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Effect of Rubber Seed Meal (*Hevea brasiliensis*) on Blood Biochemical Parameters and Enzyme Profiles of Broiler Birds

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ABSTRACT

An experiment was conducted at Department of Animal Nutrition in C.V.Sc. & A.H., C.A.U., Aizawl, Mizoram, in the month of September to November, 2022 to assess the effect of feeding rubber seed meal *(Hevea brasiliensis)* on biochemical parameters and enzyme profiles of broiler birds. 200 one-day old broiler chicks were purchased from commercial broiler chick distributor of Aizawl city, Mizoram. The chicks were distributed randomly into four experimental groups in a Completely Randomized Block Design. 50 birds of each group were further divided into five replicate with ten chicks in each replicate. The Group-1, Group-2, Group-3 and Group-4 were fed with standard basal ration formulated as per BIS (2007), standard basal ration with 10%, 15% and 20% replacement of maize with rubber seed meal, respectively. Overnight water soaked rubber seed was dried and incorporated in the diet of broiler birds as replacement of maize. The rubber seed were collected from Tripura and were subjected to grinding followed by water soaking for overnight, sun drying for 5–7 days and incorporated in the diet of the broiler birds. Feeding trial was conducted for 42 days. Blood biochemical parameters did not show any significant difference (p>0.05) between different treatment groups. ALT and AST values were not found significantly different (p>0.05) among different treatment groups. It can be concluded that rubber seed meal can be incorporated in the diet as a replacement of maize up to 20% without adversely affecting blood biochemical and enzyme profiles of broiler chickens

KEYWORDS: Rubber seed meal, biochemical, enzyme, broiler birds

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1. INTRODUCTION

The chicken farming industry is one of India's fastest-growing agricultural sectors, with an average yearly growth rate of 8–10 % (Borah and Halim, 2014 and Dinani et al., 2019). India ranks 6th globally for broiler meat output and 2nd globally for egg production (Anonymous 2019). However, livestock and poultry breeders are confronted with a constant lack of feedstuffs. This has been attributed to man's increasing demand for the same livestock/poultry feedstuffs for his meals as well as the use of industrial raw resources. As a result, the cost of conventional feedstuffs (maize, soya bean, peanut, etc) has risen, and feed now accounts for 70–80 % of overall production costs for poultry farming. Using unconventional feed ingredients available locally, to formulate the least-cost feed formulation were found to be reduction in the cost of poultry feeds (Thirumalaisamy et al., 2016). One of the unconventional feedstuff is rubber seed (Udo et al., 2018). Rubber seed is cheaper than full fat soya beans and is a good source of protein and energy (Akinsanmi et al., 2017). Rubber seed is a by-product of natural rubber plantations (*Hevea brasiliensis*), and it is abundantly available in some parts of the country (Deng et al., 2015). After Kerala, Tripura is the second-largest producer of rubber. Tripura has a rubber plantation covering over 75,000 hectares and generates 50,000 tons of rubber each year. Rubber trees produce 150-250 tons of seeds per hectare on average (Oluodo et al., 2018). Dry matter, crude protein, crude fat, crude fibre , nitrogen free extract and ash content in rubber seed meal were found to be 914 307, 87 165, 381 and 60 (g kg^{-1} DM) respectively (Deng et al., 2017). Rubber seed could be a useful protein source if processed properly, as it contains an optimum amino acid profile that supports metabolism and healthy growth (Sharma et al., 2014; Khatun et al., 2015; Oluodo et al., 2018). The utilization of rubber seed as a feed ingredient for monogastric animals has been limited by the presence of anti-nutritional factors especially hydrogen cyanide and the lack of proper processing methods that are cheaper and easy to adopt by the small scale rubber farmer or small scale poultry farmer living within the rubber producing zone (Akinsanmi et al., 2020; Aguihe et al., 2017). However, numerous techniques of treating rubber seeds like drying, soaking, boiling, and fermenting of entire seeds exist to minimize their cyanogenic glycoside concentration and toxicity (Ogundipe et al., 2008; Ogunka-Nnoka and Mepba, 2008; Kinh et al., 2006; Medugu et al., 2012 and Agbai et al., 2021). The non-adverse effect of rubber seed meal in the diet of poultry and other livestock animals has been observed by many workers (Syahruddin et al., 2014; Khatun et al., 2015; Amaefule et al., 2020 and Ahaotu et al., 2018). Khatun et al. (2015) reported that soybean meal might be replaced by the RSM at 10–20% in the diet of broiler without any detrimental effect on broiler production performance. Cooked and fermented RSM fed to birds resulted in better performance and carcass quality at a lower cost per kilogramme increase (Aguihe et al., 2017). The replacement of soybean meal in broiler chicken feed with graded quantities of RSM from both processing methods roasting and soaking in hot water up to 35% had no discernible impact on the birds' growth performance or carcass quality (Akinsanmi et al., 2020). In India, research works on the utilization of rubber seed meal in broiler birds have not been conducted so far. Hence, the present study was undertaken on to assess the effect of feeding rubber seed meal (*Hevea brasiliensis*) on biochemical parameters of broiler birds.

2. MATERIALS AND METHODS

Two hundred one-day old broiler chicks were purchased from commercial broiler chick distributor of Aizawl city, Mizoram, India in the month of September to November, 2022. The chicks were distributed randomly into four experimental groups in a Completely Randomized Block Design. Fifty birds of each group were further divided into five replicate with ten chicks in each replicate. To prevent overcrowding, each replicate has been given 0.75 square feet of floor area per broiler chick in the early stages and 1.00 square feet after 4 weeks of age. The chicks were given clean, freshly boiled water after cooling down. On the first few days of raising, electrolyte was offered. To prevent spills after four weeks, waterers were raised 2.5 cm above the height of the chicks. Every waterer is cleaned regularly each day. Each replicate contains two number of 3-liter waterers where twice-daily cleaned water has offered to the chicks. The Group-1 (control) was fed with standard basal ration formulated as per Anonymous (2007). Birds in Group-2 were fed standard basal ration with 10% replacement of maize with rubber seed meal. Birds in Group-3 were fed standard basal ration with 15% replacement of maize with rubber seed meal. Birds in Group-4 had received standard basal ration with 20% replacement of maize with rubber seed meal. The rubber seed were collected from Tripura and the collected rubber seed was subjected to grinding followed by water soaking for overnight (to remove the HCN compound), sun drying for 5–7 days and incorporated in the diet of the broiler birds. Feeding trial continued for 42 days. In order to prevent feed waste, each replicate has two feeders, which are filled one-third at a time. The birds receive food twice daily after the feeders have been cleaned with clean water and dried in the sun. On the age of 7, 14 and 21 day broiler chicks are given New castle (intra nasal), Infectious bursal (drinking water) and booster dose of new castle (drinking water) disease vaccine. As

per method described by Snedecor and Cochran (2004), the data were analysed using one-way ANOVA in SPSS using a completely randomised design. $p \leq 0.05$ probability values were deemed significant, while $0.05 > p \leq 0.01$ values were deemed to indicate a trend. The differences between the treatment means were determined using Duncan's test when the treatment effect was determined to be significant.

2.1. Collection of blood sample

Blood was taken from four experimental groups of broiler birds on the 28th, 35th and 42nd days of the trial. The wing vein was used to take about 2 ml of blood. In order to prevent clotting, the extracted blood was promptly placed to a vacutainer containing EDTA, and the sample vial was gently shaken to combine the blood and EDTA. Blood was analysed for haematological parameters on the same day, right after the collection. Another 2 ml of blood was extracted in a vacutainer containing clot activator for the measurement of blood biochemical parameters, and the serum was separated by centrifugation at 3000 rpm for 5 m and stored at -20°C for further analysis.

2.2. Estimation of blood- biochemical parameters

Blood biochemical parameters and enzymes were estimated by using commercially available kit as per the manufacturer's protocol.

2.3. Chemical composition of feed ingredients and compounded feed

Proximate composition of Raw and processed rubber seed meal and pre-starter, starter, and finisher for broiler feed were analyzed as per procedure of Anonymous (2000).

3. RESULTS AND DISCUSSION

3.1. Chemical evaluation of rubber seed (Hevea brasiliensis) meal

The chemical evaluation of rubber seed (*Hevea brasiliensis*) meal is presented on Table 1. In the present study, the CP value of rubber seed meal was 12.5%. Similar CP values were reported by Thuy and Ly (2002), Oyewusi et al. (2007). They found the crude protein (CP) content as 13.5% and 10.3±1.7%, respectively. However, higher CP in rubber seed meal was found by Eka et al. (2010), Ijaiya et al. (2011) and Chanjula et al. (2010). They found the crude protein (CP) content as 26.1%, 28.63% and 23.64%, respectively.

3.2. HCN level (mg kg^{-1}) of RSM before and after physical processing method

The HCN level of RSM was determined after processing method at different days of storage and is presented in Table 2. The HCN content in RSM before processing was found to be 384.67 mg kg^{-1}. The HCN level was checked after 18 hours soaking and it was found to be 128.67 (21 days of storage) mg kg^{-1}. However, the HCN content of raw rubber seeds also reduced during storage.

Table 1: Proximate constituents (%) of processed RSM

Attributes	Raw rubber seed	After processing (soaked RSM)
Moisture	62.77	87.86
Crude protein	12.53	12.36
Ether extract	21.61	18.70
Crude fibre	22.76	16.66
Total ash	2.37	1.84
Nitrogen free extract	40.73	50.44

RSM – Rubber seed meal

Table 2: Effect of processing techniques on reduction of hydrocyanic acid (HCN) level in rubber seed (mg kg^{-1})

Storage Period	Raw rubber seed	After processing (soaked RSM)
Day-0	384.67±1.45	187.33±0.88
Day-7	377.33±0.67	166.33±1.20
Day-14	355.33±0.88	144.67±0.88
Day-21	345.67±1.02	128.67±0.88
RSM–Rubber seed meal	2.37	1.84
Nitrogen free extract	40.73	50.44

RSM: Rubber seed meal

3.3. Chemical composition of Pre-starter, Starter and Finisher ration of experimental broiler birds

The chemical composition (DM % basis) of the pre-starter, starter, and finisher for broiler feed are presented in Table 3, 4 and 5, respectively.

3.4. Blood biochemical parameters

The blood biochemical parameters are presented in table 6 and 7. The statistically analyzed table 6 and 7, showed that blood biochemical parameters did not show significant difference ($p > 0.05$) among the treatments groups. However, glucose level was significantly different between three different period i.e. d 28, d 35 and d 42 in RSM–10, RSM –15 and RSM–20 groups. There was significantly different values of globulin between the different period with in control, RSM–10, RSM–15 and RSM–20 groups.

3.4.1. Glucose

Glucose value was not significant ($p > 0.05$) among treatment groups compared to the control group. Dodson et al. (1981) observed decrease in blood glucose level due to high fibre diet feeding. On the contrary, the results of the present study revealed that despite the high fibrous nature of RSM, the glucose level was well within the normal level, which might be due to the soluble nature of fibre in the RSM. It is similar to the findings of Ijaiya et al. (2011) where they found the non-significant changes glucose level in broiler birds by feeding of RSM.

Table 3: Chemical composition (percentage DM basis) of experimental broiler Pre-starter feed (0-7 days)

Attributes	Group 1 (Control)	Group 2 (RSM - 10)	Group 3 (RSM - 15)	Group 4 (RSM - 20)
Dry matter (%)	89.12	88.64	88.58	88.76
Crude protein (%)	22.94	23.03	23.05	23.10
Ether extract (%)	2.94	2.89	2.91	2.97
Crude fibre (%)	2.96	3.99	4.11	4.10
Total ash (%)	6.13	6.09	6.15	6.17
Nitrogen free extract (%)	65.03	64.00	63.78	63.66
Calcium (%)	1.33	1.36	1.31	1.33
Phosphorous (%)	0.82	0.81	0.84	0.83
*ME (kcal kg^{-1})	3004.30	2998.66	2999.69	3000.62
*Lysine (%)	1.30	1.29	1.29	1.28
*Methionine (%)	0.57	0.56	0.55	0.55

*Calculated value, RSM – Rubber seed meal.

Table 4: Chemical composition (percentage DM basis) of experimental broiler Starter feed (8-21 days)

Attributes	Group 1 (Control)	Group 2 (RSM - 10)	Group 3 (RSM - 15)	Group 4 (RSM - 20)
Dry matter (%)	88.92	88.64	88.58	88.76
Crude protein (%)	22.07	21.83	22.05	22.00
Ether extract (%)	2.94	2.89	3.16	3.11
Crude fibre (%)	3.83	4.05	4.11	4.24
Total ash (%)	6.13	6.16	6.17	6.18
Nitrogen free extract (%)	65.03	65.07	64.51	64.47
Calcium (%)	1.33	1.36	1.31	1.33
Phosphorous (%)	0.82	0.81	0.84	0.83
*ME (kcal kg^{-1})	3098	3110.62	3125.64	3134.66
*Lysine (%)	1.23	1.22	1.21	1.20
*Methionine (%)	0.54	0.53	0.52	0.52

*Calculated value, RSM: Rubber seed meal

Table 5: Chemical composition (percentage DM basis) of experimental broiler Finisher feed (22-42 days)

Attributes	Group 1 (Control)	Group 2 (RSM-10)	Group 3 (RSM-15)	Group 4 (RSM-20)
Dry matter (%)	86.07	86.24	86.32	86.44
Crude protein (%)	20.30	20.08	20.23	20.30
Ether extract (%)	3.51	4.12	4.09	4.06
Crude fibre (%)	4.50	4.53	4.63	4.55
Total ash (%)	6.31	6.30	6.41	6.23
Nitrogen free extract (%)	65.38	64.97	64.64	64.86
Calcium (%)	1.31	1.41	1.24	1.32
Phosphorous (%)	0.98	0.98	0.91	0.82
*Lysine (%)	1.08	1.07	1.06	1.06

Table 5 Continue.....

Attributes	Group 1 (Control)	Group 2 (RSM - 10)	Group 3 (RSM - 15)	Group 4 (RSM - 20)
*Methionine (%)	0.51	0.50	0.50	0.49
*ME (kcal kg^{-1})	3206.2	3201.59	3203.11	3204.67

*Calculated value, RSM: Rubber seed meal

Table 6: Effect of feeding rubber seed meal on serum Glucose, total protein, albumin and globulin in broiler chickens

Attributes	Treatment				SEM	*p* Value
	Group 1 (Control)	Group 2 (RSM – 10)	Group 3 (RSM -15)	Group 3 (RSM –20)		
Glucose (mg dl^{-1})						
d 28	214.85±1.84	213.79^{a} ±1.25	213.91^{a}±1.04	215.91^{a}±0.68	0.59	0.57
d 35	217.58±1.37	216.21^{ab}±0.96	217.33^{b}±0.92	218.55^{b}±0.41	0.47	0.35
d 42	218.7 5± 0.61	218.27^{b}±0.83	217.97^{b}±0.84	219.76^{b}±0.57	0.37	0.34
p value	0.17	0.03*	0.02*	<0.01**		
Average	217.06±0.87	216.1 0±0.73	216.41±0.72	218.08±0.52		
Total protein (g dl^{-1})						
d 28	4.65±0.06	4.74±0.12	4.82±0.13	4.86±0.20	0.06	0.76
d 35	4.55±0.06	5.10±0.23	4.70±0.23	4.62±0.16	0.10	0.20
d 42	4.83±0.25	4.79±0.16	4.75±0.18	4.72±0.12	0.08	0.97
p value	0.47	0.33	0.89	0.60		
Average	4.67± 0.08	4.87±0.10	4.76±0.10	4.73±0.92		
Albumin (g dl^{-1})						
d 28	1.24^{a}±0.03	1.36±0.06	1.41±0.03	1.26±0.06	0.02	0.13
d 35	1.22^{a}±0.03	1.36±0.04	1.37±0.07	1.30±0.05	0.02	0.27
d 42	1.38^{b}±0.02	1.36±0.01	1.32±0.05	1.40±0.02	0.01	0.40
p value	<0.01**	0.99	0.54	0.17		
Average	1.28±0.02	1.36±0.02	1.37±0.03	1.32±0.03		
Globulin (g dl^{-1})						
d 28	2.49^{a}±0.03	2.41^{a}±0.03	2.37^{a}±0.05	2.40^{a}±0.02	0.01	0.19
d 35	2.44^{a}±0.01	2.43^{a}±0.03	2.47^{a}±0.02	2.45^{a}±0.02	0.01	0.78
d 42	2.94^{b}±0.02	2.86^{b}±0.01	2.93^{b}±0.03	2.96^{b}±0.02	0.01	0.09
p value	<0.01**	<0.01**	<0.01**	<0.01**		
Average	2.62±0.06	2.57±0.05	2.59±0.07	2.60±0.06		

^{abc} means with different superscript in the same column differ significantly; * (p<0.05), ** (p<0.01), RSM - Rubber seed meal.

Table 7: Effect of feeding rubber seed meal on total cholesterol, LDL and HDL in broiler chickens

Attributes	Treatment				SEM	*p* Value
	Group 1 (Control)	Group 2 (RSM–10%)	Group 3 (RSM–15%)	Group 3 (RSM–20%)		
Cholesterol (mg dl^{-1})						
d 28	111.90^{b}±0.76	111.38^{a}±0.84	110.07^{a}±0.40	112.95^{b}±1.05	0.45	0.16
d 35	107.38^{a}±1.39	111.67^{a}±0.93	109.87^{a}±2.22	110.31^{a}±0.60	0.69	0.18

Table 7 Continue.....

Attributes	Treatment				SEM	*p* Value
	Group 1 (Control)	Group 2 (RSM–10%)	Group 3 (RSM–15%)	Group 3 (RSM–20%)		
d 42	122.10^{c}±1.21	122.99b±0.83	123.05b±0.98	122.94c±0.77	0.43	0.26
p value	<0.01**	<0.01**	<0.01**	<0.01**		
Average	113.80±1.95	115.35±1.51	114.33±2.00	115.40±1.52		
LDL (mg dl^{-1})						
d 28	11.78^{a}±0.54	11.67a±0.44	11.07a±0.55	11.65a±0.44	0.23	0.77
d 35	13.66^{b}±0.38	12.71a±0.35	12.57b±0.31	12.97a±0.43	0.19	0.26
d 42	19.99^{c}±0.69	20.37b±0.34	21.31c±0.42	20.89b±0.50	0.25	0.32
p value	<0.01**	<0.01**	<0.01**	<0.01**		
Average	15.14±1.09	14.92±1.05	14.98±1.37	15.17±1.11		
HDL (mg dl^{-1})						
d 28	82.63^{ab}±0.41	82.15a±0.58	82.04a±0.40	81.58a±0.42	0.23	0.51
d 35	81.76^{a}±0.61	81.88a±0.74	81.21a±0.56	81.45a±0.61	0.30	0.89
d 42	84.51^{b}±0.76	86.49b±1.13	86.17b±0.90	86.02b±0.92	0.47	0.53
p value	0.03*	<0.01**	<0.01**	<0.01**		
Average	82.97±0.47	83.51±0.72	83.14±0.73	80.02±0.67		

abc: means with different superscript in the same column differ significantly; * (p<0.05), **(p<0.01), RSM: Rubber seed meal

3.4.2. Total protein

Total protein was non-significant (p>0.05) when fed with rubber seed meal. However, Babatunde et al. (1990) observed no significant differences in the plasma total protein level but it tended to be depressed by increasing levels of RSM protein by replacing soybean meal protein in the diets of growing pigs. Ao et al. (2011) reported no variation when fed diets containing 5% PKM supplemented with or without carbohydrase cocktail in pigs.

3.4.3. Albumin

The average albumin values (g dl^{-1}) among the different treatment groups did not differ significantly (p>0.05) at 28th, 35th and 42nd day of experiment and the average of whole period. Higher protein intake increase serum albumin reported by Hallford et al. (1982) and Shetaewi and Ross (1991). The present study was similar to Babatunde et al. (1990) who reported no significant different in the plasma albumin of the growing pigs fed rubber seed meal upto 30 % level by replacing soybean meal protein. Adesehinwa et al. (2008) observed that the levels were not affected when cassava peel meal based diets was fed to growing pigs at 40 % level supplementing with avizyme.

3.4.4. Globulin

The serum globulin values were non-significant (p>0.05) among the different treatment group and the average of the whole period. Adesehinwa et al. (2008) observed no changes in the globulin levels of growing pigs fed cassava peel based diets supplemented with avizyme 1300. Akintunde et al. (2011) observed pigs fed enzyme supplemented with PKM based diets did not significantly (p>0.05) affect the globulin levels.

3.4.5. Cholesterol

Cholesterol value was not significant (p>0.05) among treatment groups compared to the control group which was similar to the findings of Ijaiya et al. (2011) where they found non-significant changes cholesterol level in broiler birds by feeding of RSM. The present finding differs with Siriwathananukul et al. (2010) who reported blood cholesterol tended to decrease in pigs fed with para rubber seed kernel (PRSK) diets (p>0.05) because PRSK diets contain high unsaturated fatty acids. Wen et al. (2019) also found total yolk cholesterol content of laying hens decreased in RSO (Rubber seed oil) supplement groups compared to the control group. Adesua et al. (2013) reported no significant difference (p>0.05) in the serum cholesterol when maize was replaced at 0, 20 and 40 % with POS in broiler poultry. On the contrary, Onibi et al. (2011) observed that the serum cholesterol levels increased significantly (p<0.05) in chickens with increasing levels of POS in diets and further suggested that POS inclusion in the diets could lead to hypercholesterolemic tendency in birds.

3.4.6. HDL-cholesterol

Serum HDL value was non-significant (p>0.05) between treatments groups. Ezekwe et al. (2011) reported feeding of

freeze dried purslane leave to growing pigs at 8 % level with 0.5 % crystalline cholesterol showed a significant (p<0.05) increase in the serum HDL-C.

3.4.7. LDL-cholesterol

Serum LDL value was non-significant (p>0.05) between treatments groups. Ezekwe et al. (2011) reported feeding of freeze dried purslane leave to growing pigs at 8 % level with 0.5% crystalline cholesterol showed a significant (p<0.05) decrease in the serum LDL-C. Ponnampalam et al. (2011) observed replacing of lard upto 11% in the diets of paediatric pig with natural palm oil (NPO), chemically modified plam oil (CMPO) and enzymetically modified plam oil (EnPO) showed no significant difference in the plasma LDL-C level.

3.4.8. SGPT and SGOT

There was no significant (p>0.05) difference among the treatment groups in SGPT and SGOT values at 28th, 35th and 42nd days of experiment period. Similarly, Ajuonuma et al. (2013) reported there was no significant (p>0.05) difference in the serum SGPT levels when turkeys are fed concentrate diet incorporated with palm kernel cake (PKC) at 10, 20 and 30% level. Adesehinwa et al. (2008) observed no variation in the serum SGOT in pigs when unconventional feed like cassava peel meal was supplemented in their diets. However, feeding of wild sunflower leaf meal to growing pigs at 10, 20 and 30% was highly significant between the treatment groups (Fasuyi et al., 2013).

Total cholesterol, LDL and HDL concentrations in serum of experimental broiler chickens did not differ significantly (p>0.05) among the treatment groups but the values of lipid profile parameters were different between the three periods of the collection during the experiment.

Serum enzymes SGOT and SGPT values were similar among the different treatment groups but SGPT level was significantly different between the periods in control and RSM – 10 groups (Table 8)

Table 8: Effect of supplementation of rubber seed meal SGOT and SGPT in broiler chicken

Attributes	Treatment					p Value
	Group 1 (Control)	Group 2 (RSM–10)	Group 3 (RSM–15)	Group 3 (RSM–20)`	SEM	
SGOT (U/I)						
d 28	164.84^{b}±0.27	163.64^{b}±0.60	162.86±0.84	162.46±1.18	0.44	0.26
d 35	161.37^{a}±0.60	160.62^{a}±0.69	161.00±0.72	160.22±0.37	0.29	0.58
d 42	160.83^{a}±0.25	159.31^{a}±0.35	160.62±0.65	160.16±0.33	0.23	0.08
p value	<0.01**	<0.01**	0.12	0.08		
Average	162.35±0.57	161.19±0.57	161.50±0.48	160.95±0.49		
SGPT (U/I)						
d 28	19.97±0.13	20.34±0.32	20.45±0.19	20.42±0.26	0.12	0.59
d 35	20.50±0.42	20.78±0.29	20.27±0.26	20.90±0.25	0.15	0.50
d 42	20.37±0.27	20.18±0.28	20.22±0.13	20.36±0.30	0.12	0.93
p value	0.46	0.37	0.72	0.34		
Average	20.28±0.17	20.43±0.17	20.31±0.10	20.56±0.16		

^{ab}means with different superscript in the same column differ significantly; ** (p<0.01). RSM - Rubber seed meal

4. CONCLUSION

Rubber seed meal after processing could be incorporated in the diet along with other feed ingredients as a replacement of maize up to 20% without any adversely affecting blood biochemical and enzyme profiles of broiler chickens.

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