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The effect of Yucca schidigera powder added to lamb feed on fattening performance, some blood parameters, the immune system, and the antioxidative metabolism of the hepatic tissue

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Abstract: In this study, *Yucca schidigera* powder (YSP) added to lamb feed was investigated for its effects on performance, some blood parameters, the immune system, and the antioxidative metabolism of the hepatic tissue. Throughout a 10-week fattening period, twenty-four 2.5-month-old male Akkaraman lambs were used. Three groups were established, including a control group (C) and groups YSPI and YSPII, which received a basal ration alone, a basal ration + 100 ppm YSP, and a basal ration + 200 ppm YSP, respectively. The groups did not differ for performance parameters ($P > 0.05$). While 100 ppm YSP increased serum NH3 levels ($P < 0.05$), 200 ppm YSP significantly decreased serum cholesterol, HDL, LDL, and Mg levels ($P < 0.05$). The groups did not differ for antibody titers against the *Brucella melitensis* vaccine (Rev 1). In groups YSPI and YSPII, hepatic CAT activity and LPO levels were significantly lower than those of Group C ($P < 0.01$). While the GSH levels of group YSPI were significantly higher than those of groups C and YSPII, the SOD activity of group YSPII was significantly lower than those of groups C and YSPI ($P < 0.01$). As a result, while YSP did not affect the performance parameters or immune system, it significantly affected NH3 levels, lipid metabolism, and the antioxidant system.

Key words: Antioxidative, fattening performance, metabolic parameters, saponin

1. Introduction

In the last decade, chemical feed additives, incorporated into feed rations with an aim to increase the yield of farm animals by enhancing ruminal fermentation, have started to be replaced by natural products. One of these natural products is the extract of the *Yucca schidigera* plant, which contains saponin and grows in the Baha California region of Mexico and in the southwestern region of the United States (1). As its extract and powdered extract are on the Generally Recognized as Safe (GRAS) list of the US Food and Drug Administration, today *Yucca schidigera* is used in the beverage, pharmaceutical, cosmetics, food, and feed industries (2).

It has been reported that dietary supplementation of *Yucca schidigera* regulates the rumen environment (3), enhances performance (4), and decreases both ammonium levels and methane production (5). In a study conducted by Kaya et al. (6) in lambs, *Yucca schidigera* was shown to have a positive impact on performance. In another study carried out in goats, it was determined to induce a positive effect on the lipid metabolism and to decrease serum cholesterol levels (7).

Apart from saponin, the *Yucca schidigera* plant contains seven phenolic compounds, namely resveratrol, yucaone A, and yuccaols A, B, C, D, and E. It is well known that, owing to their redox potential, phenolic compounds positively affect antioxidant activity (8). Javanmardi et al. (9) indicated that saponins play a major role in the neutralization of free radicals and the decomposition of peroxidases. Furthermore, it has been reported that the dietary supplementation of powdered *Yucca schidigera* extract increases the strength of the antioxidant defense mechanism of cells, which provides protection against the destructive effects of natural oxidation reactions (10).

This study was aimed at investigating the effects of *Yucca schidigera* powder (YSP) on performance, some blood parameters, the immune system, and the antioxidative metabolism of the hepatic tissue when added to the feed of lambs.

2. Materials and methods

2.1. Animals, experimental design, and feed

Twenty-four 2.5-month-old weaned male Akkaraman lambs were used in the study. Throughout a 10-day

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adaptation and a 10-week fattening period, the animals were housed in a closed area on the premises of the Animal Husbandry Research and Application Unit of Atatürk University, Faculty of Veterinary Medicine. Two animals were allocated to each compartment measuring 280 × 200 × 120 cm. The lambs were divided into a control and two treatment (YSPI and YSPII) groups, each consisting of four replicates of eight lambs. The animals were provided with preweighed feed twice a day at 0800 and 1600 hours. While the control group received a basal ration for lambs alone, groups YSPI and YSPII were given a basal ration for lambs added with 100 and 200 ppm *Yucca schidigera* powder (Ekomix Yucca), respectively (Table 1). The daily amount of roughage provided to the lambs was 125 g of wheat straw per animal (the chemical composition of wheat straw on the basis of dry matter content was as follows: crude protein: 3.1, crude ash: 6.69, neutral detergent fiber (NDF): 77.45, acid detergent fiber (ADF): 50.32). This study was approved by the ethics committee of Atatürk University Health Sciences Institute (Decision No: 2010/5.1/16).

2.1.1. Yucca schidigera powder (Ekomix Yucca)

Ekomix Yucca, with 120 mg Yucca schidigera powder per kilogram, came from Ekol Food Agriculture and Livestock Marketing Industry and Trade Inc.

2.2. Feed analysis

The analyses of the feedstuffs used in the study for crude protein and crude fat proportions were performed in accordance with the methods of the Association of Official Analytical Chemists (11), and crude cellulose analyses were performed as described by Van Soest and Robertson (12).

2.3. Performance parameters

Body-weight gain was determined for 14-day periods on the basis of the individual weighing of the animals prior to morning feeding. Daily feed intake was determined by weighing the concentrate remaining in the feeders prior to morning feeding. As the subgroups included two animals, individual daily feed intake was calculated by dividing the daily feed intake values by two. Feed efficiency was calculated as the proportion of daily concentrate feed intake to daily weight gain (kg/kg).

Table 1. Ingredients of crude nutrient proportions in the basal ration, %.

Item %	Groups		
	C	YSPI	YSPII
Barley	30	30	30
Maize	20	20	20
Sunflower meal	13.33	13.33	13.33
Cottonseed meal	13.2	13.2	13.2
Wheat shorts[4]	9.70	9.69	9.68
Maize gluten	5	5	5
DDGS[1]	5	5	5
Marble powder	2.05	2.05	2.05
Molasses	1.12	1.12	1.12
Salt	0.5	0.5	0.5
Vitamin-mineral premix[2]	0.1	0.1	0.1
Yucca schidigera powder[3]	-	0.01	0.02
Analyzed nutrient contents, %			
Crude protein	18.53	18.52	18.52
Crude fat	2.87	2.87	2.87
Crude fiber	12.74	12.74	12.74

[1]DDGS: Dried distillers grains with solubles.
[2]The vitamin and mineral premix provided the following (per kg): 4,000,000 IU vitamin A, 800,000 IU vitamin D3, 5000 IU vitamin E, 400 mg vitamin B2, 2 mg vitamin B12, 5000 mg vitamin B3, 1000 mg D-pantothenic acid, 20,000 mg choline, 50 mg Co, 5400 mg Fe, 185 mg I, 6900 mg Mn, 800 mg Cu, 6400 mg Zn, 14 mg Se.
[3]Ekomix Yucca powder: 120 mg *Yucca schidigera* powder per kilogram (Ekol Food and Agriculture Livestock Marketing Industry and Trade Inc.).
[4]*Yucca schidigera* powder was added in place of wheat shorts.

2.4. Brucella melitensis (Rev 1) vaccine

The Rev 1 (Brucella melitensis) vaccine for young animals was obtained from the Pendik Veterinary Control and Research Institute and administered to the animals at the beginning of the trial, in accordance with the instructions provided in the package insert.

2.5. Collection of blood and hepatic tissue samples

Blood samples were collected from the jugular vein of the 24 animals on the last day of the trial, prior to morning feeding, for use in biochemical analyses. Furthermore, for the measurement of antibody titers against the Rev 1 vaccine, blood samples were taken from the animals on days 20 and 90 after vaccination, prior to morning feeding. The blood samples, collected in volumes of 5 mL into dry tubes (Becton Dickinson Co. USA), were centrifuged at 4 °C and 4000 rpm for 10 min in a cooled centrifuge (Hettich 38R, Hettich Zentrifugen, Tuttlingen, Germany). The harvested serum samples were stored at –80 °C until use.

At the end of the trial, 4 animals from each group were slaughtered at a slaughterhouse, and tissue samples were taken from the liver and stored in sterile petri dishes at –80 °C until analysis.

2.6. Biochemical analyses

2.6.1. Determination of serum biochemical parameters

Serum concentrations of glucose, urea, blood urea nitrogen (BUN), ammonia (NH_3), triglyceride, cholesterol, high-density lipoprotein (HDL) and low-density lipoprotein (LDL), sodium (Na), calcium (Ca), inorganic phosphorus (P), potassium (K), chlorine (Cl), and magnesium (Mg) were measured with an automatic analyzer using commercial test kits (Cobas 8000 analyzer, Roche).

2.6.2. Determination of antibody levels (Rose Bengal agglutination test)

The rapid agglutination test was performed using the serum samples. Accordingly, decreasing volumes of serum (0.08, 0.04, 0.02, and 0.01 mL) were deposited on clean glass slides and mixed with Rose Bengal test antigen procured from Institut Pourquier. Dilutions of 1/25, 1/50, 1/100 and 1/200 were prepared. Test results were evaluated as either positive or negative according to the strength of the agglutination reaction, which developed within 4 min. The degree of positiveness determined by statistical calculations was expressed numerically (⊥ = 0.5, + = 1) (13).

2.6.3. Determination of the lipid profile (thin-layer chromatography)

Thin-layer chromatography was performed using a 20 × 10 cm Silica Gel 60 F254 high-performance thin-layer chromatography (HPTLC) plate. One milliliter of serum homogenate or serum was added to 1 mL of n-hexane/iso-propanol (2:1 (v/v)) mixture in a tube. After being mixed thoroughly, the tube content was maintained for 10 min and mixed once again. This procedure was repeated a further two times (14). Subsequently, the tubes were centrifuged at 8000 rpm for 10 min and the upper phases were loaded onto the HPTLC plate. The plates were developed in a hexane: diethyl ether: formic acid (80:20:2 (v/v/v)) mixture for 15 min and then dried. The spots on the dry plates were made visible by means of treatment with 3% $CuSO_4$ in 8% phosphoric acid followed by burning on hot plates (15). The hydrocarbon, triglyceride, steroids, and polar lipid parameters were measured for lipid profile.

2.6.4. Antioxidant enzymes

Superoxide dismutase (SOD) and catalase (CAT) enzyme activities and the levels of glutathione (GSH) and lipid peroxidation (LPO) in the liver tissues were determined. To prepare the tissue homogenates, the liver tissues were ground with liquid nitrogen in a mortar. Tissue (0.5 g) was then treated with 4.5 mL of appropriate buffer (SOD: pH 7.4/0.2 mM Tris-HCl buffer, CAT: pH 7/50 mM phosphate buffer, GSH: pH 7.4/50 mM Tris-HCl buffer, LPO: 10% KCl solution). The mixtures were homogenized on ice using an Ultra-Turrax homogenizer for 15 min. Homogenates were filtered and centrifuged at 4 °C. These supernatants were then used for biochemical measurements. All biochemical measurements were carried out using a UV-Vis spectrophotometer (BIO-TEK µ Quant, USA).

2.6.4.1. Superoxide dismutase activity

Superoxide dismutase estimation was based on the generation of superoxide radicals produced by xanthine and xanthine oxidase, reacting with nitroblue tetrazolium to form formazan dye (16). Superoxide dismutase activity was then measured at 560 nm by the level of inhibition, expressed as mmol min^{-1} mg $tissue^{-1}$.

2.6.4.2. Catalase activity

Decomposition of H_2O_2 in the presence of CAT was followed at 240 nm (17). The CAT activity was defined as the amount required to decompose 1 mmol of H_2O_2 per minute at 25 °C and pH 7.8. Results were expressed as mmol min^{-1} mg $tissue^{-1}$.

2.6.4.3. Total glutathione

The amount of GSH in the liver tissues was measured according to the method described by Sedlak and Lindsay (18), with some modifications. The liver tissues were homogenized in 2 mL of 50 mM Tris-HCl buffer containing 20 mM EDTA and 0.2 M sucrose, at pH 7.5. After adding 2 mL of ethanol (to precipitate the proteins), the homogenate was centrifuged at 197.57 × g for 40 min at 4 °C. The supernatant was used to determine GSH level using 5,5'-dithiobis (2-nitrobenzoic acid) (DTNB). The absorbance was measured at 412 nm. The results of the GSH level of the liver were expressed as nmol/mg tissue.

2.6.4.4. Determination of lipid peroxidation

The level of LPO in liver tissues was determined by estimating malondialdehyde (MDA) using the thiobarbituric acid test (19). The livers were scraped, weighed, and homogenized in 10 mL of 100 g/L KCl. The homogenate (0.5 mL) was added with a solution containing 0.2 mL of 80 g/L sodium lauryl sulfate, 1.5 mL of 200 g/L acetic acid, 1.5 mL of 8 g/L 2-thiobarbiturate, and 0.3 mL of distilled water. The mixture was incubated at 98 °C for 1 h. Upon cooling, 5 mL of n-butanol:pyridine (15:1) was added. The mixture was vortexed for 1 min and centrifuged for 30 min at 179.2 × g. The absorbance of the supernatant was measured at 532 nm. The standard curve was obtained by using 1,1,3,3-tetramethoxypropane. The recovery rate was over 90% . The results were expressed as nmol MDA per gram wet tissue (nmol/g tissue).

2.7. Statistical analyses

The data obtained were assessed using SPSS 10.01 (20). Differences between the groups were determined with the one-way analysis of variance (ANOVA) test and Duncan's posttest for other parameters, while the nonparametric Kruskal–Wallis and Wilcoxon tests were used to detect the differences for antibody titer indices. Differences between the groups were determined with the nonparametric Kruskal–Wallis and Mann–Whitney U tests for liver enzyme parameters. The data were expressed as mean ± standard error of the mean (SEM). Differences were considered significant at $P < 0.05$ and $P < 0.01$.

3. Results

While no statistically significant difference existed between the groups for body weight (Table 2), feed intake was determined to have significantly decreased between days 15 and 28 in groups YSPI and YSPII in comparison to group C ($P < 0.01$), and between days 29 and 42 in only group YSPI when compared to group C ($P < 0.05$) (Table 3). Feed efficiency was similar in all three groups (Table 3). Furthermore, serum glucose, urea, and BUN levels were also found to be similar in the groups, while serum NH_3 levels were significantly increased in group YSPI ($P < 0.05$) and slightly increased in group YSPII (Table 4) when compared to the control group. While *Yucca schidigera* powder was determined to have no significant effect on serum triglyceride metabolism, it significantly reduced serum cholesterol, HDL, and LDL levels in group YSPII in comparison to group C ($P < 0.05$) (Table 4). Furthermore,

Table 2. Effects of basal diets supplemented with *Yucca schidigera* powder on average body weights and average daily gain in lambs (mean ± SEM, n = 8).

Parameters	Groups			P-value
	C	YSPI	YSPII	
Average body weights, kg, day				
Initial body weight	23.164 ± 1.42	22.814 ± 1.34	22.800 ± 1.07	NS
14	27.300 ± 1.56	26.743 ± 1.71	25.000 ± 1.46	NS
28	31.514 ± 1.77	30.761 ± 1.97	28.419 ± 1.62	NS
42	35.243 ± 2.03	32.629 ± 2.24	31.794 ± 1.89	NS
56	38.286 ± 2.05	35.879 ± 2.83	35.256 ± 1.99	NS
Final body weight	40.100 ± 1.76	37.100 ± 2.65	37.444 ± 1.75	NS
Average daily gain, g, days				
0–14	296 ± 24.21	281 ± 50.43	157 ± 64.15	NS
15–28	301 ± 32.60	287 ± 30.57	244 ± 33.67	NS
29–42	266 ± 21.40[a]	133 ± 37.90[b]	241 ± 39.50[a]	*
43–56	217 ± 26.72	232 ± 73.32	247 ± 30.55	NS
57–70	129 ± 53.33	87 ± 70.89	156 ± 30.78	NS
0–28	298 ± 19.31	284 ± 35.52	201 ± 38.13	NS
0–42	288 ± 18.43	234 ± 26.08	214 ± 33.16	NS
0–56	270 ± 17.07	233 ± 31.72	223 ± 28.78	NS
0–70	242 ± 13.72	204 ± 27.51	209 ± 21.05	NS

a, b: A different letter in the same line means significantly different (*: $P < 0.05$).
NS: Nonsignificant ($P > 0.05$). SEM: Standard error of mean.

Table 3. Effects of basal diets supplemented with *Yucca schidigera* powder on average daily concentrate feed intake and feed efficiency in lambs (mean ± SEM, n = 8).

Parameters	Groups			P-value
	C	YSPI	YSPII	
Feed intake, g, days				
0–14	1345.286 ± 26.44	1369.286 ± 15.68	1330.500 ± 24.43	NS
15–28	1606.571 ± 25.33^{a}	1520.143 ± 14.88^{b}	1466.250 ± 20.01^{b}	**
29–42	1596.000 ± 28.75^{a}	1511.429 ± 29.10^{b}	1553.000 ± 20.47^{ab}	*
43–56	1795.714 ± 37.46	1712.857 ± 63.13	1788.750 ± 34.10	NS
57–70	1757.429 ± 16.80	1761.143 ± 24.96	1749.000 ± 30.92	NS
0–70	1620.143 ± 18.99	1575.000 ± 17.78	1577.250 ± 11.47	NS
Feed efficiency, kg, days				
0–70	6.806 ± 0.33	9.005 ± 1.68	8.189 ± 0.96	NS

a, b: A different letter in the same line means significantly different (*: P < 0.05, **: P < 0.01).
NS: Nonsignificant (P > 0.05). SEM: Standard error of mean.

Table 4. Effects of basal diets supplemented with *Yucca schidigera* powder on some serum biochemical parameters in lambs (mean ± SEM, n = 8).

Parameters	Groups			P-value
	C	YSPI	YSPII	
Glucose, mg/dL	82.000 ± 1.56	78.429 ± 4.57	73.250 ± 7.20	NS
Urea, mg/dL	40.286 ± 1.48	40.000 ± 4.21	44.625 ± 2.49	NS
BUN, mg/dL	18.829 ± 0.69	18.700 ± 1.97	20.850 ± 1.16	NS
NH_3, µg/dL	51.571 ± 13.93^{b}	75.714 ± 18.45^{a}	61.000 ± 10.49^{ab}	*
Triglyceride, mg/dL	18.000 ± 1.07	20.571 ± 2.67	18.667 ± 1.50	NS
Cholesterol, mg/dL	54.714 ± 3.64^{a}	47.167 ± 2.33^{ab}	36.750 ± 5.11^{b}	*
HDL, mg/dL	29.714 ± 1.21^{a}	27.714 ± 1.57^{a}	21.000 ± 2.73^{b}	*
LDL, mg/dL	25.143 ± 2.92^{a}	19.667 ± 0.88^{ab}	16.714 ± 2.73^{b}	*
Ca, mg/dL	9.920 ± 0.60	10.800 ± 0.16	10.054 ± 1.09	NS
P, mg/dL	8.103 ± 0.46	8.634 ± 0.64	7.430 ± 0.90	NS
Mg, mg/dL	3.233 ± 0.24^{a}	2.787 ± 0.22^{ab}	2.409 ± 0.26^{b}	*
Na, mmol/L	148.571 ± 0.95	148.714 ± 1.58	136.500 ± 13.22	NS
K, mmol/L	4.619 ± 0.07	4.754 ± 0.15	3.969 ± 0.39	NS
Cl, mmol/L	109.429 ± 0.81	108.857 ± 1.01	98.625 ± 9.83	NS
Lipid profile %				
Hydrocarbon	61.508 ± 1.13	61.680 ± 0.79	59.951 ± 0.93	NS
Triglyceride	9.091 ± 1.26^{a}	6.690 ± 0.77^{b}	8.374 ± 0.46^{ab}	*
Steroid	12.579 ± 0.50	13.150 ± 0.35	12.824 ± 0.33	NS
Polar lipid	16.822 ± 0.37	18.480 ± 0.59	18.851 ± 1.02	NS

BUN: Blood urea nitrogen, NH_3: ammonia, HDL: high-density lipoproteins, LDL: low-density lipoproteins, Ca: calcium, P: phosphorus, Mg: magnesium, Na: sodium, K: potassium, Cl: chlorine.
a, b: A different letter in the same line means significantly different (*: P < 0.05).
NS: Nonsignificant (P > 0.05). SEM: Standard error of mean.

it was observed that YSP also significantly decreased serum HDL and LDL levels in group YSPII when compared the C group ($P < 0.05$). While serum Na, Ca, P, K, and Cl levels were found to be similar in all three groups, in group YSPII serum Mg levels were determined to have significantly decreased when compared to group C ($P < 0.05$). Investigation of the lipid profile revealed that, while the triglyceride level of group YSPI was significantly lower than that of group C ($P < 0.05$), the decrease observed in group YSPII was statistically insignificant ($P > 0.05$). On the other hand, the hydrocarbon, steroid, and polar lipid levels of all three groups were found to be similar (Table 4).

The antibody titers induced by the administration of the Rev 1 vaccine were determined not to display any statistical difference between the groups (Table 5). While CAT activity in the hepatic tissue was observed to be similar in the groups that received *Yucca schidigera* powder, the hepatic CAT activity of these groups was found to be significantly lower than that of group C ($P < 0.01$). While GSH levels were higher in group YSPI when compared to the other groups ($P < 0.01$), SOD activity was determined to have significantly decreased in group YSPII in comparison to groups C and YSPI ($P < 0.01$). Lipid peroxidation levels were significantly lower in groups YSPI and YSPII in comparison to group C ($P < 0.01$) (Table 6).

4. Discussion

Previous research conducted on the impact of saponins on the performance of livestock yielded different results (3,7). While some studies reported increased body weight in sheep (21) and goats (7), some others demonstrated no impact on body weight in lambs (22) and cattle (23) with the incorporation of saponins into feed. While Hu et al. (7) reported that saponins significantly increased the feed intake of goats, some other studies suggested no effect of saponins on the feed intake of lambs (22), sheep (24), and cattle (3). The findings obtained on growth performance and feed intake in the present study are supported by literature data (7,22). Furthermore, although the feed efficiency of the groups differed mathematically, due to the presence of large in-group variations, no statistically significant difference was detected between the groups.

Hristov et al. (3) reported that the plasma glucose, urea, and ammonium levels of cattle that received 20 g and 40 g of YSP in feed were similar to the values of the control group. Furthermore, some literature reports indicated that saponins either decreased serum cholesterol, triglyceride, and LDL levels (7) or had no effect on these parameters (25). In the present study, it was ascertained that YSP did not affect serum glucose and urea levels and BUN metabolism. On the other hand, serum NH_3 levels were

Table 5. Effects of basal diets supplemented with *Yucca schidigera* powder on serum antibody titer index values 20 and 90 days after administration of Rev 1 vaccine in lambs (mean ± SEM, n = 8).

Groups	20th day	90th day
C	2.142 ± 0.282	1.500 ± 0.353
YSPI	2.786 ± 0.375	2.000 ± 0.000
YSPII	2.750 ± 0.462	2.333 ± 0.314
P-value	NS	NS

NS: Nonsignificant ($P > 0.05$). SEM: Standard error of mean.

Table 6. Effects of basal diets supplemented with *Yucca schidigera* powder on activities of catalase (CAT) and superoxide dismutase (SOD) enzymes with levels of glutathione (GSH) and lipid peroxidation (LPO) in liver tissue of lambs (median, n = 4).

Parameters	Groups			P-value
	C	YSPI	YSPII	
CAT, mmol min^{-1} mg $tissue^{-1}$	1.066^a	0.609^b	0.635^b	**
SOD, mmol min^{-1} mg $tissue^{-1}$	0.504^a	0.520^a	0.483^b	*
GSH, nmol/mg tissue	0.119^b	0.138^a	0.125^b	**
LPO, nmol MDA/g tissue	1.838^b	0.708^c	2.146^a	*

a, b: A different letter in the same line means significantly different (*: $P < 0.05$, **: $P < 0.01$).

determined to have significantly increased in group YSPI ($P < 0.05$) and to have slightly increased in group YSPII. While YSP incorporated into the feed ration was determined not to have any significant effect on serum triglyceride metabolism, it was observed that, in group YSPII, serum cholesterol, HDL, and LDL levels had significantly decreased when compared to group C ($P < 0.05$) (Table 4).

Hu et al. (7) suggested that tea saponin incorporated into goat feed significantly increased serum Ca and P levels, directly proportional to its level in the ration. In another study, in which YSP was added to quail feed at levels of 0, 30, 60, and 90 ppm, while serum P levels were determined not to have changed, in the groups that received 60 and 90 ppm YSP, serum Ca levels were determined to have significantly increased (26). These results were attributed to the interaction of saponins with cholesterol and bile acids in the intestine, resulting in a higher utilization rate of minerals (7). In the present study, saponins were determined not to affect serum Ca, P, Na, K, and Cl levels, but to significantly decrease serum Mg levels, similar to literature data (Table 4). Although the exact underlying reason remains unknown, these findings were considered to have possibly arisen from both the saponin sensitivity of animals and the saponin administration doses being different.

Despite their immunostimulatory mechanism having not been elucidated yet, it is considered that saponins enhance natural immune response. It was reported that the use of *Quillaja* as an adjuvant saponin for ovalbumin administration shows a positive effect on immune response (27). The antibody titers induced by the administration of the Rev 1 vaccine displayed no statistically significant difference between the groups ($P > 0.05$).

It is well known that antioxidants significantly reduce LPO, which is considered the primary indicator of the presence of free radicals (28,29). Son et al. (25) indicated that saponins increase the activity of the enzymes CAT, SOD, and glutathione peroxidase (GSH-Px). In another study, it was suggested that saponins decreased the level of LPO, which is an indicator of oxidative stress (30). In the present study, CAT activity being lower in groups YSPI and YSPII when compared to group C demonstrated that YSP has a positive effect on CAT activity (Table 6). It could be suggested that the saponin content of YSP reduces oxidative stress, which in return reduces the need of the organism for antioxidant defense and thus decreases CAT activity in body tissues. Furthermore, YSP having not affected hepatic SOD activity in group YSPI, but having significantly decreased this activity in group YSPII, suggested that the effect induced on antioxidant enzyme activity was dependent on the administration dose of YSP (Table 6). Hepatic GSH level having significantly increased in the group that received 100 ppm YSP ($P < 0.01$) was considered to be an indicator of the level of free radicals generated in the hepatic tissue of group YSPI being lower than that of the control group. Furthermore, the level of LPO having significantly decreased in the groups administered with YSP demonstrated that the *Yucca* plant prevents oxidative stress to a large extent ($P < 0.01$) (Table 6).

In conclusion, it was ascertained that, while the effect of YSP on performance, glucose levels, and the immune system was statistically insignificant in animals, the effects of YSP on protein and mineral metabolisms were negative. On the other hand, YSP was determined to have significant effects on the lipid and antioxidant metabolisms. It is suggested that saponins could be used as a phytochemical food source in humans and as a novel feed substance in animals. Further research is needed to fully elucidate the effects of YSP.

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