



Effect of Inclusion of Poultry Byproduct Meal and Roselle Seed Meal as Sources of Protein in Broiler Chicken Diets on Growth Performance Rates, Carcass Traits, Biochemical Blood Parameters, Tissue Antioxidants and Histopathology

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Abstract

THIS research was undertaken to identify the outcomes associated with the use of poultry byproduct meal (PBM) and roselle seed meal (RSM) in broiler chicks diets on performance parameters, carcass traits, blood indices, antioxidant enzyme activities and organs histopathology. Two hundred and seventy three (273) Cobb-500 broiler chicks, aged one day, were distributed randomly across seven dietary treatments with three replicates and provided with a corn-soybean meal based diet, including a control (no PBM or RSM), three PBM diets (5%, 10%, 15%), and three RSM diets (5%, 10%, 15%). On day 42, the results revealed that the inclusion of PBM and RSM up to 10% exerted no negative impact on growth performance, carcass characteristics or serum biochemistry. Higher inclusion level (15%) of either source significantly reduced body weight, body weight gain and feed efficiency. Although the groups fed 5% and 10% of PBM or RSM showed significant increases in both catalase and reduced glutathione levels compared to the control, 15% PBM and RSM groups showed no appreciable differences. Conversely, in reference to the control group, all PBM and RSM treated groups exhibited significant reductions in malondialdehyde concentration. Organs' histopathology remained normal across groups, yet 15% PBM and RSM were linked to changes in villus morphology. It is recommended to include poultry byproduct meal and roselle seed meal in broiler diets at levels up to 10% as alternative protein sources without compromising performance or health. Inclusion above this level should be avoided due to detrimental effects on growth and physiological parameters.

Keywords: PBM, RSM, Growth performance, Antioxidants, Broiler.

Introduction

Feed cost represents a significant challenge in poultry production, as it accounts for nearly two-thirds of the total production expenses [1]. Protein and amino acids requirements form a large portion of that cost [2]. It was highlighted that protein constitutes a fundamental part of broiler nutrition, playing a key role in numerous physiological functions, particularly those related to muscle growth and development [3]. Soybean meal (SBM) remains the predominant conventional protein source in global poultry and livestock production systems; however, its availability has become increasingly constrained due to limited supply and competition between human consumption and the livestock sector [4]. Hence, the poultry industry has prioritized

strategies aimed at reducing feed costs, particularly through the utilization of alternative feed resources which are non-competitive with human food [1].

Worldwide poultry meat output was 134 million tons in 2020, yielding approximately 40 million tons of by-products, therefore future projections suggest continued expansion of both figures in the coming decades [5]. Incorporating PBM in feed formulations helps alleviate waste-related environmental pollution and contributes to lowering greenhouse gas emissions [6]. As a significant poultry processing by-product, PBM is produced through dry rendering of inedible carcass fractions such as feathers, viscera, heads, feet, and blood [7]. It is recognized for its high nutritional value, containing essential amino acids, key minerals, and vitamin B₁₂ [8], with crude protein

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content usually ranging from 58.4% to 62% [9]. The used levels and the effects of PBM inclusion in diets are variable and subsequently the nutrient utilization of PBM in broilers is affected by this variation and diversity in feed ingredients [3]. Compared to SBM, PBM contains approximately 32% more arginine and over threefold higher glycine, and is economically advantageous, costing about one-third less [10].

Roselle (*Hibiscus sabdariffa* L.), also known as karkade, is cultivated primarily for its brightly colored calyxes which are widely used in the preparation of herbal beverages, jams, and condiments and after calyx harvesting, the seeds remain as a byproduct, often discarded or used in low-value applications despite their nutritional potential [11]. Roselle seeds are also recognized as a valuable source of antioxidants, including vitamin E [12]. Proximate analysis indicates that these seeds contain approximately 22% crude protein, 89% dry matter, 20% crude fiber, 21% lipids, and 6.4% ash [13]. Additionally, they are rich in anthocyanins which enhance their potential as a natural source of antioxidants [14]. RSM offers a sustainable, regionally sourced alternative that not only helps in reducing feed costs but also promotes the circular use of agricultural by-products [15]. However, alongside their nutritional benefits, roselle seeds also contain antinutritional factors (ANFs) such as tannins, saponins, cyanogenic compounds, oxalates, and phytates [16]. These compounds can interfere with feed utilization by reducing nutrient intake, digestion, absorption, and overall utilization, thereby negatively impacting animal health and productivity [17]. Fortunately, the detrimental effects of ANFs can be mitigated through appropriate processing techniques [13].

Therefore, the present trial sought to evaluate how the addition of PBM and RSM to broiler diets impacts key growth and performance indicators, carcass characteristics, serum biochemical indices, antioxidant enzyme activities and organs histopathology.

Material and Methods

Chemical analysis determination

PBM and RSM were analyzed for CP, CF, ash, EE and moisture percentages as presented in Table 1 according to [18].

Experimental birds and mangement

The experiment involved 273 Cobb-500 broiler, aged one day, which were procured from El Dakahlia Poultry Company and randomly allocated to seven groups, each comprising three replicates of 13 birds. Brooding conditions during the initial three days included a temperature range of 35-32°C and

continuous illumination for 24 hours daily. Afterward, the room temperature was reduced by 1-2°C at two-day intervals until stabilizing at 22-25°C by the onset of the third week. From the fourth to the sixth week, the birds were exposed to natural ambient temperature and ventilation, while continuous lighting was maintained during nighttime.

Diet preparation

Diets were designed in accordance with the nutritional specifications for Cobb-500 broilers, with details of ingredient composition, chemical characteristics, and nutrient profiles provided in Tables 2-5. The control group was fed a diet composed of corn and soybean meal across all feeding phases (starter, grower 1, grower 2 and finisher). The other groups received diets supplemented with either PBM or RSM at levels of 5%, 10% and 15%. Throughout the trial period, feed and water were consistently supplied to the birds without limitation.

Growth performance

Upon the initiation of the trial, each chick's weight was measured individually to record initial body weight (IBW), with subsequent measurements at six weeks for final body weight (FBW) and body weight gain (BWG) determination. Feed conversion ratio (FCR) was estimated as the amount of feed intake (FI) in kilograms divided by the corresponding BWG in kilograms.

Samples collection

Upon the completion of the six-week experimental period, nine birds per treatment group (three from each replicate) were randomly chosen for blood sampling. Blood was drawn from the wing vein into plain tubes and left to clot at room temperature for 20 minutes before being refrigerated for four hours. Serum was separated by subsequential centrifugation of the samples at 3,000 rpm for 15 minutes, and was preserved at -20 °C until biochemical analysis. Following blood collection, the birds were slaughtered and one gram samples from the breast and leg muscles were excised, rinsed in ice-cold saline buffer (20 mM Tris-HCL, 0.14 M NaCl buffer, pH 7.4) and homogenized in ice-cold phosphate buffered saline (PBS, pH 7.4). The homogenates were centrifuged at 4 °C for 15 min at 3,000 rpm, and the supernatants were stored at -20 °C for subsequent antioxidant biomarker analysis.

Serum biochemical analysis

The biochemical parameters of serum samples were analyzed spectrophotometrically (5010 photometer, BM Co., Berlin, Germany) to determine alanine aminotransferase (ALT) and aspartate

aminotransferase (AST) activities. Total protein (TP), albumin (ALB) and glucose concentrations were measured using commercial kits from Stanbio Laboratory (Boerne, TX, USA), while globulin (GLB) was computed by deducting albumin from the total protein value. Urea (UA) and creatinine (CREAT) concentrations were determined using commercial kits from Spinreact (Sant Esteve d'en Bas, Spain). Similarly, serum lipid profile parameters, including cholesterol (CHOL), triglycerides (TG), high density lipoprotein (HDL) and low density lipoprotein (LDL), were analyzed using the same Spinreact kits.

Antioxidant markers in tissue homogenates

Malondialdehyde (MDA) concentration, reduced glutathione (GSH) content, and catalase (CAT) activity in muscle homogenates were quantified spectrophotometrically using an enzymatic colorimetric method with commercial kits (Bio-Diagnostic, Giza, Egypt), following the manufacturer's protocols.

Histopathological examination

Tissue samples from the jejunum, liver, spleen, and pancreas of slaughtered broilers were fixed in 10% neutral buffered formalin for histopathological evaluation. The samples were processed by paraffin embedding, sectioned at 5 μ m thickness, and stained with hematoxylin and eosin (H&E) following the protocol of Bancroft et al. [19].

Jejunal slides were examined under an Olympus BX41 microscope (Olympus, New York, NY) at 4 $\times$ magnification, and images were captured using a DVC 1300C color digital camera attached to the microscope. Morphometric parameters, including villus height (VH), villus width (VW), and crypt depth (CD), were measured according to Rašković et al. [20], and the VH/CD ratio was calculated. Measurements were performed on vertically oriented villi using ImageJ software (<http://imagej.en.softonic.com>).

The liver slides were examined using eyepiece magnification of (4 $\times$, 10 $\times$ and 40 $\times$) in the Olympus BX41 microscope (Olympus, New York, NY). Images were captured at magnification of (40 $\times$) by using a DVC 1300C color digital camera adjusted to the microscope. Hepatocytes area (μ m²) was calculated in images of magnification (40 $\times$) by measuring the maximum (L_{max}) and minimum (L_{min}) lengths (μ m) of each hepatocytes passing through the nucleus from each hepatic zone using an image analysis (image J = <http://imagej.en.softonic.com>). The hepatocytes area was calculated from 30 randomly selected hepatocytes in each slide according to Rodríguez et al. [21].

For the spleen, the length and breadth of splenic lymph follicles (μ m) were considered for biometric measurement which was performed using an image analysis (image J = <http://imagej.en.softonic.com>). Six sections from each group were evaluated biometrically following the method of Ayman et al. [22].

Statistical analysis

Data were subjected to one-way ANOVA to assess the role of PBM and RSM inclusion in broiler diets on performance indicators, hematological profiles, carcass characteristics, antioxidant enzyme activities and morphometric analysis of jejunum, liver and spleen. Statistical procedures were implemented through SPSS software (version 21; IBM Corporation, USA). Differences among treatment means were compared using Duncan's multiple range test, and statistical significance was established at $P < 0.05$ [23].

Results

Growth performance

Table 6 summarizes the growth performance of broilers offered diets with varying PBM and RSM inclusion levels. IBWs were statistically similar across treatments ($P > 0.05$), confirming uniformity at the start of the experiment. Analysis revealed absence of considerable differences ($P > 0.05$) in FBW, BWG, FI, or FCR among birds receiving 5% and 10% PBM or RSM compared to the control group. However, diets containing 15% PBM or RSM resulted in significantly lower ($P < 0.05$) FBW and BWG, and a higher FCR than the control. FI was numerically lower in 15% PBM or RSM groups than the control and other treatment groups.

Carcass traits and internal organs

Table 7 provides data on the influence of experimental diets on carcass yield and the relative weights of internal organs, standardized as percentages of live body weight. Statistical analysis showed no significant differences ($P > 0.05$) in the relative weights of the heart, spleen, intestine, or dressed carcass among the groups. However, broilers fed diets containing 10% RSM exhibited significantly higher ($P < 0.05$) liver and gizzard weights compared to the control. In addition, the relative pancreas weight was higher in birds fed different levels of RSM than in the control, with the differences being statistically significant. Although no significant differences ($P > 0.05$) were found in live weights of the groups received 5% and 10% PBM or RSM in relation to the control, birds offered diets containing 15% PBM or RSM exhibited significantly lower live weights relative to the remaining groups.

Biochemical blood parameters

Table 8 provides an overview of how varying PBM and RSM levels in the diets affected serum metabolite profiles. The findings indicated that there were no significant differences observed in total protein, albumin, globulin, glucose, ALT, AST, creatinine, urea, cholesterol, and HDL among all groups. However, 5% and 10% RSM groups showed tangible increase ($P < 0.05$) in albumin levels than the control. The broilers fed 15% RSM exhibited significantly higher urea level than those in control and some groups. Additionally, triglycerides concentrations were significantly lower in the 5% PBM, 10% PBM, and 15% RSM groups relative to the other groups. Likewise, LDL levels decreased significantly in birds fed 10% PBM, 15% PBM, and 15% RSM relative to the remaining groups.

Antioxidant enzyme activities

Table 9 displays the impact of varying PBM and RSM inclusion levels on antioxidant markers. In reference to the control, all treated groups demonstrated meaningful increases ($P < 0.05$) in CAT and GSH levels; however, the 15% PBM and RSM groups were statistically similar ($P > 0.05$). In contrast, all treatment groups exhibited a significant reduction in MDA levels, whereas the 15% PBM group showed a non-significant decrease.

Histopathological examination

Normal structures of the jejunal mucosa, submucosa, and muscular layers were observed under microscopic examination in both the control and experimental groups (Fig. 1).

Relative to the control, the 5% and 10% PBM or RSM groups showed non-significant decreases in jejunal VH, VW, and VH/CD, while significant reductions were observed in the 15% PBM and RSM groups. Conversely, non-significant elevations in jejunal CD were noted in the 5% and 10% PBM or RSM groups, while significant increases were detected in the 15% PBM and RSM groups relative to the control (Fig. 2).

Normal hepatic histology, characterized by intact hepatocytes, central veins, and sinusoids, was observed in all groups under microscopic examination. No significant differences were detected in hepatocyte areas (μm^2) between treated and control groups (Fig. 3).

Histopathological analysis of H&E stained spleen sections revealed normal parenchymal structure, including red pulp and scattered lymphoid follicles, in all groups. Lymphoid follicle dimensions (length and breadth) did not differ significantly among the groups (Fig. 4).

Histopathological observations of H&E stained pancreatic tissues demonstrated normal structural integrity, characterized by well-defined endocrine islets of Langerhans (i) and exocrine acini (a) in all groups (Fig. 5).

Discussion

According to the results obtained, it appears that inclusion of 5% and 10% PBM or 5% and 10% RSM had no significant difference in BW, BWG, FI and FCR, while 15% inclusion of PBM or RSM showed significant decrease in FBW and BWG and significantly poorer FCR. However, FI of 15% PBM and RSM groups decreased numerically compared to the other groups. Regarding our results on the effect of PBM on performance, they corroborate those of Saleh *et al.* [24] indicating no substantial disparities ($P > 0.05$) in BW, BWG, FI, and FCR of the groups fed 5% or 10% PBM compared to control groups. Nevertheless, they found that the inclusion of higher level (12.5%) induced a marked reduction ($P < 0.05$) in BW, BWG and FI, while FCR was not affected by the higher inclusion level. Similarly, Mahmoudnia *et al.* [25] reported no significant discrepancies in BWG, FI or FCR between the birds fed PBM at different levels (3%, 6% and 9%) and those fed the control, as both exhibited comparable performance throughout the experiment period. Moreover, our observations agree with those previously documented by Limeneh *et al.* [26]. Furthermore, Khosravinia *et al.* [27] evaluated PBM at inclusion levels of 2, 4, 6, and 8% as replacements for 25, 50, 75, and 100% of fish meal in broiler diets, and reported no significant differences in BW, FI, or FCR among the experimental groups and the control at the completion of the study period. In partial agreement with our findings, Hassanabadi *et al.* [28] illustrated that the inclusion of 3% and 6% of PBM in broiler feed up to 42 days of age did not exert a notable influence BW, BWG, FI, or FCR compared to the control group. However, 6% PBM group showed significantly higher FCR than the control. Conversely, PBM at levels of 9, 12, and 15% significantly reduced BW, BWG, FI and feed efficiency, but 9% PBM group had FI statistically similar to the control group. However, 15% PBM group showed the lowest BW, DWG and FI, with the poorest FCR, while the control group achieved the best efficiency. They suggested that incorporating PBM in broiler diets at levels up to 6% is safe and does not compromise growth performance. Likewise, Khosravinia *et al.* [27] provided further supporting evidence, reporting that supplementing broiler diets with up to 4% PBM during the first 21 days did not alter FI. Although they reported that higher inclusion levels showed a tendency to reduce intake, an 8% PBM level during the 21–42 day period had no significant impact on FI. Similarly, Nameghi *et al.*

[29] reported that 7% PBM did not adversely affect FI. Contrary to our results, Cordova-Noboa et al. [10] found that BWG and FCR were negatively influenced by PBM inclusion up to 5%. Moreover, Mahmood et al. [3] found that FI declined as PBM levels increased from 3% to 6%, especially in diets lacking protease supplementation. According to those researchers, a significant improvement in FI was only observed at the 3% PBM level when protease was included, while higher PBM levels without the enzyme did not enhance performance. Discrepancies in the results we obtained may be attributed to variations in the composition and quality of the components, fluctuations in nutrient content, and differences in processing conditions at slaughterhouses [30]. Consequently, the origin of raw materials and the specific processing methods employed play a crucial role in determining the chemical characteristics of PBM [31].

Regarding our results on the effect of RSM on performance, our outcomes mirror those previously described by Mahmoud et al. [32], who conducted a study on Japanese quail using two levels of RSM (5% and 10%) and reported no significant improvements in BW or feed efficiency, as indicated by the low values of FCR). However, BWG of the group fed 10% RSM was higher than the control and 5% RSM groups. Furthermore, Owosibo et al. [33] reported that RSM at levels of 6% and 12% as replacement of 25% and 50% full fat soya in broiler diets did not exert any detrimental effects on BW, BWG and FI, while feed utilization efficiency was improved compared to the control. However, incorporating RSM at higher level (18%) as a replacement of 75% full fat soya significantly reduced BW, BWG and FI and negatively affected FCR. In a similar manner, the present observations concur with those documented by Angbulu et al. [34]. The authors suggested that their results were a consequence of anti-nutritional factors or low protein quality, limiting nutrient availability even with fermentation/processing, the breeds of the birds and variety of roselle seed used. In partial agreement with our findings, Mukhtar [35] observed a dose-dependent decline in growth performance when broilers were fed increasing levels of RSM (7.5, 15, and 22.5%). All RSM groups showed lower BW and BWG than the control, with the greatest reductions at 15% and 22.5%. Similarly, FI and FCR were significantly impaired at these higher levels, whereas the 7.5% RSM group maintained similarity with the control. In contrast to our findings, Naiya and Zamani [36] evaluated RSM at inclusion levels of 10, 15, and 20% in broiler diets and reported that birds fed 15% RSM achieved significant enhancements in BW, BWG, and FI ($P < 0.05$) than other groups, whereas FCR remained statistically unchanged.

These observations correspond with those described by other researchers [4,37]. Additionally, Olivia [38] who evaluated graded levels (8, 16, 24, and 32%) of roselle seed cake (RSC) as a replacement for soyabean cake (SBC) in broiler diets, reported that birds fed 24% RSC achieved superior final BW, total BWG, and average daily gain than the control group. On the contrary, both control and 8% RSC groups demonstrated significantly reduced ($P < 0.05$) total and daily FI. Moreover, this author concluded that RSC could be used at levels 16% and 24% in broiler diets to replace 50% and 75% of SBC to improve performance, whereas 32% RSC impaired feed utilization.

The status of the gastrointestinal mucosa and its microscopic structure serve as reliable indicators of the response of the intestinal tract to dietary components. An increase in villus height (VH) is typically associated with enhanced digestive and absorptive functions, elevated expression of brush border enzymes, and improved growth performance in birds [39]. Since the increase in villus height are linked to superior absorptive capacity, diets containing 5% and 10% PBM or RSM offer a comparative advantage over those with 15% inclusion levels in maintain growth performance and promoting gut health. The intestinal crypt functions as a production site of stem cells responsible for villus renewal, and greater crypt depth reflects accelerated tissue turnover [39]. Consequently, the presence of shallow crypts in birds fed 15% PBM or RSM diets suggests reduced regenerative activity, which may explain their lower performance compared to other groups. The villus height-to-crypt depth (VH:CD) ratio is widely recognized as a valuable parameter for assessing the digestive capacity of the small intestine. A higher VH:CD ratio indicates a well-differentiated mucosa with superior digestive and absorptive efficiency [40]. In this context, the reduced VH:CD ratio observed in birds receiving 15% PBM or RSM diets likely contributed to their suboptimal growth performance. Overall, the inclusion of 15% PBM or RSM significantly decreased VH, VW, and VH:CD ratio. Conversely, diets supplemented with 5% and 10% PBM or RSM maintained VH:CD ratios comparable to the control group, resulting in growth performance that was statistically similar to the control.

Our results showed statistical equivalence ($P > 0.05$) in the relative weights of dressed carcass and most organs among the treatments or compared to the control. Nevertheless, birds receiving 10% RSM had higher liver and gizzard percentages than the control and certain groups. Furthermore, the relative pancreas weight remained statistically similar across PBM groups and the control; however, RSM groups exhibited significantly greater values

than the control and the 15% PBM group. The findings presented in this work are supported by the conclusions of Saleh *et al.* [24] who found that carcass weight did not differ significantly among broilers fed 5, 7.5, 10, or 12.5% PBM or when compared to the control. Similarly, liver weight showed no significant increase in any treatment group, while heart, gizzard, and spleen weights also remained unaffected. The observed, though non-significant, increase in liver weight among PBM-fed groups could be attributed to greater protein synthesis and nutrient metabolism, as the liver plays a pivotal role in these processes and may undergo hypertrophy as a result [6]. Moreover, Hassanabadi *et al.* [28] reported that during the 42-49 day period, dressed carcass, intestine or gizzard ratios to live weight were statistically similar ($P>0.05$) among broilers fed 3%, 6%, 9%, 12%, or 15% PBM and the control group. However, Seyedi [41] who used 6 treatments of PBM (0, 2, 4, 6, 8 and 10%) in broiler diets found that broilers in the 8% PBM group recorded the greatest relative empty body weight.

The impact of RSM on carcass characteristics in this study agrees with Mahmoud *et al.* [32], who found that including 5% and 10% RSM in quail diets did not influence carcass traits or internal organ weights, as no significant differences were observed in dressed carcass or liver weight. Similarly, Egbewande *et al.* [42] found that replacing groundnut cake with differently processed RSM at 50% inclusion (13.35% dietary RSM) did not result in significant ($P>0.05$) differences in the relative weights of liver, gizzard, heart, spleen, pancreas or intestine. Also, these results agree with previous studies [35,43,44]. Furthermore, Owosibo *et al.* [33] reported that although replacing full-fat soybean with RSM at inclusion levels of 25, 50, and 75% (6, 12, and 18% dietary RSM) had no significant effect on liver, gizzard, heart, dressed carcass% or live weight, a substantial reduction ($P<0.05$) in live weight was evident in the 75% RSM group versus the control. In partial agreement to our findings, Ashom *et al.* [45] found that inclusion of 50% differently processed RSM (16.54% dietary RSM) as a replacement for full-fat soybean in broiler diets did not significantly affect heart, spleen, intestine or dressed carcass%, all of which remained within normal ranges. However, live weights decreased significantly in all treated groups, except for those fed sprouted RSM, which showed no significant difference from the control. In addition, gizzard and pancreas weights differed significantly ($P<0.05$) among treatments. Those authors reported that increasing the pancreas weight occurs due to the negative effect of ANFs which inactivate the enzymes and cause stress on pancreas in an attempt to compensate by producing more enzymes. Moreover, Olivia [38] postulated that heart,

spleen, gizzard and live weights reflected consistency among the experimental groups and when compared to the control (8%, 16%, 24% and 32%). However, birds fed 8% RSC had a statistically notable rise in gizzard weight, while those on 24% RSC displayed significantly higher live weights compared to other groups. Liver weight remained unchanged in the 8%, 16%, and 32% RSC groups but underwent a significant decrease in the 24% RSC group relative to the control. The relative dressed carcass weight was significantly higher in the 8%, 16%, and 32% RSC groups, while a significant reduction was noted in the 24% group relative to the control.

Biochemical blood indices are natural detectors to physiological processes abnormalities and pathology of organs in livestock animals [46]. Consistent with our findings, Saleh *et al.* [24] reported no changes in serum total protein, globulin, or glucose across groups administered different levels of PBM (5, 7.5, 10 and 12.5%) relative to the control, but serum albumin concentrations declined significantly likely because of blood dilution by PBM. PBM's diverse amino acid content and digestibility may affect broiler protein anabolism and metabolism and certain protein fractions in the byproduct waste may cause a clear reduction in total protein and albumin concentrations [47]. Also, there was no significant decrease in blood ALT and AST levels across PBM groups relative to the control. Incorporating liver and other organ tissues derived from byproduct waste into diets helps preserve liver health by supplying essential nutrients that act as co-factors and contain constituents with hepatoprotective properties, thereby reducing liver enzyme levels while providing high-quality proteins, vitamins, and minerals that further support and enhance liver function [26]. In addition, blood uric acids and creatinine levels in all PBM groups, which the kidney eliminates as purine waste byproducts, were not significantly different from the control. PBM is an important protein source that is rich in meat and blood which could decrease uric acid levels by using the protein of this waste byproduct for feeding different animals [48]. The improved kidney function is an evidence proving the reduction of serum uric acid as well as the minerals and bioactive compounds present in byproduct waste play a role in mitigating oxidative stress and kidney inflammation [49]. PBM serves as a dietary inclusion providing proteins, minerals, and essential nutrients to enhance nutrition and support renal health [50]. Moreover, PBM groups exhibited non-significantly different cholesterol and triglycerides levels than the control. Cartoni Mancinelli *et al.* [51] proposed that the diminished cholesterol levels are due to the particular fatty acid composition of PBM, namely its polyunsaturated fatty acid and monounsaturated fatty

acid content. However, Siddiqui et al. [52] attributed the reduced cholesterol levels to the prevention of cholesterol absorption by non-digestible fiber in PBM. Furthermore, Saleh et al. [53] suggested that the reduction in triglyceride levels could be linked to variations in the lipid profile of PBM, especially its omega-3 fatty acid content. Similarly, the high-quality protein in PBM may also contribute to this reduction by modulating lipid metabolism [54]. Also, HDL levels showed not significant increase in the groups fed 5 and 12.5% PBM and significant increase in 7.5 and 10% PSM groups than the control, while LDL level showed non-significant decrease in 5% PBM group and significant decrease in 7.5%, 10% and 12.5% PBM groups than the control. This may be ascribed to the distinctive lipid content, particularly omega-3 fatty acids, in PBM [55]. Furthermore, the alterations in HDL and LDL levels may result from the beneficial impact of PBM proteins on lipid metabolism [56]. In partial alignment, Gandi et al. [57] reported that supplementation of PBM with ginger (5, 10, and 15%) did not significantly affect total protein, albumin, ALT, urea, or cholesterol concentrations, indicating no adverse impact on liver function. However, a significant elevation was limited to the 10% PBM group relative to the control. Additionally, creatinine levels varied significantly, being lowest in the 5% PBM group and highest in the 15% PBM group, while the 10% PBM group was statistically similar to the control. Other investigations presented inconsistent results [27,58,59]

Concerning the impact of RSM on blood parameters, in conformity with our observations, Mahmoud et al. [32] revealed that incorporating 5% and 10% RSM in Japanese quail diets caused a non-significant increase in total protein, while albumin levels were significantly higher than the control. Increasing RSM inclusion level in broiler diets and providing high quality protein were believed to be accountable for increasing the albumin concentration [60]. Cholesterol levels increased significantly in the RSM groups, whereas triglycerides increased significantly at 5% RSM but declined non-significantly at 10% RSM. Meanwhile, HDL and LDL levels were unaffected, showing no significant difference from the control. In partial agreement with our results, Olivia [38] reported that the dietary interventions did not cause any significant changes in total protein, HDL, LDL, or creatinine levels. However, albumin levels increased significantly at 8 and 24% RSC and non-significantly at 16 and 32% RSC relative to the control. In addition, cholesterol values were significantly greater in all RSC groups, while triglycerides rose non-significantly at 8 and

16% but significantly at 24 and 32% RSC. She concluded that higher RSC supplementation linearly elevated cholesterol and triglycerides, though within normal limits. Obadire et al. [60] also reported comparable outcomes, in which 15% processed RSM in broiler diets did not significantly affect total protein or its fractions (albumin and globulin) which indicates the protein quality in RSM. Also, there were no significant increases in creatinine and uric acids levels of the 15% differently processed RSM groups. Creatinine estimation is used to detect kidney function as its increased level means impaired kidney function and muscle wastage, while uric acid estimation is used to measure the efficiency of protein utilization [60]. It was confirmed that decreased blood urea concentrations occur in nutritionally balanced amino acids-based diets and their increase occur in high protein diets [61]. Furthermore, Onunkwo et al. [62] reported that incorporating varying levels of RSC (8, 16, 24, and 32%) to replace SBC at 25, 50, 75, and 100% in broiler diets caused no significant differences in total protein, HDL, LDL, creatinine, or uric acid compared to the control. Although cholesterol concentrations rose significantly ($P<0.05$) in all treatments versus the control group, the differences among the 16%, 24%, and 32% RSC groups were statistically insignificant. Birds fed 8% and 16% RSC showed triglycerides concentrations comparable to the control ($P>0.05$), yet these values were lower than those recorded in the 24% and 32% RSC groups. A marked rise ($P<0.05$) in albumin was recorded in the 8% and 24% RSC groups compared with the remaining treatments and the control. However, Duwa et al. [63] examined the impact of RSM on the biochemical parameters of broiler chickens, finding significant differences in serum biochemistry among treatments. However, blood cholesterol and hydrogen carbonate exhibited no significant alterations. Another opposite point of view was presented by Angbulu et al. [34] as they concluded that broilers fed fermented RSM diet included with enzymes showed significant difference in total protein.

Our results revealed that ALT and AST concentrations remained statistically similar across all PBM and RSM groups and the control, indicating the absence of any liver stress or damage. No signs of pathological lesions were observed in the microscopic pictures of hepatic sections of all groups, reinforcing the conclusion that PBM and RSM poses no pathological effect on liver at the tested levels.

Concerning the effect of PBM and RSM on tissue antioxidants, all PBM and RSM treated groups

showed significant increases in CAT and GSH levels, yet the group fed 15% PBM and 15% RSM showed no significant increase in their levels. Conversely, MDA concentrations were significantly lower in all groups received PBM and RSM treatments than the control, with the exception of the 15% PBM group, where the decrease was not significant. Similarly, Saleh *et al.* [24] reported that all PBM groups (5, 7.5, 10, and 12.5%) had considerably lower MDA levels than the control group. However, 12.5% PBM group had non-significant decline in its MDA level, indicating reduced lipid peroxidation. Also, all PBM groups had significantly higher levels of CAT and glutathione peroxidase (GSPx) than the control group, but the group fed 12.5% PBM had non-significantly high level. According to Sayas-Barberá *et al.* [64], the decreased MDA levels were a reflection of the positive effects of byproducts waste (blood, flesh and bones) containing bioactive substances such as vitamins (E and C), minerals (selenium and zinc) and phytochemicals. Moreover, they confirmed that waste-derived antioxidants may boost the activity of intrinsic enzymes like CAT and GPx. These results agree with those found in earlier researches [65,66,67].

Limited data are available on the influence of RSM on tissue antioxidant status in broiler chickens. Mahmoud *et al.* [32] found that the expression profiles of SOD, and GPX were considerably up regulated in the Japanese quails fed 10% RSM groups compared to other groups (control and 5% RSM). However, MDA concentrations were statistically similar across groups. The enhancement of tissue antioxidant mechanisms associated with RSM administration in this research study can be attributed to the synergistic action of anthocyanins and vitamin E naturally present in roselle seeds.

Conclusion

This study concludes that PBM and RSM can be safely incorporated into broiler diets at levels up to 10% without negative effects on growth performance, carcass characteristics, biochemical parameters and antioxidant enzyme activities. However, higher inclusion levels (15%) impaired growth performance, caused changes in serum metabolites, antioxidant status, and jejunal villus morphology, likely due to antinutritional factors, reduced digestibility or palatability issues. Thus, PBM and RSM are suitable alternative protein sources in broiler diets when used at $\leq 10\%$, while higher levels should be avoided.

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Declaration of Conflict of Interest

The authors declare no conflicts of interest.

Ethical of approval

Ethical approval for this study was obtained from the Local Experimental Animals Care and Use Committee, and all procedures complied with Mansoura University guidelines, Egypt, code number: MU-ACUC (VM.PhD.25.01.52).

Authors' contributions

The research was conceptualized and experimentally implemented by Sarah A. Fahmy, while the data analysis performed by Abeer E. Aziza. Manuscript drafting was undertaken by Abd El-Hady M. Orma and Rania E. Mahmoud, with substantive revisions provided by Tarek I. Mohamed.

TABLE 1. Chemical composition of PBM and RSM.

	CP%	CF%	ASH%	Fat%	Moisture%
PBM	55.79	2.35	15.4	13.11	10.22
RSM	26.60	19.05	6.71	3.58	10.05

TABLE 2. Ingredients percentages and nutrient composition of the starter experimental diets.

Ingredients (%)	Control	PBM 5%	PBM 10&	PBM 15%	RSM 5%	RSM 10%	RSM 15%
Corn, yellow	51.77	51.85	51.90	52.05	49.86	48.00	46.90
Soybean meal	33.20	26.55	19.85	13.15	32.35	31.45	30.65
Wheat bran	7.12	10.24	13.41	16.44	5.68	4.25	2.21
Corn gluten	2.00	1.50	1.00	0.50	1.50	1.00	0.50
Oil	2.00	1.75	1.50	1.25	1.75	1.50	1.00
PBM	0.00	5.00	10.00	15.00	0.00	0.00	0.00
RSM	0.00	0.00	0.00	0.00	5.00	10.00	15.00
Limestone	1.07	0.86	0.65	0.38	1.00	0.92	0.85
Dicalcium P	1.99	1.29	0.59	0.00	2.05	2.11	2.17
Min. & Vit. Premix ¹	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.30	0.3	0.30	0.30	0.30	0.30	0.30
Methionine	0.13	0.13	0.14	0.14	0.13	0.13	0.13
Lysine	0.17	0.27	0.36	0.46	0.13	0.09	0.04
L-Threonine	0.00	0.01	0.05	0.08	0.00	0.00	0.00
Chemical Composition (%)							
Calculated CP	21.51	21.51	21.52	21.51	21.52	21.51	21.51
Calculated ME (Kcal/kg)	2900	2900	2900	2900	2900	2900	2900
Ca	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Available P	0.54	0.54	0.54	0.56	0.54	0.54	0.54

¹To ensure adequate micronutrient intake, a premix of vitamins and minerals was added to the diet at levels designed to satisfy the requirements per kilogram of feed, including Vit. A, 10000 I.U.; Vit. D3, 1500 I.U.; Vit. E, 10 mg; Vit. K3, 2 mg; Vit. B1, 2 mg; Vit. B2, 5 mg; Vit. B6, 3 mg; Vit. B12, 0.01 mg; Niacin, 27 mg; Folic acid, 1 mg; Biotin, 0.05 mg; Pantothenic acid, 10 mg; Mn, 60 mg; Zn, 50 mg; Cu, 10 mg; I, 0.1 mg; Se, 0.1 mg; Co, 0.1 mg; Fe, 50 mg.

TABLE 3. Ingredients and chemical composition of the grower 1 experimental diets.

Ingredients (%)	Control	PBM 5%	PBM 10&	PBM 15%	RSM 5%	RSM 10%	RSM 15%
Corn, yellow	56.00	56.10	56.20	56.40	54.15	53.85	51.15
Soybean meal	27.65	20.95	14.30	7.70	26.75	25.95	25.05
Wheat bran	8.85	11.99	14.98	17.63	7.40	4.80	3.95
Corn gluten	2.00	1.50	1.00	0.50	1.50	1.00	0.50
Oil	2.25	2.00	1.75	1.50	2.00	1.25	1.25
PBM	0.00	5.00	10.00	15.00	0.00	0.00	0.00
RSM	0.00	0.00	0.00	0.00	5.00	10.00	15.00
Limestone	1.12	0.91	0.62	0.00	1.05	0.97	0.91
Dicalcium P	1.25	0.55	0.00	0.00	1.31	1.38	1.43
Min. & Vit. Premix ¹	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Methionine	0.14	0.14	0.15	0.15	0.14	0.14	0.14
Lysine	0.19	0.29	0.39	0.48	0.15	0.11	0.07
L-Threonine	0.00	0.02	0.06	0.09	0.00	0.00	0.00
Chemical composition (%)							
Calculated CP	19.52	19.52	19.53	19.51	19.51	19.51	19.52
Calculated ME (Kcal/kg)	2950	2950	2950	2950	2950	2950	2950
Ca	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Available P	0.40	0.40	0.43	0.55	0.40	0.40	0.40

¹To ensure adequate micronutrient intake, a premix of vitamins and minerals was added to the diet at levels designed to satisfy the requirements per kilogram of feed, including Vit. A, 10000 I.U.; Vit. D3, 1500 I.U.; Vit. E, 10 mg; Vit. K3, 2 mg; Vit. B1, 2 mg; Vit. B2, 5 mg; Vit. B6, 3 mg; Vit. B12, 0.01 mg; Niacin, 27 mg; Folic acid, 1 mg; Biotin, 0.05 mg; Pantothenic acid, 10 mg; Mn, 60 mg; Zn, 50 mg; Cu, 10 mg; I, 0.1 mg; Se, 0.1 mg; Co, 0.1 mg; Fe, 50 mg.

TABLE 4. Ingredients and chemical composition of the grower 2 experimental diets.

Ingredients (%)	Control	PBM 5%	PBM 10%	PBM 15%	RSM 5%	RSM 10%	RSM 15%
Corn, yellow	59.82	59.9	60.00	60.25	57.95	57.65	54.95
Soybean meal	24.9	18.20	11.55	5.05	24.05	23.25	22.4
Wheat bran	7.56	10.71	13.66	16.01	6.10	3.50	2.63
Corn gluten	2.00	1.50	1.00	0.50	1.50	1.00	0.50
Oil	2.50	2.25	2.00	1.75	2.25	1.50	1.50
PBM	0.00	5.00	10.00	15.00	0.00	0.00	0.00
RSM	0.00	0.00	0.00	0.00	5.00	10.00	15.00
Limestone	1.06	0.85	0.48	0.00	0.98	0.91	0.84
Dicalcium P	1.12	0.42	0.00	0.00	1.18	1.25	1.30
Min. & Vit. Premix ¹	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Methionine	0.15	0.16	0.16	0.17	0.15	0.15	0.15
Lysine	0.30	0.39	0.49	0.58	0.26	0.22	0.17
L-Threonine	0.04	0.07	0.11	0.14	0.03	0.02	0.01
Chemical composition (%)							
Calculated CP	18.52	18.51	18.52	18.51	18.52	18.51	18.52
Calculated ME (Kcal/kg)	3020	3020	3020	3020	3020	3020	3020
Ca	0.74	0.74	0.74	0.79	0.74	0.74	0.74
Available P	0.37	0.37	0.42	0.55	0.37	0.37	0.37

¹To ensure adequate micronutrient intake, a premix of vitamins and minerals was added to the diet at levels designed to satisfy the requirements per kilogram of feed, including Vit. A, 10000 I.U.; Vit. D3, 1500 I.U.; Vit. E, 10 mg; Vit. K3, 2 mg; Vit. B1, 2 mg; Vit. B2, 5 mg; Vit. B6, 3 mg; Vit. B12, 0.01 mg; Niacin, 27 mg; Folic acid, 1 mg; Biotin, 0.05 mg; Pantothenic acid, 10 mg; Mn, 60 mg; Zn, 50 mg; Cu, 10 mg; I, 0.1 mg; Se, 0.1 mg; Co, 0.1 mg; Fe, 50 mg.

TABLE 5. Ingredients and chemical composition of the finisher experimental diets.

Ingredients (%)	Control	PBM 5%	PBM 10%	PBM 15%	RSM 5%	RSM 10%	RSM 15%
Corn, yellow	64.10	64.15	64.30	64.50	62.20	61.90	59.50
Soybean meal	23.05	16.35	9.70	3.20	22.15	21.4	20.50
Wheat bran	5.09	8.27	11.17	13.52	3.70	1.05	0.00
Corn gluten	2.00	1.50	1.00	0.50	1.50	1.00	0.50
Oil	2.75	2.50	2.25	2.00	2.50	1.75	1.66
PBM	0.00	5.00	10.00	15.00	0.00	0.00	0.00
RSM	0.00	0.00	0.00	0.00	5.00	10.00	15.00
Limestone	1.03	0.82	0.45	0.00	0.95	0.89	0.81
Dicalcium P	1.12	0.41	0.00	0.00	1.18	1.24	1.30
Min. & Vit. Premix ¹	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Methionine	0.11	0.12	0.12	0.13	0.11	0.11	0.11
Lysine	0.20	0.29	0.39	0.48	0.16	0.11	0.07
L-Threonine	0.00	0.04	0.07	0.11	0.00	0.00	0.00
L- Tryptophan	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Chemical composition (%)							
Calculated CP	17.52	17.52	17.52	17.53	17.51	17.52	17.52
Calculated ME (Kcal/kg)	3100	3100	3100	3100	3100	3100	3100
Ca	0.72	0.72	0.72	0.78	0.72	0.72	0.72
Available P	0.36	0.36	0.41	0.54	0.36	0.36	0.36

¹To ensure adequate micronutrient intake, a premix of vitamins and minerals was added to the diet at levels designed to satisfy the requirements per kilogram of feed, including Vit. A, 10000 I.U.; Vit. D3, 1500 I.U.; Vit. E, 10 mg; Vit. K3, 2 mg; Vit. B1, 2 mg; Vit. B2, 5 mg; Vit. B6, 3 mg; Vit. B12, 0.01 mg; Niacin, 27 mg; Folic acid, 1 mg; Biotin, 0.05 mg; Pantothenic acid, 10 mg; Mn, 60 mg; Zn, 50 mg; Cu, 10 mg; I, 0.1 mg; Se, 0.1 mg; Co, 0.1 mg; Fe, 50 mg.

TABLE 6. Effects of using PBM & RSM on growth performance of broiler chicks.

Traits	Control	PBM		RSM	
		5%	10%	5%	10%
IBW (g)	39.51 ± 0.67	39.42 ± 0.24	39.37 ± 0.37	40.37 ± 0.36	39.84 ± 0.25
FBW (g)	2360.29 ± 22.59 ^a	2348.03 ± 36.75 ^a	2341.37 ± 31.81 ^a	2282.83 ± 31.73 ^{ab}	2211.66 ± 21.39 ^{ab}
BWG (g)	2320.78 ± 22.596 ^a	2308.61 ± 36.76 ^a	2302.00 ± 31.82 ^a	2242.46 ± 35.73 ^a	2171.82 ± 31.03 ^{ab}
FI (g)	3665.40 ± 32.81	3731.48 ± 31.35	3805.36 ± 33.59	3617.42 ± 36.41	3656.44 ± 32.50
FCR	1.58 ± 0.13 ^c	1.61 ± 0.16 ^c	1.65 ± 0.11 ^{bc}	1.61 ± 0.12 ^c	1.68 ± 0.09 ^{bc}

Data are presented as mean ± SE, and means sharing different superscript letters within a row differ significantly at P<0.05.

TABLE 7. Effects of using PBM & RSM on carcass characteristics of broiler chicks.

Traits	Control	PBM		RSM	
		5%	10%	5%	10%
Live weight	2209.96 ± 22.94 ^a	2215.52 ± 23.39 ^a	2250.27 ± 21.93 ^a	2189.50 ± 24.06 ^a	2113.51 ± 22.48 ^{ab}
Dressed Carcass%	73.01 ± 0.65	72.38 ± 1.07	72.19 ± 0.60	72.28 ± 0.35	72.47 ± 0.72
Liver%	1.38 ± 0.04 ^b	1.51 ± 0.06 ^b	1.47 ± 0.10 ^b	1.68 ± 0.08 ^{ab}	1.76 ± 0.10 ^a
Gizzard%	0.98 ± 0.16 ^b	1.03 ± 0.07 ^b	1.06 ± 0.05 ^b	1.10 ± 0.04 ^{ab}	1.25 ± 0.08 ^a
Heart%	0.28 ± 0.01	0.27 ± 0.01	0.26 ± 0.01	0.28 ± 0.01	0.28 ± 0.01
Spleen%	0.07 ± 0.01	0.09 ± 0.01	0.07 ± 0.01	0.08 ± 0.01	0.08 ± 0.01
Intestine%	3.96 ± 0.11	4.22 ± 0.18	4.07 ± 0.06	4.32 ± 0.15	4.31 ± 0.18
Pancrease%	0.17 ± 0.02 ^c	0.18 ± 0.01 ^{bc}	0.19 ± 0.01 ^{bc}	0.21 ± 0.01 ^{ab}	0.24 ± 0.01 ^a

Data are presented as mean ± SE, and means sharing different superscript letters within a row differ significantly at P<0.05.

TABLE 8. Effects of using PBM & RSM on blood parameters of broiler chicks.

Parameters	Control	PBM 5%	PBM 10%	PBM 15%	RSM 5%	RSM 10%	RSM 15%
TP (g/dl)	5.13 ± 0.20 ^{ab}	4.93 ± 0.08 ^b	5.63 ± 0.06 ^{ab}	5.40 ± 0.40 ^{ab}	5.96 ± 0.39 ^a	5.83 ± 0.08 ^a	5.73 ± 0.41 ^{ab}
GLB (g/dl)	1.20 ± 0.05 ^{ab}	1.03 ± 0.06 ^b	1.26 ± 0.03 ^{ab}	1.06 ± 0.21 ^b	1.43 ± 0.12 ^a	1.30 ± 0.05 ^{ab}	1.23 ± 0.08 ^{ab}
ALB (g/dl)	3.93 ± 0.14 ^b	3.90 ± 0.05 ^b	4.37 ± 0.08 ^{ab}	4.34 ± 0.18 ^{ab}	4.53 ± 0.27 ^a	4.53 ± 0.03 ^a	4.50 ± 0.35 ^{ab}
Glucose (mg/100 ml)	83.00 ± 6.02 ^{ab}	76.00 ± 6.65 ^b	83.00 ± 10.26 ^{ab}	106.33 ± 7.53 ^a	104.33 ± 6.93 ^a	95.33 ± 4.48 ^{ab}	98.33 ± 12.46 ^{ab}
ALT (U/l)	9.20 ± 1.56	8.56 ± 1.82	9.63 ± 1.96	10.33 ± 1.45	10.80 ± 1.24	9.90 ± 2.16	9.56 ± 1.54
AST (U/l)	95.00 ± 12.54	99.00 ± 10.73	98.00 ± 10.57	99.33 ± 10.60	108.00 ± 8.54	105.00 ± 8.08	94.33 ± 12.75
CREAT (mg/dl)	0.55 ± 0.02	0.50 ± 0.01	0.50 ± 0.02	0.55 ± 0.02	0.50 ± 0.01	0.50 ± 0.02	0.55 ± 0.02
UA (mg/dl)	13.00 ± 0.57 ^b	13.50 ± 0.28 ^{ab}	12.50 ± 0.86 ^b	13.00 ± 0.57 ^b	13.50 ± 0.28 ^{ab}	12.50 ± 0.86 ^b	14.50 ± 0.28 ^a
CHOL (mg/dl)	112.00 ± 7.50	108.66 ± 8.66	109.33 ± 13.34	104.66 ± 8.45	115.00 ± 4.58	114.00 ± 9.29	114.66 ± 6.11
TG (mg/dl)	101.50 ± 2.59 ^a	82.50 ± 3.17 ^b	90.00 ± 1.15 ^b	107.00 ± 1.73 ^a	109.50 ± 0.86 ^a	106.50 ± 4.33 ^a	92.50 ± 2.59 ^b
HDL (mg/dl)	44.00 ± 0.57	43.50 ± 0.86	45.50 ± 0.28	44.50 ± 0.86	44.00 ± 0.57	44.50 ± 0.28	44.00 ± 0.57
LDL (mg/dl)	119.50 ± 2.59 ^a	116.00 ± 1.73 ^a	99.00 ± 3.46 ^b	97.50 ± 3.86 ^b	118.00 ± 1.73 ^a	112.50 ± 2.59 ^{ab}	101.00 ± 1.73 ^b

Data are presented as mean ± SE, and means sharing different superscript letters within a row differ significantly at P<0.05.

TABLE 9. Effects of using PBM & RSM on tissue antioxidants of broiler chicks.

Marker	Control	PBM 5%	PBM 10%	PBM 15%	RSM 5%	RSM 10%	RSM 15%
CAT (u/g tissue)	4.70 ± 0.08 ^c	5.65 ± 0.08 ^{ab}	5.25 ± 0.08 ^b	4.85 ± 0.08 ^c	5.80 ± 0.05 ^a	5.65 ± 0.08 ^{ab}	4.95 ± 0.08 ^c
GSH (mg/g tissue)	2.15 ± 0.08 ^c	2.60 ± 0.11 ^{ab}	2.42 ± 0.08 ^b	2.26 ± 0.11 ^c	2.85 ± 0.14 ^a	2.57 ± 0.08 ^{ab}	2.35 ± 0.20 ^c
MDA (nmol/g tissue)	47.20 ± 0.17 ^a	45.10 ± 0.20 ^b	45.25 ± 0.17 ^b	46.85 ± 0.11 ^a	43.55 ± 0.20 ^c	41.05 ± 0.14 ^d	41.70 ± 0.40 ^d

Data are presented as mean ± SE, and means sharing different superscript letters within a row differ significantly at P<0.05.

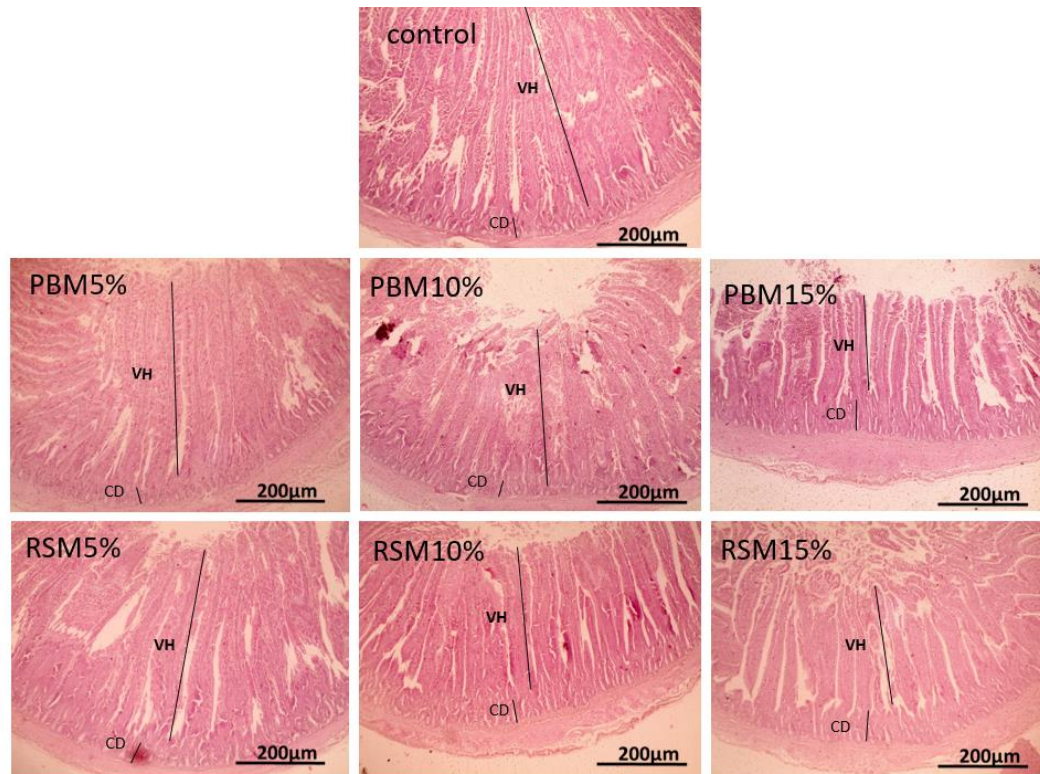


Fig. 1. Microscopic images of jejunal tissue stained with H&E (X: 40 bar 200) showing normal histology in all groups with markedly decreased VH and markedly increased CD in 15% PBM and RSM.

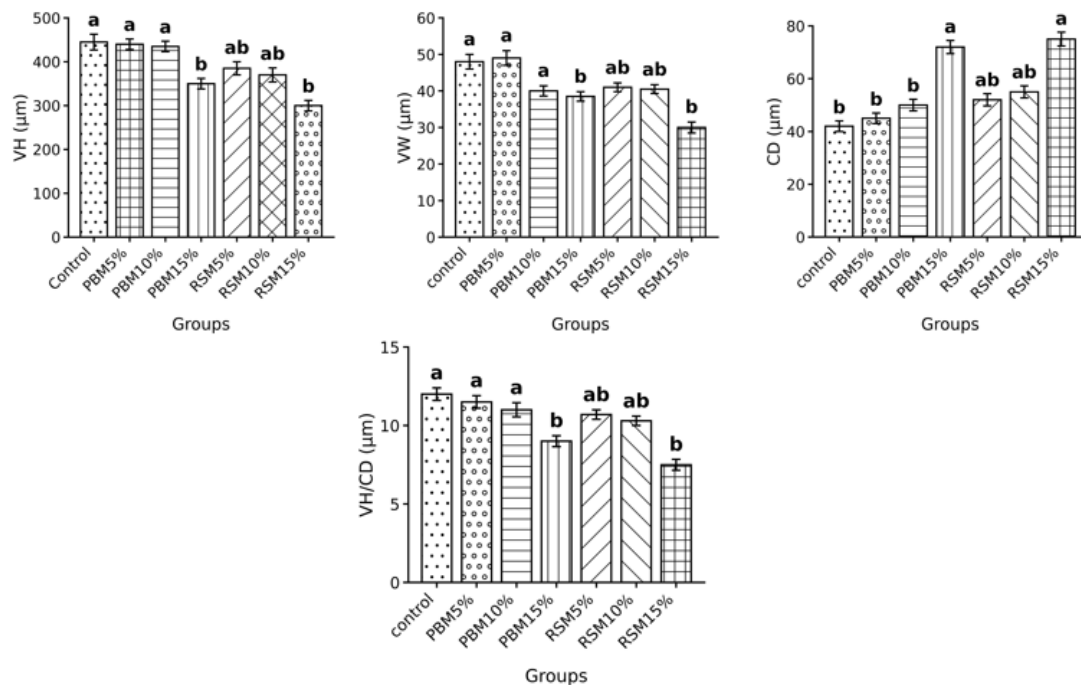


Fig. 2. Bars represent statistical analysis of significantly lower VH, VW and VH/CD ratio and significantly higher CD in jejunal sections from 15% PBM and RSM compared to control group. Different superscript lowercase letters denote significant differences at P<0.05.

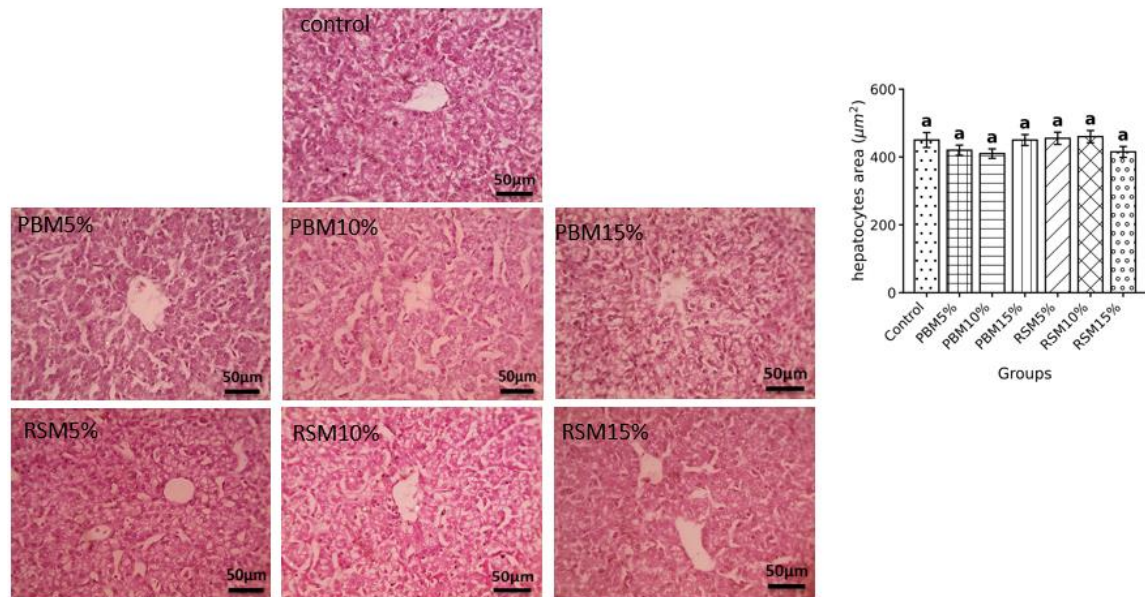


Fig. 3. Microscopic images of hepatic tissue stained with H&E showing normal histology in all groups (X: 400 bar 50). Bars represent statistical analysis of hepatocyte areas (μm^2) where the control and all treatment groups showed comparable values without significant differences.

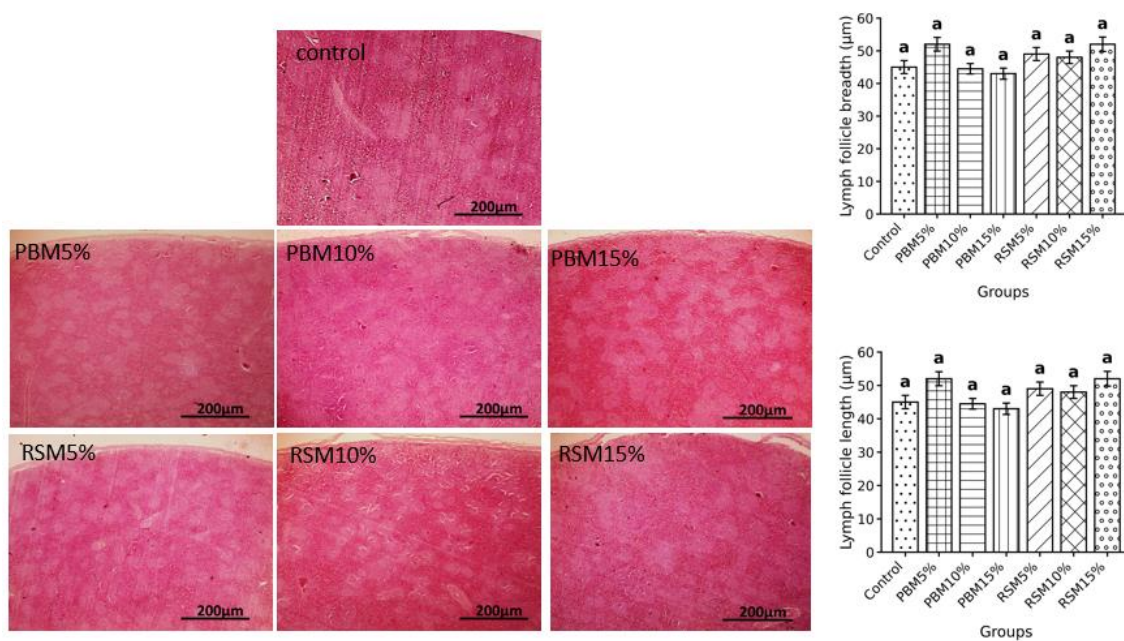


Fig. 4. Microscopic images of splenic tissue stained with H&E showing normal parenchyma consisting of red pulp and scattered lymph follicles in all groups (X: 40 bar 200). Bars represent statistical analysis lymph follicles length & breadth showing no significant difference among groups.

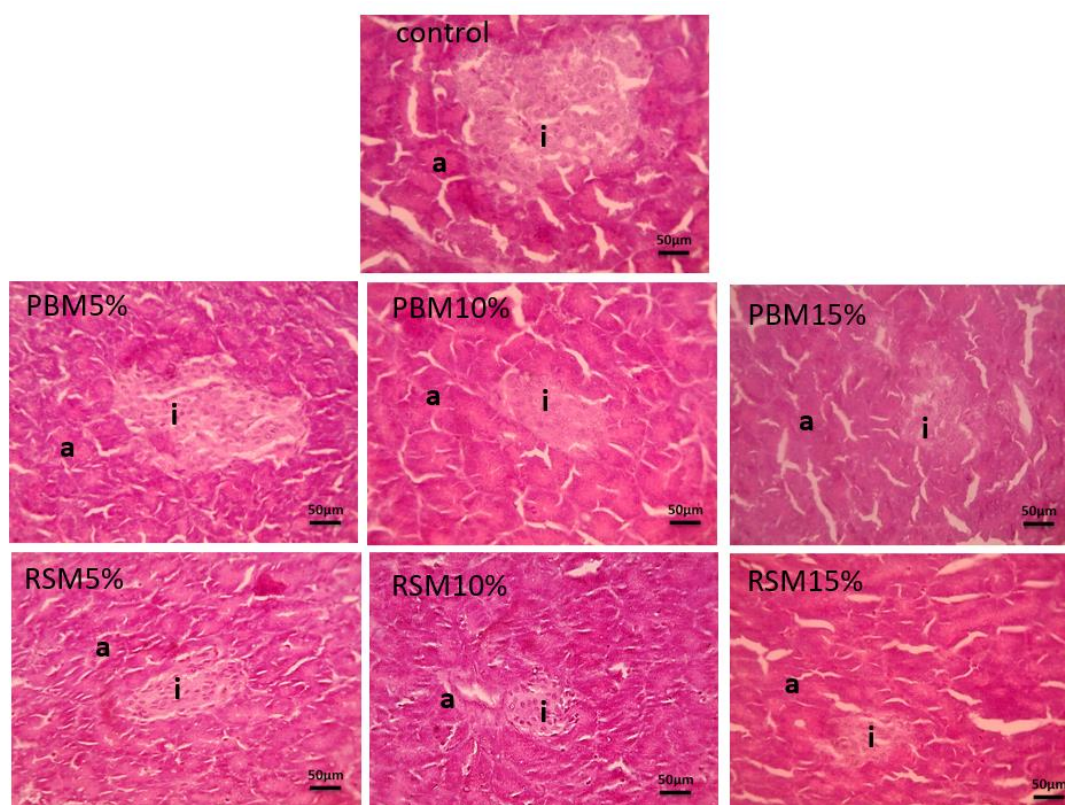


Fig. 5. Microscopic images of pancreatic tissue stained with H&E (X: 400 bar 50) showing normal histology of endocrine portion islet of Langerhans (i) and exocrine portion acini (a) in all groups.

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تأثير تضمين مستخلص مخلفات الدواجن ومستخلص بذور الكركديه كمصادر للبروتين في علائق بدارى تسمين الدجاج على معدلات اداء النمو، ومواصفات الذبيحة، وقياسات مصل الدم، ومضادات الاكسدة في الانسجة، والتغيرات النسيجية

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الملخص

هدفت هذه الدراسة إلى تقييم تأثير إدراج مسحوق مخلفات الدواجن وبذور الكركديه في علائق بدارى تسمين الدجاج على الأداء الإنتاجي، صفات الذبيحة، قياسات مصل الدم، نشاط الإنزيمات المضادة للاكسدة، والتغيرات النسيجية للأعضاء. استخدم في التجربة 273 ككتوتًا من سلالة كوب-500 بعمر يوم واحد، وتم توزيعها عشوائيًا على سبع مجموعات غذائية بثلاث مكررات لكل منها. اعتمدت العلائق على الذرة وكسب فول الصويا، واشتملت على مجموعة ضابطة لا تحتوي على أي من مسحوق مخلفات الدواجن أو بذور الكركديه، وثلاث علائق تحتوي على مسحوق مخلفات الدواجن بنسب (5، 10 و15%)، وثلاث علائق أخرى تحتوي على مسحوق بذور الكركديه بنفس النسب. أظهرت النتائج عند عمر 42 يومًا أن إدراج مسحوق مخلفات الدواجن أو بذور الكركديه حتى مستوى 10% لم يؤثر سلبيًا على الأداء الإنتاجي، صفات الذبيحة، أو المؤشرات البيوكيميائية في الدم، بينما أدى رفع النسبة إلى 15% إلى انخفاض معنوي في وزن الجسم، معدل الزيادة الوزنية، وكفاءة التحويل الغذائي. كما سجلت المجموعات المغذاة على 5% و10% من مسحوق مخلفات الدواجن أو بذور الكركديه زيادات معنوية في نشاط إنزيم CAT ومستويات GSH مقارنة بالمجموعة الضابطة، في حين لم تكن هناك أي فروق واضحة عند مستوى 15%. وعلى النقيض، انخفض MDA بشكل معنوي في جميع المجموعات مقارنة بالضابطة. أكدت الفحوص النسيجية سلامة الأعضاء في جميع المجموعات، باستثناء تغيرات في شكل الزغيات عند مستوى 15%. لذلك توصي الدراسة بإمكانية إدراج مسحوق مخلفات الدواجن وبذور الكركديه في علائق بدارى تسمين الدجاج حتى مستوى 10% كمصادر بروتينية بديلة دون التأثير سلبيًا على الأداء أو الصحة، مع تجنب المستويات الأعلى لما لها من آثار ضارة على النمو والوظائف الفسيولوجية.

الكلمات الدالة: مسحوق مخلفات الدواجن، مسحوق بذور الكركديه، اداء النمو، مضادات الاكسدة، دجاج التسمين، قياسات الدم، التغيرات النسيجية.