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Influence of Jojoba Meal Treated with *Lactobacillus acidophilus* on Digestibility, Carcass Traits and Blood Metabolites in Growing Rabbits#

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ABSTRACT

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The aim of the study was to evaluate the effect of substitution of soybean meal protein by *L. acidophilus* treated jojoba meal (JM) protein in rabbit's diets on digestibility of nutrients, N balance, caecotrophy, some blood metabolites and carcass traits. Thirty two 5-weeks-old rabbits were divided into four equal experimental groups, 8 rabbits of each in a complete random design. Soybean meal protein was partially replaced by treated JM protein at 0, 10, 20 and 30% to formulate the experimental diets. Feeding treated JM increased ($P<0.05$) of all nutrient digestibility except ether extract, accordingly nutritive values expressed as total digestible nutrients and digestible crude protein were improved ($P<0.01$) for diet contained 30% treated JM protein. N balance (g/day) was increased ($P<0.05$) in rabbits fed diet with 30% treated JM protein versus control. Incorporation of treated JM at 30% in the rabbit's diets increased ($P<0.05$) daily soft faces excretion, whereas crude protein the proportion of soft faces to total crude protein intake was higher ($P<0.05$). Plasma total protein, transaminases activity (GOT and GPT), glucose, creatinine and urea concentrations did not differ in JM supplementation diets versus control. Cholesterol and triglycerides concentrations decreased ($P<0.05$) with the substitution of JM protein in diets from 0 to 30%. Dressing percentage of the rabbit fed 30% treated JM protein was increased ($P<0.01$) by 5.1% compared to control diet. Supplementation of JM protein at 30% in rabbit's diets could increase nutrient digestibility, carcass traits quality and improve animal health.

Key words: Carcass traits, Digestibility, Jojoba meal, Lactobacillus, Rabbits.

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INTRODUCTION

Animal protein resources for human consumption can be partly met through rabbit's production. However, for intensified rabbit's production as poultry, it is necessary to develop low cost feed in developing countries. In Egypt, high feeding costs result from the shortage of protein sources used for animal feed. Therefore, there is a need to evaluate alternative protein sources to overcome such shortage problem. Jojoba (*Simmondsia chinensis*) is a shrub belonging to the Simmondsiaceae family which can be used as untraditional protein source in the animal diets. It is commonly grown in some countries such as, Argentina (2.0 hectares/year), Israel (1.1 hectares/year), and USA (1.1 hectares/year) and some Mediterranean and African lands. Around the world, 7930 hectares has been planted with jojoba shrub (Canoira *et al.*, 2006). In Egypt, the cultivation areas were concentrated in Ismailea region, New Valley, El-Sharkia and Assiut Governorates for increasing land reclamation (El-Rayes, 2010). High protein content of JM (from 20 to 30%) supports its potential as an ingredient for animal nutrition practices (Farag, 2007; El-Rayes, 2010). A limitation in the usage of JM as animal feedstuff might be due to its high content of simmondsin, simmondsin 2'-ferulate, and related cyano-methylenecyclohexyl glycosides (Van Boven *et al.*, 2000). Simmondsin is a toxic agent for broiler (Farag, 2007) and lambs (El-Kady *et al.*, 2008). The aim of the current study was to evaluate the effect of substitution of soybean meal protein by *L. acidophilus* treated JM protein in rabbit's diets on digestibility of nutrients, N balance, caecotrophy, some blood metabolites and carcass traits.

MATERIALS AND METHODS

Experimental procedures

Thirty two unsexed NZW rabbits, 5 weeks of age (650.5±5.5 g) were divided randomly into four equal experimental groups, 8 rabbits each. The experiment lasted for 12 weeks. Rabbits were housed in galvanized wire batteries of individual cages in a well ventilated building. Fresh water and diets were offered *ad libitum*. All rabbits were kept under the same managerial, hygienic and environmental conditions.

Four experimental diets were formulated to cover all the essential nutrient requirements for growing rabbits (De Blas and Mateos, 1998). The first group of rabbits was fed a basal diet containing soybean as a main source of protein. Soybean meal protein in the basal diet was partially replaced by treated jojoba meal (JM) protein with *L. acidophilus* at the level of 10, 20 and 30% to formulate the experimental diets. The composition and chemical analysis of the experimental diets are shown in Table 1.

The JM was treated with *L. acidophilus* according to the methodology of Verbiscar *et al.* (1981). *L. acidophilus* was enrichment in skimmed milk medium at 30°C for 8 days. After this period, JM was sprayed with this medium and rotating in a big bottle and incubated for 21 days at 26°C under anaerobic condition. The granular JM was ground using a hummer mill to pass a 4 mm screen. The meal was then dried

overnight in a forced air oven at 75°C, and stored in polyethylene bags until used for diet formulation.

Table 1. Composition (g/kg) and chemical analyses of the experimental diets

Ingredients	Level of JM protein (%)			
	0	10	20	30
Yellow corn	180.0	175.0	170.0	165.0
Wheat bran	165.0	161.0	158.0	155.0
Barley grain	130.0	135.0	140.0	145.0
Soybean meal[†]	150.0	135.0	120.0	105.0
Treated Jojoba meal[‡]	0.0	21.0	42.0	63.0
Berseem hay	330.0	328.0	325.0	322.0
Molasses	20.0	20.0	20.0	20.0
Limestone	10.0	10.0	10.0	10.0
Dicalsium Phosphate	6.0	6.0	6.0	6.0
Premix[§]	2.0	2.0	2.0	2.0
DL-Methionine	1.0	1.0	1.0	1.0
Commonsalt	5.0	5.0	5.0	5.0
Anti-toxicants	1.0	1.0	1.0	1.0
Chemical analyses				
Crude protein	166.6	165.8	164.2	161.9
Crude fibre	135.2	134.1	133.6	132.3
Ether extract	23.1	24.6	25.4	29.7
DL-Methionine	4.0	3.8	3.7	3.6
Lysine	10.3	9.7	9.2	8.9
Calcium	9.4	9.1	8.7	8.5
Total phosphorus	4.5	4.2	4.6	4.7
Digestible energy[¶], kcal/kg	2530	2558	2563	2582

[†]Soybean meal containing 400g CP/kg. [‡]Treated jojoba meal containing 285g CP/kg

[§]Each 3 kg of premix contained: Vitamin A 12000000 IU, vitamin D_3 2200000 IU, vitamin E 10000 mg, vitamin K3 2000 mg, vitamin B_1 1000 mg, vitamin B_2 4000 mg, vitamin B_6 1500 mg, vitamin B_{12} 10 mg, Pantothenic acid 10000 mg, Niacin 20000 mg, Biotin 50 mg, Folic acid 1000 mg, Coline chloride 500 g, Selenium 100 mg, Copper 10000 mg, Iron 30000 mg, Manganese 55000 mg, Zinc 50000 mg, Iodine 1000 mg and carrier $CaCO_3$ to 3000 g.

[¶]Calculated according to Fekete and Gippert (1985): Digestible energy (kcal/kg)=4253-32.8 (%CF)-144.4 (% ash).

Digestibility trial

A digestibility trial was performed using 16 male NZW rabbits at least three months of age and similar body weight to determine the nutrient digestibility coefficients and nutritive values of the four experimental diets. Four male rabbits in each group were housed individually in metabolic wire cages (50×50×40 cm) that allow collecting faeces and urine separately. Faecal and urinary samples were collected daily over 5 consecutive days according to the European reference method for rabbit digestion trials (Perez *et al.,* 1995). Sample of daily faeces (20%) of each rabbit were collected every day, dried at 60-70°C for 48 hrs, finally bulked, mixed, ground and kept for chemical analysis. Nutritive value in terms of total digestible nutrients (TDN) and the digestible crude protein (DCP) were calculated according to formula of Cheeke *et al.* (1982). For N balance, 10% of urine output was collected daily from each rabbit.

Sample analysis

Samples of offered feed and faeces individually taken weekly were mixed and milled through 1 mm screen and analysed for dry matter (DM, method 934.01), ash (method 942.05), nitrogen (N, method 954.01) and ether extract (EE, method 920.39) according to the AOAC (2000). Gross energy was determined by using an adiabatic bomb calorimeter. Digestible energy was calculated according to Fekete and Gippert (1985).

Semindosion was determined according to the method of Verbiscar *et al.* (1980) using the HPLC with a pump (Merck Hitachi, Germany). Samples (*i.e.,* 100g) of JM were ground to pass 1-mm, and extracted with acetone (2: 1, v/w) and refluxing for 4 h in a Soxhlet extractor. After acetone evaporation, simmondsin compounds (6.2 g of mixed toxicant) were obtained as a tan. These mixed toxicants (6.2 g) were dissolved in excess of acetone and washed through a short column containing merck silica gel 60 (230-400 mesh). The elution was concentrated to a smaller volume and acetone solution was allowed to evaporate slowly in a beaker and a product was rich in simmondsin crystallized. The simmondsin crystal was taken into 10 ml of methanol for HPLC analysis. Extraction of simmondsin was injected into a Rheodyne injector of the HPLC and samples were analysed on C_{18} silica gel column. The solvent was a mixture of methanol and water (20/80 v/v) and the flow rate was 1.0 ml/min. The column eluate was monitored at 217 nm with photodiode array detector. Calibration curve for simmondsin was obtained by plotting concentration ratio (simmondsin concentration/ concentration of internal standard) versus area ratio (area under simmondsin peak/area under internal standard peak).

Caecotrophy trial

At the end of the experiment (13 weeks), excretion of soft faeces and hard faeces were determined using four male rabbits per treatment. Plastic neck collars were used to prevent coprophagy. Soft and hard faeces of each rabbit were collected during 24 hours for three times according to the method described by Carabaño *et al.* (1988). The daily feed intake was recorded after deducting the scattered amounts. Sample of daily soft and hard faeces (about 20%) of each rabbit were taken for chemical analysis. The daily faecal samples collected were sprayed with 1% boric acid solution to prevent ammonia losses during drying. Faecal samples were dried at 70-80°C for 48 h. The dried faeces observed from each rabbit during the collection period were weighed, mixed, ground and kept for chemical analysis. Relative contribution of soft faeces to dry matter and crude protein intake were calculated according to Fraga *et al.* (1991) as follows:

Relative contribution of soft faeces to DM intake= (Soft faeces excretion, g DM/day)/ (Feed intake, g DM/day + Soft faeces excretion, g DM/day)×100.

Relative contribution of soft faeces to CP intake= (CP excreted in soft faeces, g/day)/ (CP ingested in feed, g/day + CP excreted in soft faeces, g/day)×100.

Carcass traits

Four rabbits from each treatment (2 males and 2 females) were randomly slaughtered at the end of the 14th week of age (Marketing age). Rabbits were weighed and slaughtered after fasting for 12 h (Lukefahr *et al.*, 1992). After slaughtering and complete bleeding (within 30 minutes), stomach, small intestine, caecum and large intestine weights were taken (full and empty) and carcass traits were evaluated according to Blasco *et al.* (1993). Hot carcass weight (HCW) was obtained 15-30 minutes after slaughter including liver, kidneys, head, lungs, esophagus, trachea, thymus and heart. Dressing percentage was estimated as HCW relative to pre-slaughter body weight. Cold carcass weight (CCW) was obtained after refrigerating the hot carcass between 0 and 4°C for 24 h. Giblets weight (liver, kidneys, heart and spleen), and carcass measurements were recorded.

Blood metabolites

Blood plasma was obtained by centrifugation of heparinized blood for 10 min at 3000 rpm and kept in eppendorf tubes until chemical analysis. Total protein in plasma was measured according to Tietz (1995). However, plasma albumin was measured according to Young (2001). Plasma globulin was calculated as the difference between plasma total protein and albumin. Glucose, cholesterol, triglyceride, GOT, GPT, urea and creatinine were determined using specific diagnostic kits produced by MDSS GmbH, Schiffgraben 41 (Germany) as recommended by Young (2001).

Statistical analysis

The experimental design was completely randomized. Eight rabbits per treatment were compared for digestibility and growth performance, while it was used only 4 rabbits for the evaluation of the carcass, and blood metabolites. Data were analysed using ''Mixed'' option of SAS (1996). The model included rabbits (random), jojoba protein supplementation level (fixed, 3 degrees of freedom (df)), and residual (rabbit within treatment). Levels of jojoba protein supplementation (treatments) were partitioned into linear contrasts. Significant differences were accepted when $P < 0.05$. Data were analysed according to SAS program (SAS, 1996). The application of the least of significance test for the differences among the different treatment means were done according to Duncan (1955). The following model was used:

$$Yij = \mu + Ti + eijk$$

Where, Yij=an observations; μ=Overall mean; Ti=Effect of using different levels of treated jojoba meal (i=0, 10, 20, and 30) and eijk=Residual (Random error).

RESULTS

Crude protein of treated JM increased by 19 points compared with untreated JM (Table 2), while other nutrients (ether extract, crude fiber and ash were not affected by treated JM with *L. acidophilus* bacteria, while gross energy content was also improved in treated JM.

Table 2. Nutrients and simmondsin concentrations (g/kg) and growth energy content (kcal/kg) of untreated and treated JM with *L. acidophilus*

	Untreated	Treated
Crude protein	266.2	285.2
Ether extract	113.7	111.2
Crude fiber	100.3	97.7
Ash	31.3	32.5
Simmondsin	36.0	1.6
Gross energy (kcal/kg)	5102	5114

Partial replacement of soybean meal protein by treated JM protein improved ($P<0.01$) all nutrient digestibility except ether extract (Table 3). Rabbits fed diet with treated JM protein at level 30% had the highest nutrient digestibility coefficient followed by those received the diets containing 20, 10 and 0%, respectively. Rabbits fed the 30% JM diet recorded the highest values of dry matter (DM), organic matter (OM), crude protein (CP) and crude fibre (CF) digestibility among the experimental diets, which were improved ($P<0.01$) by 12.0, 13.4, 11.0, 60.9%, respectively, *versus* control rabbits. Digestible CP of rabbits fed 20 and 30% JM diets increased ($P<0.01$) by 7.57 and 9.96%, respectively, compared to the control rabbits. Total digestible nutrient in rabbits fed diets with 20 and 30% JM increased ($P<0.01$) by 9.65 and 16.14%, respectively. Digestible energy (DE) of the experimental diets followed similar trend of the DCP and TDN, where the replacement of 10, 20 and 30% diet soybean meal protein by JM increased ($P<0.01$) DE by 1.1, 1.3 and 2.1% respectively. The partial replacement of soybean meal protein by treated JM protein at level of 30% in rabbit diets, increased ($P<0.01$) the digested-N, N-retained and N balance by 13.9, 18.8 and 3.9%, respectively, compared with control (Table 4).

Table 3. Effect of different levels of treated jojoba meal protein on nutrient digestibility and nutritive values of growing NZW rabbits

Items	Level of JM protein (%)				SEM†	P
	0	10	20	30		
Digestibility (%)						
Dry matter	703^{c}	714^{c}	752^{b}	787^{a}	23.7	**
Organic matter	722^{c}	727^{c}	779^{b}	819^{a}	11.3	**
Crude protein	709^{b}	714^{b}	781^{a}	787^{a}	9.8	**
Crude fibre	248^{c}	253^{c}	357^{b}	399^{a}	30.1	**
Ether extract	777	779	786	788	21.3	ns
Nutritive values						
TDN (g/kg)	632^{c}	64.6^{c}	69.3^{b}	734^{a}	22.7	**
DCP (g/kg)	118.1^{b}	118.4^{b}	128.2^{a}	127.4^{a}	2.41	**
Digestible energy (kcal/kg)	2530^{c}	2558^{b}	2563^{b}	2582^{a}	18.7	**

^{abcd}Means in the same row with different superscripts are significantly different ($P<0.05$); Linear at $P< 0.05$; **= $P< 0.01$; ns= Non significant

†SEM= Standard error of means.

Table 4. Effect of different levels of treated JM on N utilization of growing NZW rabbits (n=4)

	Level of JM protein (%)				SEM†	P
	0	10	20	30		
N intake (g/d)	3.33	3.44	3.40	3.45	0.43	ns
Faecal N (g/d)	1.02	1.03	1.04	0.83	0.38	ns
Urinary N (g/d)	1.02^{c}	1.28^{a}	1.02^{c}	1.10^{b}	0.49	*
N digested (g/d)	2.31^{b}	2.41^{b}	2.36^{b}	2.62^{a}	0.27	**
N retained (g/d)	1.29^{b}	1.13^{b}	1.34^{a}	1.52^{a}	0.42	**
N balance, % of N intake	38.73^{a}	32.84^{b}	39.41^{a}	44.05^{a}	1.12	**
% of N digested	55.84^{b}	46.88^{c}	56.77^{a}	58.02^{a}	1.47	*

^{abc}Means in the same row with different superscripts are significantly different (P<0.05);

Linear at P< 0.05; *= P<0.01; **= P<0.01; ns= Non significant

†SEM= Standard error of means.

Soft faeces CP was higher (P<0.01) in rabbits fed diets containing 20 or 30% treated JM protein by 11.3 and 18.6%, respectively, while, it decreased (P<0.01) in hard faeces by 11.5 and 12.7%, respectively (Table 5 and 6). CF content in soft faeces decreased (P<0.01) by 6.28 and 6.28%, respectively, in rabbits fed diets with 20 or 30% treated JM protein. However, in hard faeces, CF was decreased (P<0.01) by 6.34% in rabbits fed diets with 30% treated JM protein versus control rabbits.

No significant differences were observed in the carcass traits among treatments except for carcass and dressing weight, and relative liver of the pre-slaughter weight. Carcass and dressing weight increased (P<0.01) by 2.8 and 5.1%, respectively, in the rabbits fed 30% JM diets. In addition, relative liver of the pre-slaughter weight increased (12.9% - P< 0.05) in the rabbits fed diet with 30% JM (Table 7).

Table 5. Effect of different levels of treated JM on chemical composition of hard and soft faeces (g/kg) of growing NZW rabbits

	Level of jojoba meal protein (%)				SEM†	P
	0	10	20	30		
Soft faeces						
Dry matter	347.0	342.0	351.0	349.0	17.3	ns
Crude protein	264.0^{b}	271.0^{b}	297.0^{a}	313.0^{a}	14.7	*
Ether extract	12.8	13.3	13.9	14.7	4.3	ns
Crude fiber	177.6^{a}	176.0^{a}	166.3^{b}	167.1^{b}	7.8	**
Hard faeces						
Dry matter	482.5	497.1	493.8	475.0	16.3	ns
Crude protein	124.5^{a}	126.7^{a}	111.7^{b}	110.5^{b}	4.1	**
Ether extract	13.9	18.1	19.7	20.9	3.6	ns
Crude fiber	300.3^{a}	291.8^{a}	291.7^{a}	282.4^{b}	7.6	**

^{ab}Means in the same row with different superscripts are significantly different (P<05);

Linear at P<0.05; **= P<0.01; ns= Non significant

†SEM= Standard error of means.

Table 6. Effect of different levels of treated JM protein meal on soft faeces excretion of growing NZW rabbits

	Level of JM protein (%)				SEM†	P
	0	10	20	30		
Dry matter intake, g/d	127[c]	131[b]	137[a]	138[a]	2.83	***
Soft faeces excretion, g						
Dry matter/d	19.2[d]	20.6[c]	24.7[b]	26.2[a]	0.47	***
Dry matter/100 g	0.81[b]	0.83[b]	0.98[a]	1.03[a]	0.050	**
Chemical composition, g/kg						
Dry matter	347	342	351	349	7.3	ns
Crude protein	264[b]	271[b]	297[a]	313[a]	4.7	***
Relative contribution of soft faeces to						
Dry matter intake	13.13[b]	13.59[b]	15.28[a]	15.96[a]	0.31	**
Crude protein intake	19.33[c]	20.44[c]	24.61[b]	26.85[a]	0.25	**

[abcd]Means in the same row with different superscripts are significantly different (P<05);

Linear at P<0.05; **= P<0.01; ns= Non significant

†SEM= Standard error of means.

Table 7. Effect of different levels of treated JM on carcass traits (g/kg of live body weight) of growing NZW rabbits (n=4)

	Level of JM protein (%)				SEM†	P
	0	10	20	30		
Live body weight (g)	2046	2148	2120	2050	63.2	ns
Hot carcass weight, g	1108	1163	1150	1146	24.6	ns
Carcass (%)	54.23[b]	54.24[b]	54.41[b]	55.77[a]	1.08	**
Dressing	592.5[c]	602.8[bc]	608.9[b]	622.7[a]	20.40	**
Fur	147.1	146.9	148.6	150.7	5.70	ns
Total giblets weight	40.7	47.9	41.9	45.7	3.51	ns
Liver	30.2[b]	36.8[a]	34.4[a]	34.1[a]	1.61	*
Heart	2.8	3.1	3.0	3.1	0.90	ns
Kidneys	7.7	8.0	8.3	8.6	3.11	ns
Spleen	0.5	0.6	0.5	0.5	0.22	ns
Lungs	6.0	6.1	6.2	6.0	1.55	ns
Digestive tract (full)	199.2	197.7	198.8	203.7	8.91	ns
Digestive tract (empty)	.6.0	75.2	76.4	76.9	18.14	ns

[abcd]Means in the same row with different superscripts are significantly different (P<05);

Linear at P<0.05; **= P<0.01; ns= Non significant

†SEM= Standard error of means.

No significant differences were registered among treatments in some blood plasma parameter such as total protein, glucose, GPT, GOT, creatinine and urea (Table 8), whereas, plasma albumen decreased (P<0.05) by 8.2% in rabbits fed 30% JM diet compared to those fed control diet.

Table 8. Effect of different levels of treated JM on some blood metabolites of growing NZW rabbits

	Level of JM protein (%)				SEM†	P
	0	10	20	30		
No. of samples	4	4	4	4	--	--
Total protein, g/dl	5.8	6.1	5.7	5.9	0.43	ns
Albumin, g/dl	4.2[a]	4.4[a]	3.9[b]	3.8[b]	0.23	*
Globulin, g/dl	1.7[b]	1.7[b]	1.8[a]	2.1[a]	0.18	*
Glucose, mg/dl	128.7	127.9	128.2	127.4	0.89	ns
GPT, U/l	19.4	19.7	18.9	19.5	3.98	ns
GOT, U/l	50.1	50.4	49.7	49.5	7.11	ns
Cholesterol, mg/dl	91.2[a]	90.0[a]	81.2[b]	80.1[b]	9.18	**
Triglycerides, mg/dl	158.9[a]	158.8[a]	152.8[b]	152.3[b]	5.53	**
Creatinine, mg/dl	0.82	0.85	0.79	0.81	0.190	ns
Urea-N, mg/dl	20.6	20.8	20.1	20.4	2.89	ns

[ab]Means in the same row with different superscripts are significantly different (P<05);

Linear at P<0.05; **= P<0.01; ns= Non significant

†SEM= Standard error of means.

DISCUSSION

Chemical composition and detoxification of JM

The increase of CP in treated JM may be due to the influence of *L. acidophilus* bacteria, it converts the cyano-glycoside compounds such as (simmondsin and simmondsin -2'- ferulate) to microbial protein in their bodies. Studies indicated that *L. acidophilus* was grown on cyano-glycoside compounds as a sole carbon and nitrogen source in JM, producing some proteloytic enzymes for cyano-glycosides, and converted them to carbon chains and amides compounds (El-Shennawy, 2003). The bacteria consumed these compounds and used it in their bodies as microbial protein as previously mentioned by Abbott *et al.* (1999). Detoxification of JM has focused on the degrading of simmondsin by biological treatment with *L. acidophilus* bacteria as the principal toxic component in JM. Simmondsin contents in treated JM with *L. acidophilus* decreased by 96% as compared with untreated. This result may be due to the ability of *L. acidophilus* bacteria to produce some proteloytic enzymes for cyano-glycoside compounds and converted them to carbon chain and amides compounds. These resulting compounds were less toxic than simmondsin compounds (Abbott *et al.*, 1999).On the other hand, no differences in all nutrient contents (DM, CF, EE and ash) between raw and treated JM. Also, no significant differences in amino acids and fatty acids content between raw and treated JM. These results were nearly similar as described by earlier workers (Farag, 2007; Khalel *et al.*, 2008; Khayyal *et al.*, 2009).

Digestibility and N balance

The improvement of nutrient digestibility and nutritive value in JM rabbit's diets versus control may be attributed to some of the compounds produced from biological

treatments, which activate the digestibility or increase the caecum microbial activity (Khayyal *et al.,* 2009). The improvement in nutrient digestibility could be a result of better feed intake and nutritive value. These results are compatible with those observed by Khalel *et al*. (2008) and Khayyal *et al*. (2009) who pointed out that the nutrient digestibility coefficients were increased in rabbits fed 10% treated JM with *L. acidophilus* bacteria versus control rabbits. In this concern, Nelson *et al*. (1979) reported that fermentation of JM clearly improved its palatability, acceptability and digestibility coefficients in ruminants. These result are in accordance with those observed by Khayyal *et al*. (2009) who indicated that the nitrogen utilization of rabbits fed 10% treated JM with *L. acidophilus* bacteria were significantly increased as compared to control.

Results obtained from the chemical composition of soft and hard faeces (Tables 5 and 6) may indicate that dietary replacement of soybean protein meal by treated JM protein at levels of 20 and 30% activate the useful micro-organisms in caecum and colon, producing high crude protein content in soft faeces and improving the nutrients digestibility. Dietary treated JM protein levels effected ($P<0.01$) DM and CP contribution of soft faeces to total DM and CP intake, this is mainly due to higher DM and CP intake in the rabbits fed high level of treated JM (El-Sayaad *et al.*, 1998). The improvement of fiber digestibility coefficient leads to increase the rate of microbial protein synthesis in soft faces. The elevated microbial protein is the result of increased fiber utilization offering a suitable environment to bacterial growth in the caecum.

Carcass traits

Increments in carcass and dressing weights in rabbits fed 30% JM diets (table 7) may be due to improvements in body weight and daily gain. In general, the increase in body weight and daily weight gain in rabbits fed diets with 20 and 30% JM could be attributed to a favorable feed conversion ratio. The improvement in feed conversion may be due to the increase of protein and fiber digestibility coefficient as noticed in the current investigation. Supplementation of JM increased relative liver of the pre-slaughter weight, and these results are consistent with Khayyal *et al*. (2009) who reported that rabbits fed diets containing 10% JM with lactic acid bacteria increased carcass, dressing and liver weight as compared to those fed control diet. In comparison to poultry, Decuypere *et al*. (1996) reported that broiler breeder pullets fed diet containing 4% raw JM had increments in liver weight. On the other hand, Lisk and Brown (1985) found that live weight, carcass weight and dressing percentage of lambs fed diets containing 10% JM were not significantly affected.

Blood plasma metabolites

Decreased plasma albumin in JM rabbits may due to the higher CP digestibility observed in rabbits fed 30% JM diet. The same trend was noticed with raw JM by Khayyal *et al*. (2009). Plasma globulin increased ($P<0.05$) by 25.3% in rabbits fed diet

containing 30% JM compared to those fed control diet, this scenario might have be result of kidney dysfunction (Nephrosis). This result refers to the positive effect of JM diet on the immune response. However, plasma cholesterol and plasma triglyceride decreased ($P<0.05$) by 12.1 and 4.2%, respectively, in rabbits fed 30% JM diet versus control group probably due to the effect of biological treatment to reduce the concentration of saturated fatty acids and improving the unsaturated fatty acids in JM. These results are compatible with those obtained by Khayyal *et al.* (2009) who observed a significant decrease in both plasma cholesterol and triglycerides concentrations in rabbits fed diets containing 10% JM with *L. acidophilus* versus control. El-Kady *et al.* (2008) noticed that there were significant differences in the concentration of plasma triglycerides and cholesterol among groups of lambs fed different levels of JM. Where the group fed 30% raw JM increased ($P<0.01$) by 26.96 and 46.00%, respectively versus control. However, El-Shennawy (2003) found that there were no significant differences of plasma triglycerides and cholesterol concentrations among groups of rats fed untreated and treated JM with irradiation, heat, microwave and fermentation as compared to the control.

CONCLUSIONS

Treated JM by *L. acidophilus* bacteria could eliminate the harmful effect of its content of anti-nutritional factors and improve the effect on nutrient digestibility, caecotrophy, carcass traits and some blood plasma metabolites in rabbits. Using the JM at 30% in rabbit's diet could improve rabbit's health by reducing blood cholesterol and triglyceride concentrations and improve the immune response.

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