Improved performance and immunological responses as a result of dietary *Yucca schidigera* extract supplementation in broilers

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**ABSTRACT**

This study aimed to study the growth performance and immunological effects of *Yucca schidigera* extract (YSE) in broilers. A total of 128 15-day-old broiler chickens were randomly assigned to four treatments: maize-soybean meal as the basal control diet or the basal diet containing either 100, 200 or 300 mg/kg of YSE. Each treatment was consisted of four replicate pens with eight broilers per pen. The experiment lasted 28 days. Body weight gain (BWG) and European broiler index (EBI) were recorded during grower period (d 15–28) and finisher period (d 29–42), respectively. On d 28 and 42, serum was collected to measure interleukin-1β (IL-1β), interleukin-2 (IL-2), interleukin-4 (IL-4), interleukin-6 (IL-6), interferon gamma (IFN-γ), tumour necrosis factor alpha (TNF-α) concentrations and antibody titres against Newcastle disease virus (NDV) in broilers. During grower period, growth performance and serum cytokine concentrations were not exhibited differences except the decreased IL-6 concentrations. During finisher period, BWG and EBI were both increased at 100 mg/kg group; IL-6 and IFN-γ concentrations were enhanced with 100 mg/kg YSE incorporation, while 200 and 300 mg/kg YSE levels reduced IL-4 production. Antibody titres against NDV was improved at 100 mg/kg YSE level in both grower and finisher period. We concluded that dietary YSE supplementation could improve growth performance and immunological functions in broilers.

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**Introduction**

Antibiotics are effective in increasing disease resistance in modern poultry industry, and eliminating the use of antibiotics during production cycle may cause negative effects on the conversion rate of diets (Salois et al. 2016). However, with consumers’ concern about health issues, and the tendency of banning antibiotics, poultry industry is compelled to find alternatives such as phytogenic feed additives in order to increase disease resistance in poultry flocks.

Another concern in poultry industry is the prevention of Newcastle disease virus (NDV), which is defined as the fourth most serious diseases affecting poultry flocks worldwide (World Bank 2011), as the immunocompromised status of birds in intensive poultry farming would exacerbate the NDV vulnerability in chicks (Kumar and Koul 2016). Although strict vaccination measures are implemented to control NDV, the wide-spreading occurrence of NDV and the consecutive outbreaks worldwide indicated that current NDV vaccines alone may not effectively in controlling the disease in the poultry industry (Dimitrov et al. 2017). Therefore, combining NDV vaccination practices with other immunisation strategies may exhibits better protective potential towards NDV infection.

Researches have proved the effectiveness of saponin/polyphenol containing plants in enhancing immune functions in broilers by stimulating specific cytokines’ levels. For example, Bhardwaj et al. (2014) illustrated that tea saponin with ovalbumin upregulated the gene expression of interleukin-1 (IL-1), interleukin-2 (IL-2), interleukin-12, interferon gamma (IFN-γ) and tumour necrosis factor alpha (TNF-α) and downregulated the expression of interleukin-10 and interleukin-8 (IL-8) in T-lymphocytes and inhibited the MAPK-signalling pathway through decreasing IL-4, IL-8 and nuclear factor kappa B (NF-κB) activities in EL4 cells. It was reported that *Aloe vera* exhibited anti-inflammatory effects by modulating cytokine production in various of studies (Budai et al. 2013; Altincik et al. 2014). And the effectiveness of saponins in combating NDV was reported (Yu et al. 2015).

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**Yucca schidigera**, a plant native to south-western United States and northern Mexico, is regarded highly for its pharmaceutical values due to the presence of saponins and polyphenols (Cheeke et al. 2006; Patel 2012). The current state of knowledge indicated that *Yucca schidigera* extract (YSE) also have marked immunological effects in chickens (Cheeke et al. 2006). However, the only existing literature related to this was from Gurbuz et al. (2011) who observed higher antibody titres of NDV with the combination of YSE and yeast cell walls in layer hens. YSE was widely used for ammonia reduction and manure odour control (Cheeke 2000; Patel 2012), but whether YSE alone could influence the serum cytokines’ concentrations, as well as to control NDV in broilers was not reported yet. Thus, the objective of the present study was to elucidate the effects of YSE on growth performance and serum immunological indicators in broilers when kept under normal environmental condition.

**Materials and methods**

**Ethics statement**

The experiment was carried out in a poultry research facility located in Inner Mongolia Agricultural University, Hohhot, China. All experimental procedures performed were approved by the Animal Research and Ethics Board of College of Animal Science, Inner Mongolia Agricultural University, China.

**Animals, experiment design and treatments**

One-day-old Arbor Acres (AA) broilers were purchased from a commercial farm in Hohhot, Inner Mongolia, China. They were housed in electrically heated battery brooders until d 7 and transported to the experimental site at d 14. Then, 128 15-day-old chickens of uniform body weight were selected to raise in stainless steel wire cages. Their average initial body weight was 372.82 ± 6.35 g. Broilers were assigned to four dietary treatments. Each treatment was randomly divided into four equal replicates, with eight chickens/cage (100 × 50 × 50 cm). The duration of experimental period was 28 days and was divided into grower period (d 15–28) and finisher period (d 29–42). Experimental diets and water were available *ad libitum* during the entire experimental period. Broilers were vaccinated at d 1 and d 7 against NDV and on the d 7 against infectious bronchitis, Gumboro vaccination was given at d 14.

**YSE product and diets**

YSE powder was purchased from Shanxi Yuanzhixing Biotechnology Co., Ltd (Xian, China), steroidal saponin content of YSE was >7%. Diets were formulated to meet nutrients recommendation of Feeding Standard of Chicken, China (NY/T 33-2004) (Chinese Ministry of Agriculture 2004). Diets were fed in mash form. Diet treatments were as follows: (1) control diet (basal diet without supplement), (2) basal diet with 100 mg/kg of YSE, (3) basal diet with 200 mg/kg of YSE and (4) basal diet with 300 mg/kg of YSE. The formulation and composition of the control diet is found in Table 1.

**Growth performance and sample collection**

The European broiler index (EBI) was calculated according to Euribrid (1994), calculated as 100×[(body weight × livability)/(age of slaughtering × feed intake)]. Body weight gain (BWG) was recorded during grower period and finisher period. On d 28 and 42, two birds closest to the median weight from each pen (8 per treatment) were randomly selected, weighed, stunned and slaughtered by exsanguination. Blood samples were taken from wing vein and centrifuged for 15 min at 1250×g and 4°C. Serum was collected and stored refrigerated at −20°C pending analysis.

**Table 1. Feed composition and nutrient content of the basal experimental diet.**

| Ingredients       | Grower (d 15–28) | Finisher (d 29–42) |
|-------------------|------------------|--------------------|
| Maize             | 51.68            | 58.49              |
| Soybean meal, CP44%| 41.00            | 34.30              |
| Soybean oil       | 3.00             | 3.00               |
| Dicalcium phosphate| 1.90             | 1.80               |
| Limestone         | 1.10             | 1.20               |
| NaCl              | 0.37             | 0.37               |
| Lysine            | 0.05             | 0.03               |
| Methionine        | 0.19             | 0.10               |
| Premix<sup>a</sup> | 0.71             | 0.71               |
| Total             | 100.00           | 100.00             |

Chemical composition, %

| ME, kcal/kg | 3018 | 3078 |
|------------|------|------|
| 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 |
| Choline chloride | 0.40 | 0.37 |

ME metabolisable energy.

<sup>a</sup>Contents per kg premix: Fe 60.91 mg; Cu 6.01 mg; Zn 65.75 mg; Mn 62.3 mg; I 0.9 mg; Se 0.21 mg; vitamin A 6141.5 IU; vitamin D3 1789.2 IU; vitamin E 7.99 IU; vitamin K 1.82 mg; vitamin B<sub>12</sub> 0.65 mg; vitamin B<sub>2</sub> 3.93 mg; vitamin B<sub>6</sub> 2.08 mg; vitamin B<sub>1</sub> 0.01 mg; niacin 18.06 mg; calcium panthenate 6.65 mg; folic acid 0.59 mg; biotin 0.07 mg; choline chloride 332.28 mg.
Immunological responses in serum

Interleukin-1β (IL-1β), IL-2, IL-4, IL-6, IFN-γ, TNF-α concentrations were analysed using ELISA kits (Becton, Dickinson and Company, Franklin Lakes, NJ) following the manufacturer’s instructions. Antibody titres against NDV was measured by haemagglutination-inhibition test according to Jahanian (2009), and results were expressed as log2 of the reciprocal of the last dilution.

Statistical analyses

The results were expressed as mean ± SD. The statistical significance of data was evaluated by ANOVA procedure of SAS 9.2 (SAS Institute 2002). Data were analysed by Duncan’s multiple range test. Differences in the mean values were considered significant at p < .05.

Results

The result of growth performance is shown in Figures 1 and 2, the result of antibody titres against NDV is shown in Figure 3, and serum cytokine concentration is presented in Table 2. In grower period, there was no difference in both EBI and BWG (p = .308, p = .687, respectively). IL-6 concentration in serum was

Figure 1. Effects of Yucca schidigera extract on body weight gain in broilers. Statistical comparisons are made between control group and YSE-added groups. Results are expressed as means ± SD. Asterisks indicate significant differences according to different supplementing level of YSE (*p < .05).

Figure 2. Effects of Yucca schidigera extract on European broiler index in broilers. Statistical comparisons are made between control group and YSE-added groups. Results are expressed as means ± SD. Asterisks indicate significant differences according to different supplementing level of YSE (*p < .05).
decreased at 200 and 300 mg/kg YSE levels. During finisher period, EBI and BWG were both stimulated at 100 mg/kg group (p = .04, p = .034, respectively); IL-4 activity was decreased at 200 and 300 YSE dosage, IL-6 and IFN-γ concentrations were enhanced at 100 mg/kg YSE group. Antibody titres against NDV were increased at 100 mg/kg YSE group in both grower and finisher period (p < .001, p = .032, respectively).

Discussion

It is well documented that YSE is beneficial to animal performance (Piacente et al. 2005). However, Alagawany et al. (2016) reported that YSE exhibited little purpose to BWG in laying hens. Our study observed higher BWG and EBI with the incorporation of YSE. The results were consistent with that reported in the literature in which 0.01% YSE addition improved average daily gain and feed conversion ratio in broilers at 42 d of age (Alfaro et al. 2007). According to existing literature, the growth-promoting effects of YSE is attributed to saponin components (Alagawany et al. 2016). However, it is speculated that steroidal saponins may exacerbated body weight loss and decrease in body fat mass (Kim et al. 2005; Kucukkurt et al. 2016). Hence, the biological functions of YSE might be not only due to the presence of saponin components (Duffy et al. 2001). In our study, the growth stimulating effects of YSE fell on the later stage in broiler production cycle. This may be due to the more severe oxidative status of broilers in early phase in comparison with later stage during trials based on our earlier studies (Su et al. 2016). Thus, it is speculated that the body was mobilised first to combat the unbalanced oxidative status with the supplementation of YSE. According to our results, the optimum dose of YSE was 100 mg/kg. This corresponded with the results of Sahoo et al. (2015) who found out that 125 mg/kg YSE

Figure 3. Effects of YSE on antibody titre of Newcastle disease virus in broilers. Statistical comparisons are made between control group and YSE-added groups. Results are expressed as means ± SD. Asterisks indicate significant differences according to different supplementing level of YSE (*p < .05).

Table 2. Effects of YSE on serum cytokines’ concentrations in broilers.

| Dietary YSE level, mg/kg | Control | 100 | 200 | 300 | p value |
|--------------------------|---------|-----|-----|-----|---------|
| IL-1β                    |         |     |     |     |         |
| Grower                   | 314.52a ± 8.32 | 331.67a ± 15.56 | 304.17a ± 34.05 | 301.67a ± 27.45 | .125 |
| Finisher                 | 816.88 ± 53.98 | 825.31 ± 75.74 | 782.81 ± 57.33 | 764.06 ± 79.88 | .251 |
| IL-2                     |         |     |     |     |         |
| Grower                   | 120.14 ± 5.41 | 124.76 ± 19.70 | 124.17 ± 15.85 | 130.12 ± 13.15 | .684 |
| Finisher                 | 176.57 ± 12.22 | 181.29 ± 7.20 | 175.67 ± 23.80 | 169.50 ± 28.11 | .78 |
| IL-4                     |         |     |     |     |         |
| Grower                   | 63.41 ± 4.49 | 65.42 ± 3.91 | 61.95 ± 8.45 | 68.14 ± 9.32 | .486 |
| Finisher                 | 72.98a ± 5.35 | 77.50a ± 4.09 | 66.55a ± 8.26 | 65.00a ± 2.99 | .002 |
| IL-6                     |         |     |     |     |         |
| Grower                   | 19.04 ± 0.71 | 19.30 ± 1.28 | 17.39 ± 2.06 | 16.31b ± 0.66 | <.001 |
| Finisher                 | 14.58 ± 0.54 | 15.52 ± 0.88 | 13.86 ± 0.49 | 14.16 ± 0.49 | .004 |
| TNF-α                    |         |     |     |     |         |
| Grower                   | 88.92 ± 3.54 | 87.74 ± 5.90 | 86.34 ± 3.91 | 86.56 ± 2.47 | .678 |
| Finisher                 | 94.71 ± 6.47 | 94.53 ± 7.56 | 89.38 ± 8.92 | 92.09 ± 5.16 | .460 |
| IFN-γ                    |         |     |     |     |         |
| Grower                   | 95.18 ± 0.86 | 98.16 ± 7.23 | 93.82 ± 1.85 | 93.73 ± 3.00 | .271 |
| Finisher                 | 86.79 ± 6.68 | 94.82 ± 4.89 | 85.86 ± 5.56 | 85.89 ± 4.09 | .026 |

*Means within a column that do not share a common superscript are significantly different (p < .05).
possesses optimum growth performance in broilers. Based on the absence of clinical signs, broilers were considered healthy throughout the trials. This could be attributed to the low density of broilers, and the high hygienic condition of cages used in the current study compared to commercial floor pens.

Interleukins are composed of cytokines, which are important components of the immune system. They exhibit important functions in inflammation and systemic inflammatory status, and pathological disorders occur when there is imbalance in terms of cytokine production or dysregulation in a cytokine process (Tayal and Kalra 2007). The concentrations of Th1 cytokines including IFN-ϒ, TNF-α, IL-2, IL-6 (known as pro-inflammatory cytokines) and a Th2 cytokine, IL-4 (known as anti-inflammatory cytokines) level were measured in the present study. During grower period, there were no marked improvements of cytokines with YSE addition. However, supplementation of YSE at doses higher than 100 mg/kg to basal diet resulted in a decrease of IL-6 production in grower stage. Among the cytokines, IL-6 has the most endocrine activity such as involving in the functioning of metabolism (Gabler and Spurlock 2008) and is generated by different cell types such as antigen presenting cells, B cells and Th2 cells. Despite its pro-inflammatory role (Xing et al. 1998), IL-6 is a pleiotropic cytokine that expresses anti-inflammatory effects (Scheller et al. 2011). The results of our study indicated that high dosage of YSE ingestion might impair immunological status of broilers and elevate their susceptibility to disease during early stage of broiler rearing. This was corresponded with our earlier study which suggested that lower dosage (100 mg/kg) of YSE exhibited the optimum effects on immune functions (Su et al. 2016). Our results suggested that YSE supplementation caused limited inflammatory response to birds in the early growing phase of broilers. During finisher period, addition of YSE at higher levels to basal diet resulted in the decrease of IL-4 concentration, and low YSE dose caused the enhancement of IL-6 and IFN-γ production. IL-4 is crucial in the stimulating process of B lymphocytes and T lymphocyte proliferation, as well as the formation of Th2 cells by differentiating of CD4+ T cells (Fietta and Delsante 2008). While IFN-γ plays a key role in activation of macrophages for nitric oxide production (He et al. 2011) and participated in the differentiation of naive T cells to Th1 cell (Schoenborn and Wilson 2007). Our results suggested that YSE improved the immune response of chickens at low YSE levels, probably due to the up-regulation of IL-6 and IFN-γ production. And, higher YSE levels might exacerbate immune status such as decreasing IL-4 production in broilers. The changes of both Th1 and Th2 cytokines in our study could be attributed to the immunological balance and cross-regulatory effects between both inflammatory and anti-inflammatory cytokines, suggesting that YSE could maintain immune homeostasis and prevents further activation of immune system.

YSE is a rich source of polyphenols such as resveratrol (Piacente et al. 2005). Conversely, other authors reported lowered IL-1β and TNF-α gene expression with increasing level of resveratrol in splenocytes (Zhang et al. 2014). According to Zhang et al. (2014), resveratrol could inhibit the NF-κB pathway and eventually result in the suppression of transcription of pro-inflammatory cytokines like IL-1β and TNF-α. But Lai et al. (2016) found that resveratrol could dose-dependently upregulate serum cytokines’ concentrations related to immune function such as IL-1/β, IL-2, TNF-α and NF-κB levels in immunosuppressive mice, suggesting that resveratrol might express its immune activity through activating the NF-κB-signalling pathways. However, our study failed to detect any changes in IL-1β and TNF-α concentrations in the whole experimental period. It is hypothesised that the discrepancy might be explained by the different content of polyphenols between YSE and resveratrol, and it might also be related to the actual physiological status of animals.

In our study, both grower period and finisher period experienced increases of antibody titres against NDV, and the same low YSE level being the optimum dosage. This illustrated that YSE supplementation might be effective in increasing immunity response in broilers. The effectiveness of YSE towards NDV has been attributed to the presence of saponin components (Gurbuz et al. 2011). However, the relatively low YSE concentration observed in our study corresponded with a study of Iqbal et al. (2015) who reported that antibody titres against NDV were increased in broilers fed the 25 and 75 ppm grape polyphenols diets. Conversely, Zhang et al. (2014) suggested that 400 mg/kg of resveratrol had the optimum antibody titres at d 40 of age, which was higher than the suitable dose in our study. Gessner et al. (2017) postulated that anti-inflammatory effects of polyphenols were unlikely to be mediated by their direct antioxidant effects as a result of the poor bioavailability and the corresponding improvements of gut health. Therefore, less translocation of pro-inflammatory and pro-oxidative stimuli would occur. We hypothesised that the positive effects of YSE on NDV in the current trials was a composite effect of both saponin and polyphenols components, which in line with the hypothesis of
Balestrieri et al. (2006) who suggested that the anti-inflammatory properties of YSE could be attributed to the synergic action of resveratrol and yuccaols.

Environmental pollution, outburst of infectious diseases and food safety concerns are three serious problems, which haunted modern Chinese-farming industry. The current study gave us a cue of using YSE as an immunological stimulant to improve broilers’ resistance of disease. Reports about ammonia depressing effects of YSE in poultry were also available (Chepete et al. 2012; Onbasilar et al. 2013; Matusiak et al. 2016). The multibeneficial effects of YSE, its easy access and the low cost all together made YSE a strong candidate in poultry health feeding industry in China.

Conclusions
The present results suggested that YSE exhibited positive effects on growth performance and immune functions in broilers. The changes of the inflammatory response following YSE supplementation in chickens were related to stimulation of IL-6 and IFN-γ concentrations during later phase in broiler production and the enhancement of antibody titres against NDV in the whole period. The optimum YSE dosage is 100 mg/kg.

Geolocation information
Hohhot (E: 111.65°, N: 40.82°) is the capital of Inner Mongolia which located in the north of China. The climate in Hohhot is based off a four-season, monsoon climate.

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The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

References
Alagawany M, Abd El-Hack ME, El-Kholy MS. 2016. Productive performance, egg quality, blood constituents, immune functions, and antioxidant parameters in laying hens fed diets with different levels of Yucca schidigera extract. Environ Sci Pollut Res Int. 23:6774–6782.

Alfaro DM, Silva AVF, Borges SA, Maiorka FA, Vargas S, Santin E. 2007. Use of Yucca schidigera extract in broiler diets and its effects on performance results obtained with different coccidiosis control methods. J Appl Poult Res. 16:248–254.

Altincik A, Sönme F, Yenisey Ç, Duman S, Can A, Akev N, Kirdar S, Sezak M. 2014. Effects of Aloe vera leaf gel extract on rat peritonitis model. Indian J Pharmacol. 46:322–327.

Balestrieri C, Felice F, Piacente S, Pizza C, Montoro P, Oleszek W, Visciano A, Balestrieri ML. 2006. Relative effects of phenolic constituents from Yucca schidigera Roezl. bark on Kaposi’s sarcoma cell proliferation, migration, and PAF synthesis. Biochem Pharmacol. 71:1479–1487.

Bhardwaj J, Chaudhary N, Seo HJ, Kim MY, Shin TS, Kim JD. 2014. Immunomodulatory effect of tea saponin in immune T-cells and T-lymphoma cells via regulation of Th1, Th2 immune response and MAPK/ERK2 signaling pathway. Immunopharm Immunoton. 36:202–210.

Budai MM, Varga A, Milesz S, Tözşér J, Benkő S. 2013. Aloe vera downregulates LPS-induced inflammatory cytokine production and expression of NLRP3 inflammasome in human macrophages. Mol Immunol. 56:471–479.

Cheeke PR. 2000. Actual and potential applications of Yucca schidigera and Quillaja saponaria saponins in human and animal nutrition. J Anim Sci. 77(E-Suppl):1–10.

Cheeke PR, Piacente S, Oleszek W. 2006. Anti-inflammatory and anti-arthritic effects of yucca schidigera: a review. J Inflamm (Lond). 3:6.

Chepette HJ, Xin H, Mendes LB, Li H, Bailey TB. 2012. Ammonia emission and performance of laying hens as affected by different dosages of Yucca schidigera in the diet. J Appl Poultry Res. 21:522–530.

Chinese Ministry of Agriculture. 2004. Feeding Standard of Chicken, China (NY/T 33-2004). Hunan Feed. 4:19–27.

Dimitrov KM, Afonso CL, Yu QZ, Miller PJ. 2017. Newcastle disease vaccines – a solved problem or a continuous challenge? Vet Microbiol. 206:126–136.

Duffy CF, Killeen GF, Connolly CD, Power RF. 2001. Effects of dietary supplementation with Yucca schidigera Roezl ex Ortgies and its saponin and non-saponin fractions on rat metabolism. J Agric Food Chem. 49:3408–3413.

Euribrid BV. 1994. Technical information for hybro broilers. Euribrid Poultry Breeding Farm, Boxmeer. p. 22.

Fietta P, Delsante G. 2008. The effector T helper cell triade. Riv Biol. 102:61–74.

Gabler NK, Spurlock ME. 2008. Integrating the immune system with the regulation of growth and efficiency. J Anim Sci. 86:E64–E74.

Gessner DK, Ringseis R, Eder K. 2017. Potential of plant polyphenols to combat oxidative stress and inflammatory processes in farm animals. J Anim Physiol Anim Nutr. 101:605–628.

Gurbuz E, Balevi T, Kurtoglu V, Oznurlu Y. 2011. Effects of adding yeast cell walls and Yucca schidigera extract to diets of layer chicks. Br Poult Sci. 52:625–631.

He HQ, Genovese KJ, Kogut MH. 2011. Modulation of chicken macrophage effector function by T(H)1/T(H)2 cytokines. Cytokine. 53:363–369.

Iqbal Z, Kamran Z, Sultan JI, Ali A, Ahmad S, Shahzad MI, Ahsan U, Ashraf S, Sohail MU. 2015. Replacement effect of vitamin E with grape polyphenols on antioxidant...
status, immune, and organs histopathological responses in broilers from 1- to 35-d age. J Appl Poult Res. 24:127–134.

Jahanian R. 2009. Immunological responses as affected by dietary protein and arginine concentrations in starting broiler chicks. Poult Sci. 88:1818–1824.

Kim JH, Hahn DM, Yang DC, Kim JH, Lee HJ, Shim I. 2005. Effect of crude saponin of Korean red ginseng on high-fat diet-induced obesity in the rat. J Pharmacol Sci. 97:124–131.

Kucukkurt I, Akkol EK, Karabag F, Ince S, Süntar I, Eryavuz A, Sözbilir NB. 2016. Determination of the regulatory properties of Yucca schidigera extracts on the biochemical parameters and plasma hormone levels associated with obesity. Rev Bras Farmacogn. 26:246–250.

Kumar S, Koul M. 2016. Newcastle disease virus: a constant threat to the poultry industry in India. Vaccine. 34:597–598.

Lai X, Pei QS, Song X, Zhou X, Yin ZQ, Jia RY, Zou YF, Li LX, Yue GZ, Liang XX, et al. 2016. The enhancement of immune function and activation of NF-κB by resveratrol-treatment in immunosuppressive mice. Int Immunopharmacol. 33:42–47.

Matusiak K, Oleksy M, Borowski S, Nowak A, Korczyński M, Dobrzański Z, Gutarowska B. 2016. The use of yucca schidigera and microbial preparation for poultry manure deodorization and hygienization. J Environ Manage. 170:50–59.

Onbasilar EE, Erdem E, Unal N, Kocakaya A, Torlak E. 2013. Effect of Yucca schidigera spraying in different litter materials on some litter traits and breast burn of broilers at the fifth week of production. Kafkas Univ Vet Fak Derg. 19:749–753.

Patel S. 2012. Yucca: a medicinally significant genus with manifold therapeutic attributes. Nat Prod Bioprospect. 2:231–234.

Piacente S, Pizza C, Oleszek W. 2005. Saponins and phenolics of Yucca schidigera Roezl: chemistry and bioactivity. Phytochem Rev. 4:177–190.

Sahoo SP, Kaur D, Sethi APS, Sharma A, Chandra M. 2015. Evaluation of Yucca schidigera extract as feed additive on performance of broiler chicks in winter season. Vet World. 8:556–560.

Salois MJ, Cady RA, Heskett EA. 2016. The environmental and economic impact of withdrawing antibiotics from US broiler production [abstract]. J Food Distribution Res. 47:79–80.

SAS Institute. 2002. SAS user's guide: statistics. Cary (NC): SAS Institute.

Scheller J, Chalaris A, Schmidt-Arras D, Rose-John S. 2011. The pro- and anti-inflammatory properties of the cytokine interleukin-6. Biochim Biophys Acta. 1813:878–888.

Schoenborn JR, Wilson CB. 2007. Regulation of interferon-gamma during innate and adaptive immune responses. Adv Immunol. 96:41–101.

Su JL, Shi BL, Zhang PF, Sun DS, Li TY, Yan SM. 2016. Effects of yucca extract on feed efficiency, immune and antioxidative functions in broilers. Braz Arch Biol Technol. 59:e16150035.

Tayal V, Kalra BS. 2007. Cytokines and anti-cytokines as therapeutics-an update. Eur J Pharmacol. 579:1–12.

World Bank. 2011. World livestock disease Atlas: a quantitative analysis of global animal health data A (2006–2009) forum. Washington (DC): World Bank.

Xing Z, Gauldie J, Cox G, Baumann H, Jordana M, Lei XF, Achong MK. 1998. IL-6 is an antiinflammatory cytokine required for controlling local or systemic acute inflammatory responses. J Clin Invest. 101:311–320.

Yu J, Shi FS, Hu S. 2015. Improved immune responses to a bivalent vaccine of Newcastle disease and avian influenza in chickens by ginseng stem-leaf saponins. Vet Immunol Immunopathol. 167:147–155.

Zhang CY, Tian YD, Yan FB, Kang XT, Han RL, Sun GR, Zhang HR. 2014. Modulation of growth and immunity by dietary supplementation with resveratrol in young chickens receiving conventional vaccinations. Am J Vet Res. 75:752–759.