

Effects of Yucca Extract on Feed Efficiency, Immune and Antioxidative Functions in Broilers

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ABSTRACT

Effects of yucca extract (YE) on feed efficiency, immune and antioxidative function in Arbor Acres broilers were studied. One hundred and twenty-eight fourteen-day-old broiler chickens were randomly divided into four treatments with four replicates of 8 birds each. These four diets were formulated by adding 0, 100, 200 and 300 mg/kg YE to the basal diet. The results showed that: diets supplemented with 100 and 200 mg/kg YE increased average body weight gain, feed efficiency, IgG, IgM, T-AOC, CAT and SOD levels, and have positive effects on inducing immune organs' maturation. In addition, 100 mg treatment mainly improved the feed efficiency whereas 200 mg treatment mainly acted on immunity and anti-oxidation. In conclusion, YE can be used as a feed additive due to its capability to improve feed efficiency, immune and antioxidative function in broilers.

Key Words: yucca product, chicken, feed efficiency, immunity, antioxidant

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INTRODUCTION

Chicken meat is an important source of dietary protein, and the industry has developed high grade because of intensive farming techniques, comprehensive and balanced feeding, automation equipment, and other new technologies. However, diseases in production are problematic especially with the development of antibiotic-resistant bacteria. Therefore exploring safe, green and efficient additive that increase immunity in broilers has become a research priority.

Yucca schidigera (Agavaceae), commonly named yucca, a native plant in arid deserts of American southwest and Mexico, is also in Zhejiang Province, China grown as an ornamental. It is recognized as a source of sustenance and drug by native Indians due to its health-promoting activity (Patel 2012), and already has possessed GRAS label as food supplements.

Yucca powder and juice are available in the market, and their main applications are in animal nutrition, in particular as a feed additive to reduce fecal odors and ammonia, hydrogen sulfide and some other harmful volatile compounds in domestic animal excreta (Kelly and Kohler 2003; El-Saidy and Gaber 2004; Gaber 2006).

Yucca extract (YE) contains steroidal saponins and polyphenols. The former fractions are involved in the reduction of ruminal ammonia as kinds of urease inhibitor, and have antiprotozoal activity due to their ability to complex with cholesterol of protozoal cell membranes causing cell lysis and death, furthermore, they also reduce total cholesterol and LDL levels in blood plasma. The latter fractions that founded in *Y. schidigera* bark contain resveratrol, which possesses antioxidant, antiplatelet, antimutagenic, antiviral, antiinflammatory and iNOS expression-inhibiting, also cancer preventing activities (Piacente et al. 2005).

The dietary supplementation with YE has positive effects on the growth rates, feed efficiency, and livestock health (Colina and Chang 2001; Duffy et al. 2001; Flaoyen et al. 2002; Kaya et al. 2003; Liang et

al. 2009). Some studies have showed the potential of yucca as a source of antioxidants (Piacente et al. 2004; Fidan and Dundar 2008; Sobia et al. 2013). However, other experiments gave the opposite view (Oztasan et al. 2008; Yang et al. 2015). Previous studies have yielded varying results, and no animal testing has been carried out in chickens to examine such effects. Furthermore, saponins are capable to stimulate the immune system and enhance resistance to a disease challenge (Cheeke 2001). In addition, YE added in the diet was shown to be beneficial in nonspecific immunity of white shrimp (Yang et al. 2015).

In this study, on the basis of previous research, we examine the effects of 3 different dietary supplementation levels of YE on feed efficiency immune and antioxidative functions in broiler chickens.

MATERIALS AND METHODS

Animals and Diets

One hundred and twenty-eight fourteen-day-old birds of similar body weight were selected and randomly assigned to one of 4 dietary treatments with 4 replicate cages of 8 chicks per cage (100×50×50 cm³). The control birds were provided the basal diet, and the treatment birds were fed on the basal diet supplemented with either 100, 200, or 300 mg/kg YE powder (Shaanxi Yuanzhixing Bioengineering Co., Ltd., Xi'an, China; extract of whole plant, content of saponins is not less than 40%). The basal diet was formulated according to the nutrient requirements recommended by the NY/T 33-2004 (Agricultural Industry Standards of People's Republic of China) for broilers and actual situation in Inner Mongolia, its composition for two experimental phases is listed in Table 1. Experimental diets and water were available *ad libitum* during the experimental period. YE was mixed directly into the diets and provided in mash form. The experiments were conducted in accordance with the guidelines of Animal Care and Use Committee of Inner Mongolia Agricultural University.

Table 1 - Composition and nutrient levels of basal diet* (air-dry basis, %)

Ingredients	d 14 to 28	d 29 to 42
Corn	51.68	58.49
Soybean meal	41.00	34.30
Soybean oil	3.00	3.00
Dicalcium phosphate	1.90	1.80
Limestone	1.10	1.20
Salt	0.37	0.37

Lysine	0.05	0.03
Methionine	0.19	0.10
Premix	0.71	0.71
Total	100.00	100.00
Nutrients levels		
ME (MJ/kg)	12.62	12.87
Crude Protein	21.84	19.95
Calcium	1.00	1.00
Available phosphorus	0.48	0.46
Lysine	1.40	1.20
Methionine	0.56	0.44

* Premix provided the following per kilogram of diet: Fe 60.91 mg; Cu 6.01 mg; Zn 65.75 mg; Mn 62.3 mg; I 0.9 mg; Se 0.21mg; vitamin A 6141.5 IU; vitamin D₃ 1789.2 IU; vitamin E 7.99 IU; vitamin K 1.82 mg; vitamin B₁ 0.65 mg; vitamin B₂ 3.93 mg; vitamin B₆ 2.08 mg; vitamin B₁₂ 0.01 mg; niacin 18.06 mg; calcium pantothenate 6.65 mg; folic acid 0.59 mg; biotin 0.07 mg; choline chloride 332.28 mg. The level of crude protein is measured value, and the others are calculated values.

Sample Collection and Preparation

Live body weight (BW) of each bird and feed consumption were recorded when they are 14, 28 and 42 days old, then calculated the average body weight gain (BWG), average feed intake (AFI) and feed efficiency (FE) in the period of d 14 to 28, 28 to 42 and 14 to 42. Two broilers were chosen randomly from each replicate group at 28 and 42 day of age which had approximately average weight of the group. BW was recorded after fasting for 12 h, then the birds were slaughtered by bleeding the left jugular vein. Blood were collected into 5-mL normal vacutainer tubes and centrifuged at 4,000 r/min for 10 min. The serum was transferred and stored at -20°C until analysis. The thymus, spleen, and bursa of Fabricius were removed and immediately weighed to calculate the immune organ index (g of organ/kg of BW).

Sample Analyses

The concentrations of immunoglobulin G (IgG), immunoglobulin A (IgA), immunoglobulin M (IgM), soluble CD4 (sCD4), and soluble CD8 (sCD8) in the serum were measured using chicken-specific IgG, IgA, IgM, sCD4, and sCD8 Elisa kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China) and automatic microplate reader (Stat Fax 2100, Awareness Inc., USA). Total superoxide dismutase (T-AOC), catalase (CAT), malondialdehyde (MDA), glutathione peroxidase (GSH-Px), and superoxide dismutase (SOD) were measured using commercial

assay kits provided by Nanjing Jiancheng Bioengineering Institute. All the procedures were operated according to the manufacturers' instructions as described by Li et al. (2015).

Statistical Analyses

Data were analyzed by one-way ANOVA with the procedure appropriated for a completely randomized design by the GLM procedure of SAS 9.0 (SAS Institute Inc., Cary, NC). The differences among treatments were tested by Duncan's multiple range test and were considered significant at $P < 0.05$; whereas a $P < 0.10$ was considered to constitute a tendency. The results are expressed as mean and standard error of the mean (SEM).

RESULTS

Feed Efficiency

Table 2 showed the effects of YE on feed efficiency in broilers. As a result of feeding YE, birds' BW had a trend to increase at day 42 ($P = 0.083$). The BWG of 100 mg/kg YE treatment was significantly higher from day 28 to 42 ($P < 0.05$) and tended to be higher from day 14 to 42 ($P = 0.072$) than the others. There was no difference among all the treatments in AFI ($P > 0.05$). The FE value of 100 mg/kg YE treatment was significantly upgraded at the latter period ($P < 0.05$), what's more, diets added 100 and 200 mg/kg YE enhanced FE compared to the control during the whole experiment ($P < 0.05$).

Table 2 - Effects of YE on feed efficiency in broilers

Items	Dietary YE level (mg/kg)				SEM	<i>P</i> -value
	0	100	200	300		
BW (g)						
14 d	375.42	369.12	375.90	370.83	2.559	0.152
28 d	1156.87	1161.83	1187.69	1177.68	19.524	0.705

42 d	2425.39 ^b	2548.12 ^a	2540.69 ^{ab}	2455.76 ^{ab}	42.529	0.083
BWG (g)						
14-28 d	781.45	792.71	811.79	806.85	18.443	0.687
28-42 d	1268.52 ^b	1386.29 ^a	1352.99 ^{ab}	1278.08 ^b	36.285	0.034
14-42 d	2049.96 ^b	2179.00 ^a	2164.79 ^{ab}	2084.93 ^{ab}	42.452	0.072
AFI (g)						
14-28 d	1362.05	1290.69	1356.53	1302.02	39.048	0.489
28-42 d	2347.67	2312.94	2286.32	2370.92	76.772	0.454
14-42 d	3709.72	3603.64	3642.86	3672.94	52.373	0.573
FE						
14-28 d	0.57	0.62	0.60	0.62	0.016	0.195
28-42 d	0.54 ^b	0.60 ^a	0.59 ^{ab}	0.54 ^b	0.020	0.044
14-42 d	0.55 ^c	0.60 ^a	0.59 ^{ab}	0.57 ^{bc}	0.014	0.015

^{a,b,c} Means in rows without a same superscript differ significantly ($P < 0.05$) or tend to differ significantly ($0.05 < P < 0.10$). Same with the following forms.

Immune Organ Index

The effects of YE on immune organ index in broilers are presented in Table 3. The result showed that all the three organ indexes of 28 and 42 day-old birds were increased by 100 mg/kg YE as compared to the control, but the differences were not significant ($P >$

0.05). And so did the 200 mg/kg YE, except thymus index in 42 day-olds was decreased ($P > 0.05$). Diet added 300 mg/kg YE brought lower thymus index, bursa of Fabricius index and higher spleen index, however, the effect was not significant ($P > 0.05$).

Table 3 - Effects of YE on immune organ index in broilers (g/kg)

Items	Dietary YE level (mg/kg)				SEM	<i>P</i> -value
	0	100	200	300		
Thymus index						
28 d	4.73	4.78	5.63	4.57	0.351	0.204
42 d	5.65	5.73	4.97	4.51	0.423	0.213
Spleen index						
28 d	0.82	0.96	0.90	0.83	0.070	0.526
42 d	1.01	1.03	1.10	1.12	0.093	0.854
Bursa of Fabricius index						
28 d	1.90 ^{ab}	2.15 ^a	2.18 ^a	1.57 ^b	0.171	0.099
42 d	1.23	1.42	1.56	1.20	0.123	0.240

Serum Immunoglobulins

As shown in Table 4, dietary supplementation of 100 mg/kg YE significantly increased the serum IgG level of broilers at 28 day of age while the 300 mg treatment decreased IgG level compared to the control ($P < 0.001$). The 100 mg treatment tended to enhance level of serum IgG in 42 day-olds ($P = 0.082$). However, serum IgA levels were significantly depressed in the 200 mg treatment in 42

day-olds and in the 300 mg treatment in both 28 and 42 day-olds ($P < 0.001$). On day 28, IgM level of 200 mg/kg YE treatment tended to be higher than the control ($P=0.087$). However, in 42 day-olds, serum IgM levels in treatments of 100 and 200 mg/kg YE were significantly higher compared to the control ($P < 0.05$).

Table 4 - Effects of YE on the level of immunoglobulins in serum of broilers

Items	Dietary YE level (mg/kg)				SEM	<i>P</i> -value
	0	100	200	300		
IgG (ng/mL)						
28 d	779.35 ^b	871.02 ^a	805.28 ^{ab}	690.99 ^c	31.855	<0.001
42 d	389.05 ^b	440.82 ^a	426.53 ^{ab}	424.29 ^{ab}	11.943	0.082
IgA (ng/mL)						
28 d	70.41 ^{ab}	74.48 ^a	66.52 ^b	57.52 ^c	3.125	<0.001
42 d	174.54 ^a	162.32 ^a	92.35 ^b	98.52 ^b	13.886	<0.001

IgM ($\mu\text{g/mL}$)							
28 d	10.00 ^b	10.36 ^{ab}	12.61 ^a	10.16 ^{ab}	0.779	0.087	
42 d	7.43 ^b	9.40 ^a	9.10 ^a	7.82 ^b	0.387	0.002	

Serum sCD4 and sCD8

The effects of YE on the concentration of sCD4 and sCD8 in serum of broilers are given in Table 5. The sCD4 levels at 28 day had a trend to be decreased by 300 mg/kg YE ($P = 0.078$), and induced by 200 mg/kg reduced by 300 mg treatment at 42 day ($P =$

0.068). There was no difference of sCD8 concentration among all the treatments in 28 day-olds ($P > 0.05$); whereas, 200 mg/kg YE treatments had lower sCD8 level compared to the control in 42 day-olds ($P = 0.093$).

Table 5 - Effects of YE on the concentration of sCD4 and sCD8 in serum of broilers

Items	Dietary YE level (mg/kg)				SEM	<i>P</i> -value
	0	100	200	300		
sCD4 (U/mL)						
28 d	1.95 ^a	1.95 ^a	1.70 ^{ab}	1.38 ^b	0.179	0.078
42 d	1.59 ^a	1.45 ^{ab}	1.05 ^b	1.66 ^a	0.168	0.068
sCD8 (U/mL)						
28 d	18.01	17.96	16.11	15.36	1.071	0.278
42 d	36.95 ^a	35.71 ^{ab}	28.90 ^b	31.85 ^{ab}	2.112	0.093

Antioxidant Function

Table 6 illustrates the effects of YE on antioxidative function in broilers. As a result of YE diet supplementation, T-AOC was upgraded in both 28 and 42 day-olds; the maximum value was in 200 mg treatment and the minimum was in the control ($P < 0.05$). The 200 mg treatment increased CAT levels in 28 day-olds ($P < 0.05$). This was not observed in all other YE treatments at 42 day ($P > 0.05$). There were no significant differences in the concentration of MDA among all the treatments in 28 day-olds ($P >$

0.05). On the other hand, the 300 mg treatment MDA levels were significantly lower than the control in 42 day-olds ($P < 0.05$). There were no significant differences of GSH-Px levels among the four groups at either 28 or 42 day ($P > 0.05$). The value of SOD in 28 day-olds increased by 30.97%, 33.32% and 31.22% for 100, 200 or 300 mg treatments, respectively, as compared to basal diet ($P < 0.05$). However, no significant differences were found among treatments at 42 day on SOD level ($P > 0.05$).

Table 6 - Effects of YE on antioxidant function in broilers

Items	Dietary YE level (mg/kg)				SEM	<i>P</i> -value
	0	100	200	300		
T-AOC (U/mL)						
28 d	5.21	5.77	6.43	5.28	0.298	0.031
42 d	2.81	3.31	3.91	3.82	0.220	0.006
CAT (pg/mL)						
28 d	36.58	43.68	50.49	36.49	3.174	0.009
42 d	21.07	26.39	27.50	33.43	2.926	0.123
MDA (mmol/mL)						
28 d	16.10	15.58	15.21	13.99	1.238	0.713
42 d	15.28	15.15	12.46	10.78	1.041	0.019
GSH-Px (pg/mL)						
28 d	19.92	21.79	24.18	22.34	1.221	0.203
42 d	48.41	52.12	44.31	40.22	2.952	0.119
SOD (ng/mL)						
28 d	36.52	47.83	48.69	47.92	2.451	0.014
42 d	81.92	74.85	81.89	74.00	3.579	0.462

DISCUSSION

Steroidal saponins and polyphenols are the main active fractions of YE, they play an important role in its application. First of all, saponins can make better environment for digesting and absorbing due to their ammonia-inhabiting activity. Secondly, resveratrol can protect animals from diseases because of its antioxidant, antiviral, antiinflammatory and iNOS expression-inhibiting capability (Piacente et al. 2005). Previous studies showed that body weights of birds fed on diet containing 120 mg/kg YE were higher than the others (Cabuk et al. 2004), and addition of YE to the diet improved broiler's average daily gain and feed conversion rate at 42 day of age (Alfaro et al. 2007). In this study, 100 mg/kg YE treatment improved average gain and feed efficiency at days 28 to 42, furthermore, 100 and 200 mg treatments presented positive effects on feed efficiency in the whole experiment.

Immune cells develop and proliferate in immune organs, and their status determines the level of immune function. The thymus is a central immune organ that can induce the maturation of T lymphocyte. The spleen is the largest peripheral immune organ in birds and is the location where blood is produced, stored, filtrated and serves in distributing lymphocytes. It is also the place where immune response occurs. The bursa of Fabricius is a poultry unique immune organ, which can induce the lymphoid stem cells to mature in the bursa dependent lymphocyte. In our study, supplementation with YE did not result in any discernable effects on weight of these organs, but had a trend that low dose (100 and 200 mg/kg) can induce while high dose (300 mg/kg) reduce the immune organ indexes.

The cellular immune response (T cell mediated immunity) mainly depends on T cell immune response where the helper T cells (Th, CD4+) can promote the proliferation, differentiation and maturation of other immune cells. Suppressor T cells (Ts, CD8+) can secrete T cell inhibitory factor so that the body switches to immunosuppression. Their coordination and constraint can produce moderate immune response that regulates immune function of the body. Th or Ts takes CD4 or CD8 as the main surface differentiation antigen, respectively; whereas, sCD4 and sCD8 take the soluble form of CD4, CD8 scattered in peripheral blood. Under normal conditions, lymphocytes naturally release an

amount of sCD4 and sCD8, but its secretion will have a significant change when infected with certain diseases. Therefore, sCD4, sCD8 may reflect the degree of activation of T lymphocytes and as signs of certain diseases or infection, and reflect the immune status more accurately than T cell sub-types. The humoral immune response (B cell mediated immunity) produces antibodies which can protect organisms from bacteria and virus (McKee et al. 2007). IgG is the major antibody for systemic anti-infection, involves in mucosal immunity and is the primary antibody which eliminates bacteria and other large particles antigens in the blood vessels.

Saponins can stimulate secretion of cytokines and trigger innate immunity (Song and Hu 2009), as well as enhance antibody humoral and cellular immune responses (Palatnik de Sousa et al. 2004). Feeding stem-and-leaf saponins increased IgA+ cells of chickens tissues (Zhai et al. 2011). A mixture of oil and ginseng stem-leaf saponins increased IgG titer and IgG1, IgG2a, IgG2b and IgG3 responses, as well as T and B lymphocyte proliferation, and promoted both Th1 and Th2 immune responses (Song et al. 2009). Significant immunostimulation and protection to challenge are achieved by immunization of chickens with immunostimulating complexes contained purified saponins (Berezin et al. 2010).

In the present study, all the three YE treatments tended to decrease sCD4 and sCD8, except the 300 mg treatment decreased sCD4 at first and then increased it. The 100 mg/kg YE mainly increased IgG, and induced IgM along with the time gone, 200 mg treatment brought lower IgA and higher IgM, and 300 mg made IgA down. The results showed an adjustment effect of YE on the humoral and cellular immune responses, and 100 or 200 mg/kg YE had a positive effect.

Animals produce free radicals in normal physiological processes like superoxide anion radicals ($O_2^{\cdot-}$) and hydroxide radical ($\cdot OH$). Excess radicals will damage the structure and function of sugars, proteins, nucleic acids and other biological macro molecules and membrane, resulting in functional and metabolic disorders. T-AOC is an index to measure the total antioxidative capacity of the antioxidant substances (antioxidant macro molecules, small molecules and enzymes). MDA, a product of lipid peroxidation, can be used as a general biomarker for biological oxidative stress (Kadiiska et al. 2005). GSH-Px is considered to be the first line of cellular defense against oxidative damage (Ferrecchio et al. 1998). As the major organisms' antioxidative enzymes, CAT and SOD have strong radical

scavenging activity. This confirms that radical formation and removal are in dynamic equilibrium. Methanol extract of *Yucca gloriosa* roots or *Yucca aloifolia* leaves exhibited strong radical scavenging activity (Bassarello et al. 2007; Sobia et al. 2013). Kucukkurt et al. (2008) reported MDA levels in blood of the rats significantly decreased in groups fed diet added 100 or 200 ppm yucca powder compared to control. However, Oztasan et al. (2008) indicated YE-treatment increased MDA, but decreased the antioxidant activity. In addition, Yang et al. (2015) showed dietary YE did not affect SOD. In the current study, T-AOC and CAT were increased by supplementation of 200 and 300 mg/kg YE, and MDA was decreased by 300 mg/kg YE. However, all the groups fed YE demonstrated higher SOD levels compared to the control. These results suggest YE supplementation of chicken feed may be beneficial in the antioxidative functions of broiler chickens.

CONCLUSIONS

In conclusion, YE was capable to increase broiler's average gain and feed efficiency, adjust immune response including humoral and cellular immune responses, and had strong antioxidative activity. Therefore, yucca can be developed as a commercial source of natural additive in broiler chicken production.

REFERENCES

- Alfaro DM, Silva AVF, Borges SA, Maiorka FA, Vargas S, Santin E. Use of *Yucca schidigera* extract in broiler diets and its effects on performance results obtained with different coccidiosis control methods. *J Appl Poult Res.* 2007; 16(2): 248-254.
- Bassarello C, Bifulco G, Montoro P, Skhirtladza A, Benidze M, Kemertelidze E, et al. *Yucca gloriosa*: a source of phenolic derivatives with strong antioxidant activity. *J Agr Food Chem.* 2007; 55: 6636-6642.
- Berezin VE, Bogoyavlenskiy AP, Khudiakova SS, Alexuk PG, Omirtaeva ES, Zaitceva IA, et al. Immunostimulatory complexes containing *Eimeria tenella* antigens and low toxicity plant saponins induce antibody response and provide protection from challenge in broiler chickens. *Vet Parasitol.* 2010; 167: 28-35.
- Cabuk M, Alcicek A, Bozkurt M, Akkan S. Effect of *Yucca schidigera* and Natural Zeolite on Broiler Performance. *Int J Poult Sci.* 2004; 3(10): 651-654.
- Cheeke PR. Actual and potential applications of *Yucca schidigera* and *Quillaja saponaria* saponins in human and animal nutrition. *Recent Adv Anim Nutr Aust.* 2001; 13: 115-126.
- Colina JJ, Chang EJ. Dietary manipulation to reduce aerial ammonia concentrations in nursery pig facilities. *J Anim Sci.* 2001; 79: 3096-3103.
- Duffy CF, Killeen GF, Connolly CD, Power RF. Effects of dietary supplementation with *Yucca schidigera* Roezl ex Ortgies and its saponin and non-saponin fractions on rat metabolism. *J Agr Food Chem.* 2001; 49: 3408-3413.
- El-Saidy DMS, Gaber MMA. Effect of *Yucca schidigera* on water quality and growth performance of Nile tilapia (*O. niloticus* L) fingerlings Egyptian. *J Aquat Biol Fisher.* 2004; 8: 33-50.
- Ferreccio C, Psych CG, Stat VM, Gredis GM, Sancha AM. Lung cancer and arsenic exposure in drinking water: a case-control study in northern Chile. *Cad Saude Publica.* 1998; 14: 193-198.
- Fidan AF, Dundar Y. The effects of *Yucca schidigera* and *Quillaja saponaria* on DNA damage, protein oxidation, lipid peroxidation, and some biochemical parameters in streptozotocin-induced diabetic rats. *J Diabetes Complicat.* 2008; 22: 348-356.
- Flaoyen A, Wilkins AL, Sandvik M. Ruminant metabolism in sheep of saponins from *Yucca schidigera*. *Vet Res Commun.* 2002; 26: 159-169.
- Gaber MM. The effects of plant-protein based diets supplemented with *Yucca* on growth, digestibility, and chemical composition of Nile Tilapia (*Oreochromis niloticus*, L) fingerlings. *J World Aquacult Soc.* 2006; 37: 74-81.
- Kadiiska MB, Gladen BC, Baird DD, Germolec D, Graham LB, Parker CE, et al. Biomarkers of oxidative stress study II: are oxidation products of lipids, proteins, and DNA markers of CCl₄ poisoning? *Free Radical Bio Med.* 2005; 38: 698-710.
- Kaya S, Erdogan Z, Erdogan S. Effect of different dietary levels of *Yucca schidigera* powder on the performance, blood parameters and egg yolk cholesterol of laying quails. *J Vet Med A.* 2003; 50: 14-17.
- Kelly AM, Kohler CC. Effects of *Yucca schidigera* extract on growth, nitrogen retention, ammonia excretion, and toxicity in channel catfish *Ictalurus punctatus* and hybrid tilapia *O. mossambicus* × *O. niloticus*. *J World Aquacult Soc.* 2003; 34: 156-161.
- Kucukkurt I, Ince S, Fidan AF, Ozdemir A. The effects of dietary supplement of different amount of *Yucca schidigera* powder (sarsaponin 30®) on blood and tissue antioxidant defense systems and lipid peroxidation in rats. *J Anim Vet Adv.* 2008; 7: 1413-1417.
- Liang GQ, Wang XP, Wang XM, Li CP, Chen AG. Effects of camphor familial plant extract and yucca extracts on emission of NH₃ and H₂S in slurry of weaned pigs. *Chinese J Anim Sci.* 2009; 45: 22-25 (in Chinese).

- Li T, Na R, Yu P, Shi B, Yan S, Zhao Y, et al. Effects of dietary supplementation of chitosan on immune and antioxidative function in beef cattle. *Czech J Anim Sci.* 2015; 60: 38-44.
- Mckee AS, Munks MW, Marrack P. How do adjuvants work? Important considerations for new generation adjuvants. *Immunity.* 2007; 27: 687-690.
- Oztasan N, Bulbul A, Eryavuz A, Avci G, Kucukkurt I, Fidan AF. Effect of *Yucca schidigera* extract on blood pressure, antioxidant activity and some blood parameters in the L-name-induced hypertensive rats. *Ankara Univ Vet Fak.* 2008; 55: 149-153.
- Palatnik de Sousa CB, Santos WR, Casas CP, Paraguai de Souza E, Tinoco LW, da Silva BP, et al. Protective vaccination against murine visceral leishmaniasis using aldehyde-containing *Quillaja saponaria* sapogenins. *Vaccine.* 2004; 22: 2470-2479.
- Patel S. *Yucca*: A medicinally significant genus with manifold therapeutic attributes. *Nat Prod Bioprospect.* 2012; 2: 231-234.
- Piacente S, Montoro P, Oleszek W, Pizza C. *Yucca schidigera* bark: phenolic constituents and antioxidant activity. *J Nat Prod.* 2004; 67: 882-885.
- Piacente S, Pizza C, Oleszek W. Saponins and phenolics of *Yucca schidigera* Roetzl: chemistry and bioactivity. *Phytochem Rev.* 2005; 4, 177-190.
- Sobia A, Zubair M, Rasool N, Mansha A, Anjum F, Munawarlqbal, et al. Antioxidant, antibacterial, antifungal activities and phytochemical analysis of dagger (*Yucca aloifolia*) leaves extracts. *J Med Plants Res.* 2013; 7: 243-249.
- Song X, Bao S, Wu L, Hu S. Ginseng stem-leaf saponins (GSLs) and mineral oil act synergistically to enhance the immune responses to vaccination against foot-and-mouth disease in mice. *Vaccine.* 2009; 27: 51-55.
- Song X, Hu S. Adjuvant activities of saponins from traditional Chinese medicinal herbs. *Vaccine.* 2009; 27: 4883-4890.
- Yang Q, Tan B, Dong X, Chi S, Liu H. Effects of different levels of *Yucca schidigera* extract on the growth and nonspecific immunity of Pacific white shrimp (*Litopenaeus vannamei*) and on culture water quality. *Aquaculture.* 2015; 439: 39-44.
- Zhai L, Li Y, Wang W, Wang Y, Hu S. Effect of oral administration of ginseng stem-and-leaf saponins (GSLs) on the immune responses to Newcastle disease vaccine in chickens. *Vaccine.* 2011; 29: 5007-5014.

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