as Albumin (g/dl) divided by Globulin (g/dl). For the evaluation of plasma lipid profile, the enzymatic CHOD-PAP method was utilized for cholesterol determination, as per the methodology outlined by Allain *et al.* (1974); GPO/PAP method for triglycerides (Luley *et al.*, 2000). HDL cholesterol was estimated via polyethylene glycol precipitation following Seigler and Wu (1981), and LDL cholesterol was calculated using the Friedewald equation (Friedewald *et al.*, 1972).

Statistical analyses

The data collected on various parameters were subjected to statistical analysis as per the methods suggested by Snedecor and Cochran (1989). The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 20.0 software. Data from the conducted experiments were rigorously analysed using a one-way ANOVA framework, expressed as follows: $X_{ij} = \mu_i + \varepsilon_{ij}$, where X_{ij} represents the observed value for the dependent variable for the jth observation in the ith group, μ_i denotes the mean value for the ith group, and åij represents the random error associated with the jth observation in the ith group. The group means (μ_i) were compared using Tukey's multiple range test at a significance level of $P \leq 0.05$ to determine if the differences between them were statistically significant.

RESULTS AND DISCUSSION

Proximate Analysis

The proximate composition of the soya oil cake, an agro-industrial byproduct is presented in Table 3. The results indicate that the product possesses a high level of gross energy, along with reduced free fatty acid content and lower moisture levels. These attributes confirm that a diet incorporating soybean oil cake can be effectively safeguarded against rancidity and fungal growth during storage. The high energy content enhances the nutritional value, while the lower free fatty acid and moisture levels minimize the risk of spoilage, ensuring the diet's stability and safety over time.

Production parameters

Dietary energy constitutes the most significant expense in poultry production. Further investigation is needed to understand how modern broiler strains utilize this energy. Identifying the optimal protein-to-energy ratio in their diet is essential for maximizing broiler performance. From results (Fig. 2) it is noted that, at first week of age, group T4 had recorded significantly ($P<0.05$) higher mean body weight gain (105.58g) compared to T1 (98.16g) group whereas T2, T3 and T5 groups did not differ significantly. Similarly, at consecutive weeks of age (2nd, 3rd and 4th week), T3 and T4 exhibited better and higher weight gain when compared with other treatment groups in this study. At fifth week of age, T3 and T4 groups showed significantly ($P<0.05$) higher body weight gain of about 1890.90g and 1845.34g respectively, compared to T1, T2 and T5 groups. Broilers exhibit varying nutritional needs for energy and proteins at different growth stages. During the early stages, they require high protein levels to support the development of muscles, feathers, and other organs. As they mature, their demand for energy to accumulate fat rises, while their protein requirements diminish (Ayed *et al.*, 2015). Shehu *et al.* (2021) reported that birds fed with soybean cake achieved the highest final weight (959.81 g) and weight gain (909.12 g) at four weeks of age. This finding aligns with Ghadge *et al.* (2009), who observed optimal performance in chickens with soybean cake inclusion at 75% and 100%. Conversely, it contradicts the results of Ojileh (2017), who found that birds fed with soybean cake exhibited lower final weight and weight gain compared to other diets when soybean cake constituted 24% of the feed. These discrepancies in final weight and weight gain may be attributed to variations in diet ingredient composition, inclusion levels, and the presence of antinutrients, all of which can significantly influence the birds' performance.

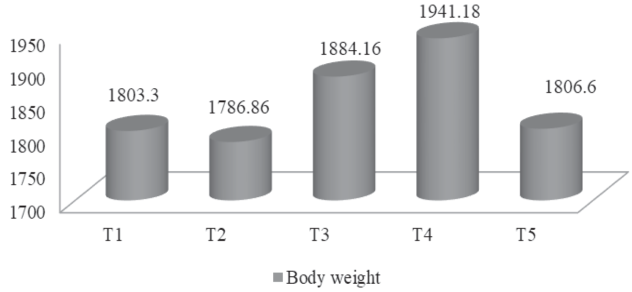

Fig. 2: Mean body weight (g) of broilers fed with different levels of soya oil cake

Feed Conversion Ratio

During the experimental period, the feed conversion ratio (FCR) of the treatment groups exhibited fluctuations (Fig 3). In the first week, group T4 achieved a superior FCR of 0.97. By the second week, groups T3 and T4 recorded significantly (P<0.05) better FCRs of 1.16 and 1.17, respectively. In the third week, group T3 significantly (P<0.05) outperformed the others with an FCR of 1.32, while in the fourth week, group T4 achieved a significantly (P<0.05) better FCR of 1.44. Finally, at the fifth week, group T3 had a significantly (P<0.05) better FCR of 1.58 compared to the other groups. These findings align with the earlier research of Wangsuthavas *et al.* (2007) and Fascina *et al.* (2009), who also reported, improved FCR in broilers fed with soybean oil due to enhanced body weight gain and reduced feed consumption. However, Zakaria *et al.* (2013) and Laszlo *et al.* (2015) found no significant difference in the FCR of broilers fed soybean oil, possibly because it was due to combination of oils in their diet. Newman *et al.* (2002) observed that the inclusion of polyunsaturated fatty acids (n-3 and n-6 sources) in the diet improved the FCR of broilers, particularly after three weeks of age. Ayed *et al.* (2015) noted that the type of oil in the diet significantly influences feed intake, with palm oil containing higher levels of long-chain saturated fatty acids like palmitic (16:0), palmitoleic (16:1), and oleic (18:1) acids, while soybean oil is rich in linoleic (18:2) and linolenic (18:3) acids. The higher levels of unsaturated fatty acids in soybean oil reduce feed intake due to its higher energy yield. Saturated fatty acids in palm oil have lower digestibility compared to the unsaturated fatty acids in soybean oil. The present study's results are consistent with those of Ferreira *et al.* (2015) and Orduña-Hernández *et al.* (2016), who found that increased dietary energy concentration improves broilers' FCR.

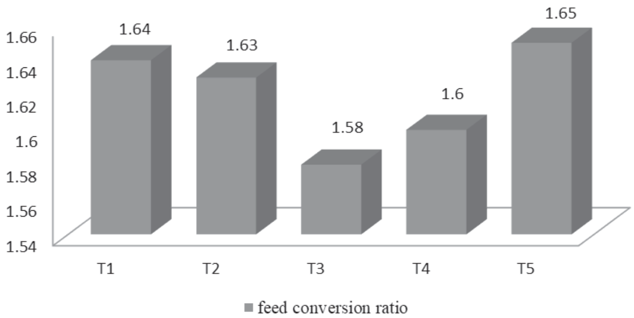

Fig. 3: Mean feed conversion ratio of broilers fed with different levels of soya oil cake

Carcass characteristics

The results of impact of supplementation of soya oil cake on broiler diets pertaining to carcass traits were mentioned in the Table 4. The analysis of variance of data showed significant (P<0.05) influence on eviscerated weight, ready to cook weight and heart weight whereas there was no significant difference in liver, gizzard, giblet and abdominal fat yields. Highest eviscerated weight was recorded in T_4 (74.60%) group whereas the least weight was recorded in T_1 (70.28%) group. With respect to ready to cook weight, T_4 (79.37%) group recorded significantly (P < 0.05) highest weight than T_1 (74.79%) group. Heart yield was significantly higher (P<0.05) in T_4 group (0.75%) than rest of the treatment groups. There was no significant difference in the giblet, liver, gizzard and abdominal fat yield among treatment groups. The results align with the findings of Nobakht *et al.* (2011) and Owoahene *et al.* (2016), who also observed no significant difference in the carcass characteristics of broilers fed with soybean oil. Conversely, Abdulla *et al.* (2016) found that feeding soybean oil to broiler chickens increased their abdominal fat levels, likely due to the higher energy content of the soybean oil. Periæ *et al.* (2022) reported significant differences in carcass quality; however, their findings do not concur with the results of the present study. Additionally, Kaki *et al.* (2020) observed no consistent pattern of variation across dietary groups when soybean residues were used as a replacement for groundnut cake.

Intestinal histomorphology

The jejunal intestinal villi height and villi height: crypt depth showed significant difference (P<0.01) among the treatment groups, but the crypt depth showed no significant difference among the treatment groups (Table-5). The group T_5 (1334.55µm) recorded significantly (P<0.05) highest intestinal villi height than other treatment groups. The intestinal crypt depth was recorded numerically higher in T_1 group (196.85 µm) and lower in T_3 group (189.10 µm). The group T_5 (7.02) recorded significantly (P<0.05) highest intestinal villi height: crypt depth ratio than other treatment groups. The results were

Table 4: Effect of feeding soya oil cake on carcass characteristics of broiler birds (% live weight)

Treatment groups	Eviscerated weight	Ready-to-cook yield	Giblets yield	Heart yield	Liver yield	Gizzard yield	Abdominal fat yield
T_1	70.28^c±0.96	74.79^c±0.89	4.51±0.22	0.74^{ab}±0.06	1.87±0.15	1.89±0.09	0.89±0.08
T_2	71.88^{bc}±0.63	76.53^{bc}±0.66	4.65±0.12	0.61^{bc}±0.03	1.98±0.06	2.05±0.11	0.78±0.07
T_3	73.16^{ab}±0.92	77.79^{ab}±0.97	4.63±0.15	0.59^c±0.03	1.96±0.09	2.08±0.09	0.81±0.05
T_4	74.60^a±0.91	79.37^a±0.88	4.77±0.18	0.75^a±0.04	1.91±0.05	2.12±0.13	0.79±0.05
T_5	71.22^{bc}±0.93	75.79^{bc}±1.03	4.57±0.18	0.62^{bc}±0.05	1.95±0.07	2.00±0.14	0.78±0.05
P Value	0.001	0.000	0.350	0.004	0.251	0.652	0.782

Each value is the mean of 10 observations^{a-c} Means within a column with no common superscript differ significantly (P<0.05)

Table 5: Effect of feeding soya oil cake on Intestinal histo-morphology

Treatment groups	Villi height (µm)	Crypt depth (µm)	Villi height: Crypt depth ratio
T_1	$1190.40^{bc}\pm30.09$	196.85 ± 2.86	$6.06^{b}\pm0.24$
T_2	$1123.75^{c}\pm47.75$	190.77 ± 2.13	$5.89^{b}\pm0.25$
T_3	$1154.75^{bc}\pm21.53$	189.10 ± 1.96	$6.11^{b}\pm0.16$
T_4	$1233.80^{b}\pm32.90$	192.20 ± 3.10	$6.42^{ab}\pm0.16$
T_5	$1334.55^{a}\pm28.59$	190.53 ± 3.21	$7.02^{a}\pm0.23$
P Value	0.000	0.021	0.001

Each value is the mean of 10 observations[a-c] Means within a column with no common superscript differ significantly (P<0.05)

in accordance with the earlier works of Abdulla *et al.* (2016) who also reported that feeding of soya oil to broiler diet had greater villi length. (Fig. 4)

Treatment group (T_2)

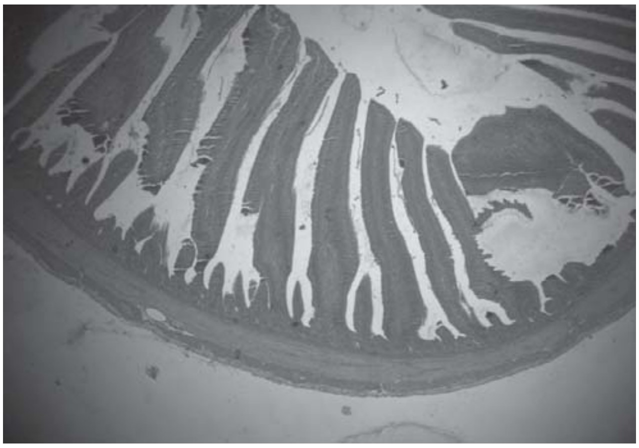

Fig. 4: Intestinal histo-morphology of broilers fed with different levels of soya oil cake at fifth week of age (H&E, x100)
Treatment group (T_5) fed with 100 per cent of soya oil cake
V– Intestinal Villi; **S–** Submucosa; **C–** Crypt of Lieberkuhn; **M–** Tunica musucularis

Serum biochemical profile

Serum protein profile: Results (Table 6) revealed significant differences (P<0.05) on serum protein profiles such as total protein, albumin and albumen to globulin ratio values whereas serum globulin did not show any significant difference between treatment groups at five weeks of age. The serum protein level was significantly (P<0.05) higher in T_4 group (6.40 g/dl) and lower in T_2 (6.02 g/dl) group. Similarly, the serum albumin was significantly higher in T_3 group (2.36 g/dl) and lower in T_2 group (1.80 g/dl). The serum albumin: globulin ratio was significantly (P<0.05) higher in T_3 group (0.61) and lower in T_2 group (0.44). Globulin was numerically higher in T_4 group (4.30 g/dl) and lower in T_3 group (3.87 g/dl). Serum proteins are primarily produced in the liver. Elevated serum albumin levels can be attributed to various factors, including breed, age, physiological condition, environmental influences, and exposure to antigens, all of which contribute to its significant variability (Marcelo, 2021). Additionally, serum albumin levels rise when protein consumption surpasses the needs for growth and maintenance (Kalita *et al.*, 2017). This could explain the notable increase in protein values observed in this experiment.

Serum lipid fraction: Results (Table 6) exhibits the serum lipid fraction values such as lipid profile, high density lipoprotein, low density lipoprotein and triglycerides (mg/dl). Values revealed no significant difference between treatments groups at five weeks of age in broilers. However, the group T_4 recorded numerically higher level of total cholesterol (149.98 mg/dl), low density lipoprotein (69.83 mg/dl) and triglyceride (143.36 mg / dl) and T_5 group recorded numerically higher level of high-density level lipoprotein (85.36 mg/dl). The results were in accordance with the earlier works of Fascina *et al.* (2009), Guerreiro *et al.* (2011) and Jalali *et al.* (2015) who also reported that addition of soya oil in broiler ration has no significant influence in total cholesterol, HDL and LDL level in broilers.

In contrast, Ozdogan and Aksit (2003), Navidshad *et al.* (2010) and Abdulla *et al.* (2016b) reported that addition of soya oil in broiler diet had significant influence in total cholesterol, HDL and LDL level in broilers. Navidshad *et al.* (2010) conducted an experiment in broilers fed with diet containing fish oil and soyabean oil

Table 6: Serum biochemical profile of broiler chickens fed different levels of dietary soya oil cake

Treatment groups	Total protein (g/dl)	Albumin (g/dl)	Globulin (g/dl)	A/G ratio	Total cholesterol (mg/dl)	High density lipoprotein (mg/dl)	Low density lipoprotein (mg/dl)	Triglycerides (mg/dl)	Total cholesterol mg/dl
T_1	$6.10^{ab}\pm0.11$	$2.08^{ab}\pm0.12$	4.02 ± 0.13	$0.52^{ab}\pm0.48$	135.95 ± 9.15	79.98 ± 3.85	55.97 ± 5.49	130.36 ± 10.55	135.95 ± 9.15
T_2	$6.02^{b}\pm0.08$	$1.80^{b}\pm0.19$	4.22 ± 0.25	$0.44^{b}\pm0.06$	140.74 ± 2.01	82.95 ± 2.55	57.79 ± 3.49	134.07 ± 11.67	140.74 ± 2.01
T_3	$6.23^{ab}\pm0.09$	$2.36^{a}\pm0.07$	3.87 ± 0.11	$0.61^{a}\pm0.03$	147.03 ± 5.00	84.91 ± 3.95	62.12 ± 2.61	141.99 ± 8.43	147.03 ± 5.00
T_4	$6.40^{a}\pm0.15$	$2.09^{ab}\pm0.04$	4.30 ± 0.16	$0.44^{ab}\pm0.02$	149.98 ± 4.29	80.13 ± 4.53	69.85 ± 4.59	143.36 ± 10.67	149.98 ± 4.29
T_5	$6.16^{ab}\pm0.14$	$2.08^{ab}\pm0.06$	4.07 ± 0.15	$0.52^{ab}\pm0.02$	142.76 ± 4.01	85.36 ± 3.74	56.40 ± 2.78	140.23 ± 5.72	142.76 ± 4.01
P Value	0.004	0.002	0.214	0.001	0.321	0.980	0.022	0.871	0.654

Each value is the mean of 10 observations
[a&b]Means within a column with no common superscript differ significantly (P<0.05)

at different levels (0, 3.5 and 7 per cent) and reported that triglycerides and cholesterol levels were positively correlated with each other.

CONCLUSION

The study clearly indicates that soybean oil cake can effectively replace vegetable oils in broiler diets. It is recommended that agro-industrial byproducts like soybean oil cake be included in broiler diets up to 75% as a replacement for vegetable oil to enhance production and gut health for sustainable production.

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