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Influence of biologically treated jojoba meal with or without *Alpinia galanga* on growth performance and blood profile of weanling rabbits in North Sinai, Egypt

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ABSTRACT

The purpose of this work was to assess the utilization of biologically treated jojoba meal without or with *Alpinia galanga* as a protein source in weanling rabbits' feed. Thirty weaned New Zealand white (NZW) rabbits, aged 35 days and weighed 653.0±45.03 g, were assigned at random to three treatment groups (10/group). Experimental groups were as follows: the 1st group: Basal diet (CON), the 2nd group: Basal diet containing 10% treated jojoba meal (JML; substituted 40% of the soybean protein) and the 3rd group: Basal diet containing 10% treated jojoba meal and 0.25% *Alpinia galanga* (JMLA). At the finish of the experiment duration, four rabbits were randomly picked from each group and slaughtered to examine carcass features and blood characteristics. Results indicated that replacement of 40% soybean protein by protein of biologically treated jojoba meal without or with *Alpinia galanga* did not affect growth performance such as live body weight (LBW), total weight gain (TWG), daily weight gain (DWG), total and daily feed intake (TFI and DFI), feed conversion ratio (FCR), relative growth weight (RGW) and performance index (PI) at different ages (5-13 weeks age). Viability (%) was 100% for all treatment groups. Results indicated no discernible variations in blood parameters or carcass features among treatment groups. It could be concluded that the weanling rabbits' growth performance and health are unaffected using biologically processed jojoba meal without or with *Alpinia galanga* as a partial substitute for soybean meal protein.

Introduction

Soybean protein is regarded as the primary source of protein in a rabbit's diet. However, the soybean meal price has increased in the last years. As a result, it is essential to explore non-conventional protein sources to supplement the diets of rabbits (Zewail *et al*., 2008).

Jojoba (*Simmondsia chinensis*) is a native desert shrub found in the Sonora Desert of Mexico and the southwestern United States. It is now cultivated in several countries, including the United States, Argentina, and various Mediterranean and African nations. Egypt is ranked fifth globally in jojoba cultivation Khalil (2021), with an area of 20,000 acres dedicated to this crop (Mostafa, 2023). In Egypt, jojoba farming is primarily concentrated in the Ismailia, El-Sharkia, New Valley, and Assiut Governorates (El-Rayes, 2010). The leftover meal after oil extraction contains between 20% to 33% crude protein, which can serve as a protein source for livestock (El-Rayes, 2010; Elsanhoty *et al*., 2017). Jojoba meal comprises anti-nutritional components including simmondsin, trypsin inhibitors, phytic acid and bitter substances which can impair feed intake and growth in animals (Abbott *et al*., 2004). Various techniques can be employed to lessen these harmful and bitter components in a jojoba meal. These methods include solvent extraction, heating, chemical, and biological treatments (Bellirou *et al*., 2005).

Alpinia galanga is a medicinal plant that can be utilized in rabbits' diet to enhance the productive performance of rabbits. *Alpinia galanga* contains antioxidants and flavonoids like galangal, alpinin, 3-dioxy-4-methoxy and 1'Sacetoxyeugenol acetate (El-Zaher *et al*., 2020; Liu *et al*., 2023). In addition, it contains lectin which is crucial for the immunomodulatory response which helps cells development (Yuandani *et al*., 2023).

The study's objective was to evaluate the impact of biologically treated jojoba meal with or without *Alpinia galanga* on rabbits' growth performance and blood parameters.

Materials and methods

This study was approved by the ethical committee at Faculty of Environmental Agricultural Sciences, Arish University, Egypt (Research code: #ARU/Agri.36#). This current research was conducted at the Rabbitry Farm of the Department of Animal and Poultry Production, Faculty of Environmental Agricultural Sciences, Arish University, located in North Sinai, Egypt. It started from the beginning of September to end of October 2023 (56 days). Jojoba meal (*Simmondsia chinensis*) was purchased from a private Oil Mill at Sadat City, Menoufyia Governorate, Egypt. *Alpinia galanga* rhizomes (powder) was obtained from the local market, Cairo, Egypt.

Bio-detoxification of jojoba meal

Lactobacillus acidophilus was obtained from Friendly Human Bacterial Unit-National Research Center, Dokki, Cairo, Egypt. It was cultivated in MRS broth (De Man–Rogosa–Sharpe) and then placed in skimmed milk (120 mg skimmed milk powder/liter distilled water) in a sterile environment. The mixture was then incubated at 37°C for 48 hours to allow it to curdle. One day before the detoxification implementation, bulk cultures were prepared. The resulting culture at 10% (v/w) of jojoba meal was sprayed on jojoba meal after sterilized by autoclaving it for 20 minutes at 125°C under pressure. Then, packaged in polyethylene bags and incubated for 21 days at a temperature of 26°C under anaerobic conditions according to Verbiscar *et al*. (1981). The treated jojoba meal was sun-dried and stored in a temperature room until it was used.

Total simmondsin extracted from jojoba meal

Based on methodology of Van Boven *et al*. (1993) total simmondsin was extracted from defatted jojoba meal. The fat was extracted from the

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jojoba meal using n-hexane for 16 hours with a Soxhlet apparatus. Then, total simmondsin was extracted from defatted jojoba meal using acetone for 72 hours with a Soxhlet apparatus. Then, a rotary evaporator was used to evaporate the solvent, and the amount of simmondsin (%) that remained was quantified.

Designing of experiment and diets

Thirty unsexed weaned New Zealand White (NZW) rabbits were obtained from the Rabbitry Farm, Faculty of Environmental Sciences, Arish University, aged 35 days were randomly divided into three equal treatment groups (10 rabbits per group) with initial live body weight (653.0±45.03 g). Each group contained 5 replicates of 2 rabbits each. Experimental groups were as follows:

The 1st group: Basal diet (Control).

The 2nd group: Basal diet containing 10% Treated jojoba meal (JML), (substitute 40% soybean protein).

The 3rd group: Basal diet containing 10% Treated jojoba meal and 0.25% *Alpinia galanga* (JMLA).

The treated jojoba meal and *Alpinia galanga* were efficiently mixed with the feed ingredients and formed into pellets. The three experimental diets were designed to fulfill the rabbits' dietary requirements (NRC, 1977) and similar in crude protein (~16%) and DE (2500 kcal /kg diet). The formulation of the experimental diets utilized in this work is presented below in Table 1.

Samples of the untreated and treated jojoba meal, *Alpinia galanga* and three experimental diets were analyzed to measure moisture, dry matter (DM), fat (EE), crude fiber (CF), ash and crude protein (CP) according to AOAC (2012). The carbohydrate content (NFE) was calculated mathematically using the formula: NFE% = (Moisture+CF+CP+EE+Ash).

Table 1. Composition of the three diets for the experiment.

Ingredient	Experimental diets[1]		
	CON	JML	JMLA
Yellow corn	10	8.5	8.5
Wheat bran	22	24.5	24.25
Soybean meal (46%)	15	9.7	9.7
Treated jojoba meal	0	10	10
Alfalfa hay	31	31	31
Barley grains	16.7	11	11
Alpinia galanga	0	0	0.25
Molasses	3	3	3
Dicalcium Phosphate	0.5	0.5	0.5
Limestone	0.9	0.9	0.9
Sodium chloride (salt)	0.3	0.3	0.3
Premix * (Vitamins & Minerals)	0.3	0.3	0.3
Antifungus	0.1	0.1	0.1
Lycine	0.1	0.1	0.1
Methionine	0.1	0.1	0.1
Total	100	100	100

[1]Experimental diets: CON= Control, JML=10% Treated Jojoba meal, JMLA=10% Treated Jojoba meal+ 0.25% *Alpinia galanga*. *: 1 Kg. of premix contains Vitam. A 12000IU, Vitam.B1 1000mg, Vitam.B2 4000mg, Vitam. B6 100mg, Vitam. B12 10mg, Vitam.D3 2200IU, Vitam. E 1000mg, Vitam. K3 2000mg, folic acid 0.83 g, pantothenic acid 3.33g, chloride 200g, biotin 33mg, Mn 5g, Zn 11.79g, Cu 0.5 g, Se 16.60mg, Fe 12.50g, Mg 66.7 g and I 33.30mg.

Habitation and administration

Rabbits were housed (two rabbits/ cage) measuring (30 x 40 x 40 cm), each equipped with an automatic stainless-steel drinking nipple and a feeder. The building was well-ventilated, with an average temperature of 26.92°C to 28.73°C and relative humidity (RH) of 69.70%, under a 12-hour light/12- hour dark cycle. All rabbits had continuous access to diet and water. They were raised in the same managerial, sanitary and environmental circumstances and were clinically free of both internal and external parasites. Rabbits of each treatment group were weighed at the start of the experimental period and biweekly. Growth performance as live body weight, total weight gain and daily gain. Feed intake was recorded biweekly and feed conversion ratio was measured (g feed intake / g weight gain) and relative growth rate (RGR%) was recorded and viability (%) was also determined. Performance index (PI%) was recorded as stated by North (1981) formula: PI%= (final live body weight (kg)/ feed conversion ratio)×100.

Carcass traits

Four rabbits (two males and two females) were randomly chosen from each treatment group at the end of the 56-day of the experiment and slaughtered to assess the carcass features. The rabbits were weighed and slaughtered by cutting their jugular veins with a sharp knife following a 12-hour fast. The slaughtered rabbits were skinned and disemboweled once the bleeding had finished. Carcass traits were estimated according to Cheeke (1987). Edible giblets (heart, liver and kidney) were separated and weighed. Next, the empty carcass with the head was then weighed. Dressing (%) was estimated as the weight of the hot carcass relative to pre-slaughter body weight.

Blood metabolites

Blood samples were taken from the jugular veins of slaughtered rabbits. The samples were placed in dry plastic tubes and allowed to coagulate at room temperature for 30 minutes. After coagulation, the samples were centrifuged at 3500 rpm for 15 minutes. The resulting blood serum was then used to estimate various blood constituents. Total protein content was measured using the method described by Henry *et al*. (1974). Albumin levels were assessed according to Dumas and Biggs (1972). The globulin concentration was determined by subtracting the albumin value from the total protein content. The albumin-to-globulin (A/G) ratio was calculated. Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities were measured using the methods outlined by Reitman and Frankel (1957). Total cholesterol and triglyceride levels were determined according to the method by Zollner and Kirsch (1962). Serum glucose concentration was measured using the method described by Trinder (1969). Lastly, serum creatinine and urea levels were assessed following the procedure established by Husdan and Rapoport (1968).

Statistical analysis

The present study's data were analyzed using a one-way (ANOVA). This was done with the general linear model (GLM) procedure in SAS (2004), following the methods outlined by Steel and Torrie (1980). When the F value was significant ($P<0.05$), the means were compared using the least significant difference (LSD) test.

Results

Chemical analysis of jojoba meal, Alpinia galanga and the tested diets

The chemical composition of both untreated and treated jojoba meal (using *Lactobacillus acidophilus*), *Alpinia galanga* and the tested diets were displayed in Table 2. Crude protein (CP), fat (EE) and ash of jojoba meal (JM) were not affected by treating JM with *Lactobacillus acidophilus*. Crude fiber (CF) of treated JM decreased by 15.67% in comparison with the untreated JM, while nitrogen free extract (NFE) increased by 13.86% compared with the untreated JM. Digestible energy (DE Kcal/kg) of treated JM improved compared to the untreated JM. Bacterial treatment (*Lac-*

tobacillus acidophilus) decreased simmondosin content from 2.75% in untreated JM to 0.5% in treated JM (by about 81.8%) (Table 2).

Growth performance of weanling rabbits

There were no discernible variations observed in live body weight (LBW), total weight gain (TWG), and daily weight gain (DWG) among the treatment groups at all ages (from 5 to 13 weeks), as indicated in Table 3. Rabbits that were given JML diet exhibited lower LBW, DWG and DWG values than those given CON diet (P>0.05). In contrast, rabbits that were given a diet of JMLA exhibited higher (P>0.05) values in these parameters than those were given CON diet.

Feed intake, feed conversion, relative growth rate and performance index

The results shown in Table 4 indicated that replacement of 40% soy-abean protein by protein in treated JM without or with *Alpinia galanga* did not statistically affect FI, FCR, RGR% and PI% at different ages (from 5 weeks to13 weeks). Regarding FCR, RGR% and PI% of rabbits fed on JMLA diet had best values followed by that fed CON diet, while that fed JML diet had the worst values.

Carcass traits

There were no noticeable variations in carcass features among the treatment groups (P>0.05) (Table 5). The internal organs (liver, kidneys, heart and spleen) were normal in size and showed no toxicity. However, there were slightly increases in giblets (liver, kidneys, heart and spleen) in rabbit fed JMLA compared with the other two groups (JML and CON).

Blood biochemical changes

Liver function

As demonstrated in Table 6, dietary treatments did not noticeably influence total protein (TP), albumin (AL), globulin (GL) and AL/GL ratio . Results revealed that there was an increase (P>0.05) in GL of rabbits fed treated JM without or with *Alpinia galanga* compared to that fed CON diet.

Table 6 indicates that there were no noticeable variations in the AST, ALT values, and AST/ALT ratio among the treatments (P>0.05). It is worth noting that the JML group had higher (P>0.05) AST and ALT activities than the JMLA and CON groups.

Kidney function

Dietary treatments had no effect (P>0.05) on creatinine and urea in rabbits blood serum as shown in Table 6. However, it tended to be lower (P>0.05) in JML and JMLA groups in comparison to CON group.

Table 2. Chemical analysis (%) of jojoba meal, *Alpinia galanga* and the tested diets.

Items	DM	DM basis%							DE[3] (kcal/kg)	Simmondosin%
		OM	CP	EE	CF	NFE	Ash	NDF[2]		
Untreated Jojoba Meal	91.6	87.46	31.42	15.88	14.48	25.68	12.54	38.44	2476	2.75
Treat Jojoba Meal	91.1	88.03	31.67	14.91	12.21	29.24	11.97	36.95	2550	0.5
Alpinia galanga	92.56	90.8	8.93	14.36	7.55	59.97	9.19	33.88	2.70	-
Chemical composition of experimental diets[1]										
Diet (1): CON	90.4	90.4	18.04	4.56	13.04	54.76	9.6	37.49	2523	
Diet (2): JML	90.5	90.97	18.45	5.35	16.32	50.85	9.03	39.65	2417	
Diet (3): JMLA	90.5	90.96	18.42	5.37	16.31	50.86	9.04	39.64	2413	

[1]Dite (1): CON, Control, basal diet, Dite (2): JML, 10% Treated jojoba meal, Dite (3): JMLA, 10% Treated jojoba meal and 0.25% *Alpinia galanga* Calculated according to Cheeke, (1987): 2NDF% = 28.924 + 0.657 (CF%) and 3DE (Kcal/kg) = 4.36 – 0.0491 (NDF%).

Table 3. Impact of dietary interventions on weanling rabbits' growth performance from 5-13 weeks of age (56 days).

Items	Experimental diets[1]			SE[2]	Sig.[3]
	CON	JML	JMLA		
No. weanling rabbits	10	10	10		
No. dead weanling rabbits	0	0	0		
Viability (%)	100	100	100		
		Live body weight (LBW; kg)			
5 weeks (Initial)	0.65	0.65	0.65	0.05	NS
9 weeks	1.55	1.56	1.59	0.05	NS
13 weeks (Final)	2.27	2.2	2.35	0.06	NS
		Total weight gain (TWG; kg) from:			
5-9 weeks	0.90	0.90	0.94	0.05	NS
9-13 weeks	0.714[ab]	0.644[b]	0.753[a]	0.03	
5-13 weeks	1.62	1.55	1.69	0.06	NS
		Daily weight gain (DWG; g) from:			
5-9 weeks	32.18	32.23	33.50	1.66	NS
9-13 weeks	25.501[ab]	23.001[b]	26.894[a]	1.08	
5-13 weeks	28.84	27.62	30.20	1.10	NS

Table 4. Impact of dietary interventions on feed intake, feed conversion, relative growth rate and performance index of weanling rabbits from 5-13 weeks of age (56 days).

Weeks	Experimental diets[1]			SE[2]	Sig.[3]
	CON	JML	JMLA		
			Total feed intake (TFI; g) from:		
5-9 weeks	1998.4	2025.25	2029.28	84.6	NS
9-13 weeks	3342.37	3305.2	3466.04	130.37	NS
5-13 weeks	5340.77	5330.46	5495.32	199.93	NS
			Daily feed intake (DFI; g) from:		
5-9 weeks	71.37	72.33	72.47	3.02	NS
9-13 weeks	119.37	118.04	123.78	4.65	NS
5-13 weeks	95.37	95.18	98.13	3.57	NS
			Feed conversion ratio (FCR) from:		
5-9 weeks	2.14	2.3	2.13	0.09	NS
9-13 weeks	4.84	4.84	4.53	0.27	NS
5-13 weeks	3.27	3.41	3.2	0.12	NS
			Relative growth rate (RGR, %) from:		
5-9 weeks	82.66	82.56	84	4.75	NS
9-13 weeks	37.47	34.46	38.57	1.78	NS
5-13 weeks	111.2	108.93	113.15	4.53	NS
			Performance index (PI. %) from:		
5-9 weeks	72.52	67.38	74.78	3.79	NS
9-13 weeks	47.14	46.35	51.61	2.54	NS
5-13 weeks	69.26	65.26	73.29	2.97	NS

[1]Treatment, CON, Control, basal diet, JML, 10% Treated jojoba meal, JMLA, 10% Treated jojoba meal and 0.25% *Alpinia galanga*. [2]SE= standard error. [3]NS= non-significant

Table 5. Impact of dietary interventions on weanling rabbit carcass features at 13 weeks of age.

Weeks	Experimental diets[1]			SE[2]	Sig.[3]
	CON	JML	JMLA		
Live Body wt. (kg)	2.16	2.17	2.24	0.03	NS
Empty carcass with head wt. (kg)	1.29	1.29	1.34	0.04	NS
Liver (g)	60.25	59.45	60.98	1.75	NS
Kidney (g)	12.83	13.73	14.51	0.92	NS
Heart (g)	6.55	6.88	6.98	0.47	NS
Edible Glits (g)	79.64	80.07	82.48	2.38	NS
Hot carcasses (Total Edible Parts) (kg)	1.36	1.37	1.42	0.04	NS
Dressing (%)	63.25	63.16	63.49	1.55	NS
Non-Edible Parts	792.85	798.67	816.27	33.82	NS
Head (g.)	138.96	134.47	141.33	4.72	NS
LHW (g.)	10.63	10.93	10.96	0.64	NS
Hind legs (g.)	455	451.25	455	13.4	NS
Spleen (g.)	1.57	1.58	2.05	0.55	NS
Abdominal Fat (g.)	22.39	20.93	24.25	2.05	NS

[1]Treatment, CON, Control, basal diet, JML, 10% Treated jojoba meal, JMLA, 10% Treated jojoba meal and 0.25% *Alpinia galanga*. [2]SE = standard error. [3]NS= non-significant

Serum glucose

Results illustrated in Table 6 revealed no significant variations (P>0.05) among treatment groups in serum glucose. However, the mean tended to be higher (P>0.05) in the JMLA group (121.5 mg/dL) compared with the CON and JML groups (105.5 and 101 mg/dL), respectively.

Cholesterol and triglycerides

There were no discernible variations (P>0.05) in cholesterol and triglyceride values among the treatment groups. However, the JML group exhibited higher cholesterol and triglyceride values than the CON group (Table 6). While cholesterol and triglyceride levels decreased (P>0.05) in the JMLA group compared to the JML group.

Discussion

The improvement in the CF of treated jojoba meal may be attributed to microbial degradation throughout the incubation time. The microorganisms present in the jojoba meal treatment produced cellulase enzymes, which enhanced the nutrient content (El-Banna *et al.*, 2010; Abdel-Aziz *et al.*, 2014). In this regard, Khayyal *et al.* (2009) observed that treating JM with lactic acid bacteria resulted in an increase in CP by 22% and ash by 34%, while CF was declined by about 22% compared with untreated JM. Additionally, simmondosin content decreased from 4.82 in raw JM to 0.15 in treated JM. In this respect, El-damrawy *et al.* (2015)

Table 6. Impact of dietary interventions on some blood metabolites of weanling rabbits (at 13 weeks of age).

Items	Experimental diets[1]			SE[2]	Sig.[3]
	CON	JML	JMLA		
			Liver function		
Total Protein (TP) (g/dl)	6.05	6.37	5.95	0.49	NS
Albumin (AL) (g/dl)	3.87	3.82	3.52	0.19	NS
Globulin (GL) (g/dl)	2.17	2.55	2.42	0.48	NS
(A/G) ratio	2.03	1.67	1.62	0.33	NS
AST (U/L)	48	67.75	50.25	11.43	NS
ALT (U/L)	48.25	54.75	47	6.89	NS
AST/ALT	1.01	0.89	1.12	0.21	NS
			kidney function		
Creatinine (mg/dl)	1.29	1.26	1.23	0.09	NS
Urea (mg/dl)	45.75	44	40.5	5.03	NS
urea / creatinine	35.18	34.86	32.91	2.57	NS
Glucose (mg/dl)	105.5	101	121.5	9.69	NS
Cholesterol (mg/dl)	81.33	117	101	26.21	NS
Triglycerides (mg/dl)	41	52.67	44.67	12.5	NS

[1]Treatment, CON, Control, basal diet, JML, 10% Treated jojoba meal, JMLA, 10% Treated jojoba meal and 0.25% *Alpinia galanga*.[2]SE = standard error. [3]NS= non-significant

confirmed that using Trichoderma reesei and *Lactobacillus acidophilus* to treat raw jojoba meal reduced simmondosin content from 3.6% in untreated jojoba meal to 0.036 and 0.037% in treated jojoba meal, respectively. This finding may be attributed to *Lactobacillus acidophilus*, which produces certain proteolytic enzymes that act on compounds of cyano-glycoside, specifically simmondsin and simmondsin-2′-ferulate. These enzymes convert these compounds into carbon chains and amid compounds, which are less toxic than simmondsin. Additionally, *Lactobacillus acidophilus* can convert microbial proteins in its own body (Abbott *et al*., 1999; El-Shennawy, 2003).

There were no discernible variations observed in growth performance between the JML group and CON group. These findings align with previous research by Abd El-Maksoud (2011), who reported that incorporating jojoba meal treated with the fungus *Aspergillus fumigatus* in rabbits' diets did not affect growth performance (LBW and TWG) compared to the CON diet. However, Khayyal *et al.* (2009) found that using lactic acid bacteria to treat jojoba meal significantly improved rabbits' growth performance (LBW and TWG) compared to the CON diet at different ages. The positive effects observed in the JM treated with lactic acid bacteria may be attributed to a reduction in simmondsin, which is considered a major toxicant in jojoba meal (Decuypere *et al*., 1996). Improvement of growth performance in JMLA group may be due to slightly improved feed intake and *Alpinia galanga* contains rich minerals and trace elements, which play a role in enhancing both physiological and nutritional efficiency (Khalifah *et al*., 2022; Imchen *et al*., 2022). Viveros *et al.* (2011) discovered that the compounds found in galanga rhizomes stimulated digestive enzymes, improved overall digestion, and consequently led to an increase in body weight. Similarly, El-Speiy *et al*. (2022) exhibited that rabbits given a diet supplemented with *Alpinia galanga* (100 mg/kg) demonstrated significantly improved growth performance, as (LBW, BWG and ADG), compared to those given a CON diet.

The lack of significant differences in feed intake among treatment groups suggests that the tested diets were balanced in both energy and protein (Khadr and Abdel-Fattah, 2008). It is evident that there was a slight increase in feed intake of JMLA group compared to the other two treatment groups (JML and CON). Similarly, El-Speiy *et al*. (2017) observed that adding *Alpinia galanga* at level (100 mg/kg diet) significantly increased feed intake of rabbits compared with control diet. The improvement in FCR, RGR and PI of JMLA diet may be due to the components found in *Alpinia galanga* stimulated digestive enzymes which led to increased digestibility coefficients of nutrients and so reflected on increasing body weight (Viveros *et al*., 2011; El-Speiy *et al*., 2017).

The increase (P>0.05) in internal organs weight was because of the slightly increase of pre-slaughter weight in JMLA group compared with the two other groups (JML and CON). According to Ortiz *et al.* (2001) it confirmed that pre-slaughter weight is a crucial factor influencing carcass traits in rabbits. These findings align with Abd El-Maksoud (2011), who discovered that carcass characteristics are expressed as a percentage of pre-slaughter of rabbit fed on diet containing treated JM with fungus at level (10%) did not differ significantly than that fed control diet. In a similar vein, El-Adawy *et al.* (2013) found that most of carcass characteristics were not affected as result of replacement of 30% soyabean protein by protein of treated JM with *Lactobacillus acidophilus* except for dressing and liver weights and carcass% of the pre-slaughter weight. Ibrahim *et al*. (2011) showed that different levels of *Alpinia galanga* (0.5 and 1%) did not affect carcass parts, digestive tract and chemical analysis of 9, 10 and 11th ribs.

Results revealed that there was an increase (P>0.05) in GL of rabbits fed treated JM without or with *Alpinia galanga* compared to that fed CON diet. The rise in GL levels may be associated with enhanced innate immune response and increased antibody production (Riche *et al*., 2007). These findings align with El-Adawy *et al*. (2013) who reported that increase (P<0.05) by 25.3% in plasma GL values in rabbits given a diet containing 30% treated jojoba meal in comparison to those on a control diet. These findings suggest that a diet enriched with jojoba meal positively affects immune response (Abdel-Azize *et al*., 2019). The amount and quality of protein consumed generally affects total protein, albumin and globulin (Onifade and Tewe, 1993). However, the synthesis of serum proteins is mainly associated with the quantity of available protein in the diet (Amaza *et al*., 2020). This study found that the amount of dietary protein consumed was sufficient for nutritional needs of growing rabbits. In the same trend, Abd El-Maksoud (2011) reported that fed diets with 10% fungus-treated jojoba meal led to an insignificant decrease (P>0.05) in TP, AL and GL concentrations compared with control group. This confirms that the bacteria-treated jojoba meal in the current work reduced the simmondsin concentration therefore reduced the effect of anti-nutrients in rabbit diet. Our findings may be due to polyphenol compounds found in the jojoba meal and *Alpinia galanga*.

There were no discernible variations in the AST, ALT activities, and AST/ALT ratio among the treatments. These findings were similar to the ones found by Khayyal *et al*. (2009) and El-Adawy *et al*. (2013) when rabbits given a diet containing a jojoba meal treated with lactic acid bacteria

and *Lactobacillus acidophilus*, respectively. In rabbits fed the JMLA diet, the levels of AST and ALT showed a slight decrease compared with those on the JML diet. The observation may be attributed to the bioactive compounds found in Alpinia species, such as phenols and total flavonoids, which are known to enhance liver function through their antioxidant activity (Negm and Ragheb, 2019).

Creatinine and urea in rabbits blood serum were lower (P>0.05) in JML and JMLA groups in comparison to CON group. These findings are consistent with results acquired by Khayyal *et al*. (2009) and El-Adawy *et al*. (2013). Also, Kaushik *et al*. (2013) reported that the *Alpinia galanga* decreased blood urea nitrogen in rats.

Increasing serum glucose (P>0.05) in the JMLA group compared with the CON and JML groups was align with earlier research carried out by Khattab *et al*. (2017) who showed that *Alpinia galanga* caused an increase (P>0.05) in the plasma glucose of lactating Barki goats. Our findings were consistent with the results obtained by Khayyal *et al*. (2009) and El-Adawy *et al*. (2013).

In this study the JML group exhibited higher (P>0.05) cholesterol and triglyceride values than the CON group. This finding is consistent with the work by El-Kady *et al*. (2008) who indicated that lambs fed varying amounts of jojoba meal in their diets had elevated total cholesterol and triglyceride values. While cholesterol and triglyceride levels decreased (P>0.05) in the JMLA group compared to the JML group. This finding aligns with research by El Speiy *et al*. (2022) who showed significant reductions in cholesterol levels in rabbits fed on *Alpinia galanga*. The observed decrease may be due to the presence of saponins and tannins in *Alpinia galanga*. Matsura (2001) reported that saponins from various sources can lower serum cholesterol levels in different animal species. Several dietary saponins have demonstrated hypocholesterolemic effects (Francis *et al*., 2002). Additionally, saponins inhibit pancreatic lipase activity, which leads to delayed dietary fat absorption (Han *et al*., 2000; Shin *et al*., 2003; Ibrahim *et al*., 2011). Tannins also significantly impact lipid digestibility by forming complexes with fatty acids Romero *et al*. (2000), resulting in decreased cholesterol absorption and increased fat excretion (Bravo *et al*., 1993).

Our results indicate that all serum parameters fell within the normal range for growing rabbits (Manning *et al*., 1994). This suggests that the rabbits received adequate protein and minerals from their diets and utilized them effectively. The blood parameters assessed in this study confirm that the rabbits were in good health and that the feed provided was sufficient and properly balanced with the necessary nutrients for optimal growth.

Conclusion

This study showed that up to 40% of soybean protein can be replaced with protein of biologically treated jojoba meal using *Lactobacillus acidophilus*, with or without *Alpinia galanga* in the diet of growing rabbits. This substitution have no harmful effects on their growth performance.

Conflict of interest

The authors have no conflict of interest to declare.

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