Ammonia emission and performance of laying hens as affected by different dosages of *Yucca schidigera* in the diet

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Primary Audience: Poultry Nutritionists, Veterinarians, Researchers

SUMMARY

A laboratory-scale study was conducted to determine the effect of feeding laying hens a standard commercial diet supplemented with different dosages of *Yucca schidigera* powder on NH₃ emission rate and production performance. A total of 72 W36 laying hens at 25 wk of age were used during the 12-wk study. The birds were equally divided into 4 groups and randomly allocated among 4 diets containing, respectively, 0, 50, 100, and 200 ppm (by weight) yucca powder. The hens were reared in an environment of 24 ± 1°C and a concomitant RH of 45 to 65%. Measurement of NH₃ emission rate was done with a Gaseous Emission Vessels System. The *Y. schidigera* powder in the laying-hen diet at a dosage of 50, 100, or 200 ppm did not affect the production performance of laying hens when compared with the 0-ppm dosage. The 100-ppm dosage significantly (*P* < 0.05) reduced NH₃ emission by 44 and 28%, respectively, for the first and second day of manure storage when compared with the other dosages. On the third day, NH₃ reduction was 14% but was not significantly different from the other treatments. Adding 50 or 200 ppm of yucca in the diet did not reduce NH₃ emission. Hence, adding 100 ppm of yucca in the laying-hen diet coupled with frequent manure removal (once every 1 to 2 d) would be conducive to reducing NH₃ generation and emission in laying-hen barns.

Key words: ammonia mitigation, laying hen, *Yucca schidigera*

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DESCRIPTION OF PROBLEM

*Yucca schidigera* is a species of the yucca plant that is native to the southwestern United States and Mexico. The yucca plant is rich in the natural steroid saponin, which adds commercial value to the plant. Saponins are naturally occurring chemical compounds found in a wide variety of food, forage plants, and a few marine animals [1]. They have detergent or surfactant properties because they contain both water-soluble and fat-soluble components. They consist

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of a fat-soluble nucleus, having either a steroid or triterpenoid structure, with one or more side chains of water-soluble carbohydrates [2]. Unlike the triterpenoid saponins, steroid saponins of Y. schidigera (yucca) powder have proven beneficial to livestock and poultry producers [3, 4].

Most commercial production of Y. schidigera currently takes place in Mexico. The trunk of the plant is mechanically macerated and either dried and ground to produce 100% yucca powder, or the macerated material is subjected to mechanical squeezing in a press to produce yucca juice or extract. Yucca is currently used as a dietary additive for livestock primarily for NH₃ and odor [2, 4, 5] and odor [6, 7] control. Although the mode of action is not certain, the effects of yucca on reducing aerial NH₃ levels in livestock buildings are probably not due to the saponin components [8]. These authors could not conclusively identify the active NH₃-reducing constituent. There are propositions that carbohydrates [8] and stilbenes (trans-tetrahydroxy-methoxystilbene) [9] may be involved, and the yucca bark is rich in stilbenes [10].

Yucca has been reported to reduce NH₃ concentration in poultry barns [11, 12] and to improve egg production [11]. However, others have reported no effect on production parameters of laying hens [13], laying quail [14], or on turkey poults [15]. Poultry feed has been supplemented with different levels of yucca powder in different studies to examine their effect on various parameters. Although most of the studies were focused on the effect of yucca on aerial NH₃ concentration, which is subject to the influence of air exchange or ventilation rate (VR), this study was focused on the effect on NH₃ emission rate (ER), which combines the effects of both concentration and VR. Sectors of the US egg industry have adopted 100 ppm of yucca powder as the recommended level of dietary supplementation to reduce NH₃ levels in pullet or laying-hen barns. Hence, the objectives of this study were to determine the effect of the recommended yucca dosage (100 ppm) vs. higher or lower dosages (0, 50, and 200 ppm of yucca) in the laying-hen diet on 1) production performance of the hens and 2) NH₃ ER from the laying-hen manure. Yucca powder with a >9% saponin content was used.

MATERIALS AND METHODS

The use and handling of the laying hens in this experiment were approved by the Iowa State University Institutional Animal Care and Use Committee before the experiment commenced.

Experimental Facility

Livestock Environment and Animal Physiology Laboratory I of Iowa State University was used in the study. A 2.21 × 2.26 × 2.41 m (width, length, height) environmentally controlled room was used to rear the laying hens. The birds were kept in 24 metabolic cages, each measuring 0.34 × 0.51 × 0.35 m (width, length, height). One water trough and one feed trough were provided for each cage. The feeders were placed such that cross-feeding between neighboring cages was not possible. Similarly, the cages were partitioned with a solid sheet-metal plate to avoid cross-deposition of manure. Manure trays were provided underneath each cage and were lined with plastic film for easy manure removal. Air temperature, RH, and VR of the room were controlled to maintain an indoor environment of 24 ± 1°C and 45 to 65% RH [16].

Dietary Regimens

The dietary regimens involved a standard laying-hen diet supplemented with different dosages of yucca powder, namely, 0, 50, 100 (positive control), and 200 ppm. The 100-ppm level was considered the positive control because it was the industry-recommended level. A single batch of basal diet was prepared and divided among the regimens, which ensured that the feed was consistently the same throughout the experiment. The basal diet was formulated and mixed at the Iowa State University Poultry Research Farm feed mill plant.

Laying Hens

A total of 72 Hy-Line W36 laying hens [17] at 25 wk of age were procured from a commercial laying-hen farm in Iowa. Upon arrival at the laboratory, the hens were randomly divided into 4 groups of 18 hens each. Each group was randomly assigned a dietary regimen. Each
group was further divided into subgroups of 3 hens, resulting in 6 subgroups or replicates per treatment. The subgroups were then randomly placed in the cages at a stocking density of 581 cm² (90 in²) per hen.

The experiment lasted 12 wk, with the first week being the acclimation period, when all the birds were fed the 0-ppm diet. At the beginning of the second week, the respective diets were fed to the hens as earlier assigned until the end of the experiment. Water and feed were provided ad libitum, and the lighting program was 16L:8D for the entire experiment. Manure was removed once a week until the 10th week, after which it was handled differently for NH₃ emission measurements, as described below. The welfare of the hens was monitored throughout.

On a daily basis, the eggs were collected, counted and weighed. The feed supplied to the birds was also weighed daily. Once a week, 9 hens per treatment were weighed. These data were used to determine production performance of the hens, including feed intake (FI), egg production (hen-day egg production and mass output), and FE. The FI was determined as the difference in mass between the feed given to the hens and that left over after a particular period. Feed efficiency was calculated as the ratio of the mass of feed consumed to the mass of eggs produced over the same time period.

**Manure Handling for NH₃ ER Measurement**

The manure produced during wk 11 and 12 was used in comparative NH₃ emission measurements. During this period, the hens had been well conditioned to the dietary regimens. At the beginning of wk 11, all the manure was removed. Manure was then allowed to accumulate for 3 d. At end of the third day, 2 manure pans per regimen were randomly selected and their manure was separated collected into Ziploc bags [18] and transported to another laboratory (approximately 5 km away on campus), where NH₃ emissions from the manure samples were measured continuously for 3 d using a Gaseous Emission Vessels System [19, 20], as illustrated in Figure 1. Further manure handling is described in the following section. At the same time the samples were taken the first time, another pair of manure pans per regimen were randomly selected and manure was removed in preparation for manure accumulation to be used in the second NH₃ emission measurement session. The remaining pair of manure pans in the regimen were similarly scheduled for the third session. Thus, for each of the 3 measurement sessions, there were 8 manure samples (i.e., 2 manure samples or replicates per regimen × 4 regimens).

**Placement of Manure Samples in the Emission Vessels**

Upon arrival at the emissions measurement laboratory, the manure samples were placed in individual plastic containers and thoroughly mixed with an electric handheld mechanical mixer. A sample of 500 g from each container was placed in small plastic buckets (16.5 cm in diameter and 19.0 cm in height) and leveled by hand to obtain a uniform surface area in all the buckets. The small buckets were then randomly placed in each of the 8 vessels and their lids were tightly closed. The vessels were then placed into the measurement system, followed by the emissions monitoring. A thorough check for leaks on the vessels and air lines was performed. Another manure sample from each mixing container was separately placed in Ziploc bags [18] and stored in the freezer for analysis of physical and chemical properties. Measurements of NH₃ concentration and emissions were made continuously for 3 d, after which a new session was begun following the same procedures described above.

After completion of the 3 measurement sessions, all the stored manure samples were thawed at room temperature overnight. Manure samples belonging to the same dietary regimen were thoroughly mixed together and a composite sample was taken. The manure samples were then sent to a certified commercial manure testing laboratory for analyses of total N [21], ammonium N [21], organic N [21], moisture content (MC) [22], and pH [23].

**Calculation of NH₃ ER**

The NH₃ ER (ER_NH₃, g/h per kilogram of manure) was calculated as follows:
\[ ER_{\text{NH}_3} = \left\{ \left[ \text{NH}_3 \right]_e - \left[ \text{NH}_3 \right]_i \right\} \times 10^{-6} \times \frac{Q}{M} \times \frac{W_m}{V_m} \times \frac{T_{\text{std}}}{T_a} \times \frac{P_a}{P_{\text{std}}}, \]

where \([\text{NH}_3]_e\) and \([\text{NH}_3]_i\) are the \(\text{NH}_3\) concentration in the vessel exhaust and fresh air (ppm), respectively, \(Q\) is the airflow rate through the vessel (m\(^3\)/h per vessel) at the ambient temperature and pressure, \(M\) is the initial mass of manure in the vessel (kg), \(W_m\) is the molar weight of \(\text{NH}_3\) (17.031 g/mol), \(V_m\) is the molar volume of \(\text{NH}_3\) (0.022414 m\(^3\)/mol) at the standard temperature (0°C) and pressure (101.325 kPa), \(T_{\text{std}}\) is the standard temperature (273.15 K), \(T_a\) is the absolute room ambient temperature (°C + 273.15 K), \(P_a\) is the atmospheric barometric pressure (98 kPa, based on site elevation), and \(P_{\text{std}}\) is the standard barometric pressure (101.325 kPa).

**Experimental Design and Statistical Analysis**

For measurement of production performance, the experiment was a completely randomized design. Analysis of variance was conducted on the data using the GLM procedure of SAS software [24] to determine treatment effects on the various production performance variables. The production performance data were summarized into daily averages per hen before being analyzed. For \(\text{NH}_3\) ER, the experiment may be described in 2 parts: 1) a com-
pletely randomized block design, in which the 3 measurement sessions were the blocks and the cages within each session (that were randomly assigned the dietary regimens) were the experimental units, and 2) repeated measures undertaken on manure from each cage over a 3-d period. The same SAS procedure was used to determine treatment effects on \( \text{NH}_3 \) ER. The \( \text{NH}_3 \) ER data were summarized into daily totals before being analyzed.

**RESULTS AND DISCUSSION**

**Production Performance**

The data collected during the first week were excluded from the analysis because the hens were still acclimatizing to their new environment. No mortality was recorded in the entire experiment. The results of the production performance of the hens are shown in Table 1. No significant differences \((P = 0.3463 \text{ to } 0.9146)\) were observed among the regimens in all the production performance variables. Kutlu et al. [13] reported that yucca powder with a 10.76% saponin content at dosages of 0, 30, 60, and 120 ppm did not affect FI, egg production, FE, BW gain, or egg quality parameters of White Hy-Line laying hens reared over an 8-wk period (28 to 36 wk of age). Similar results had been reported in laying quails fed dosages of 0, 100, and 200 ppm of yucca powder [14] and in turkey poults [15]. The addition of 31 to 155 ppm of yucca extract containing 40% steroid saponins increased egg production and 465 ppm of extract decreased egg production in laying hens [11]. Further, the 31- to 155-ppm dosage had little effect on FE and mortality. Positive effects on growth rate and FE had been reported when yucca was included at a dosage of 60 or 120 ppm in the broiler diet [25]. Only the regimen × bird age interaction for the FI variable was significant \((P = 0.05435)\). The ADFI per hen was approximately 100 g, which agrees with the literature value of 100 g/ hen per day [26]. However, it was lower at 35 and 36 wk of age, ranging from 92.2 to 97.5 g/ hen per day across all treatments. During this period, slightly warmer temperatures were experienced, which may have caused the decline in FI when compared with the other time periods. The \( P\)-values for the regimen × bird age interactions for other production variables ranged from 0.3739 to 0.7916.

**\( \text{NH}_3 \) ER**

Figure 2 shows typical dynamic \( \text{NH}_3 \) emission profiles of the laying-hen manure over a 3-d measurement period for each of the 4 regimens. It was observed that the \( \text{NH}_3 \) ER generally increased with storage time, especially in the first 2 d. This may be due to a higher microbial degradation rate because the nutrients were abundant during this period when manure was relatively fresh [27]. The trend was expected to diminish with time because of exhaustion of the nutrients by the microbes. Variations existed in \( \text{NH}_3 \) ER between replications, and these may have been caused by the differences in manure MC as manure moisture evaporated to varying degrees during the 3-d accumulation or collection period. Furthermore, some \( \text{NH}_3 \) may have volatilized during the manure collection period. No significant differences \((P = 0.4863)\) were observed among the 3 measurement sessions conducted. As such, the data from all the sessions were pooled for each regimen. Compared

### Table 1. Effect of *Yucca schidigera* powder on production performance of laying hens

<table>
<thead>
<tr>
<th>Dietary regimen (yucca dosage)</th>
<th>Production performance variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>0 ppm</td>
<td>98 ± 1.7</td>
</tr>
<tr>
<td>50 ppm</td>
<td>99 ± 1.7</td>
</tr>
<tr>
<td>100 ppm</td>
<td>100 ± 1.7</td>
</tr>
<tr>
<td>200 ppm</td>
<td>98 ± 1.7</td>
</tr>
<tr>
<td>Average</td>
<td>99 ± 0.8</td>
</tr>
</tbody>
</table>

1FI = feed intake (g/hen per day); HD = hen-day egg production (%); \( M_{\text{egg}} \) = mass of eggs produced (g of egg/hen per day); FE (g of feed consumed/g of egg produced); BW (kg/hen). Values are means ± SEM.
among themselves, the 0-, 50-, and 200-ppm regimen means (nonrecommended dosages) were not significantly different ($P = 0.3973$). Subsequently, the means for these regimens were averaged by day for comparison with the 100-ppm regimen. These data are presented in Table 2.

When the regimen means were compared on a daily basis, the mean $\text{NH}_3\text{ER}$ for the 100-ppm dosage was significantly lower ($P < 0.05$) than that of the other dosages on the first and second days of manure storage (280 vs. 500 and 390 vs. 544 mg/d per kilogram of manure, respectively). The means were not significantly different on the third day ($P = 0.7609$) of manure storage. Therefore, yucca powder (100-ppm dosage) was effective in suppressing $\text{NH}_3$ emission during the first and second days of manure storage. Thus, to make use of the $\text{NH}_3$-emission mitigation effect by the yucca powder (100-ppm dosage) in laying-hen barns (e.g., manure-belt houses), frequent manure removal (every 1 to 2 d) is desirable. For manure-belt laying-hen houses in the United States, manure is commonly removed once every 1 to 3 d to reduce $\text{NH}_3$ levels in the laying-hen barns and protect

### Table 2. The average ammonia emission rates (mg/d per kilogram of manure ± SEM) of the 4 treatments

<table>
<thead>
<tr>
<th>Dietary regimen (yucca dosage)</th>
<th>Manure storage time, d</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>100 ppm (rec. rate)</td>
<td>$280 \pm 92^a$</td>
<td>$390 \pm 92^a$</td>
</tr>
<tr>
<td>Mean of 0, 50, and 200 ppm (nonrec. rate)</td>
<td>$500 \pm 53^b$</td>
<td>$544 \pm 53^b$</td>
</tr>
<tr>
<td>Mean difference$^2$</td>
<td>$-220 \pm 46$</td>
<td>$-154 \pm 46$</td>
</tr>
</tbody>
</table>

$^a,b$Means within a column with the same superscript letters are not significantly different ($\alpha = 0.05$).

$^1$Rec. rate = recommended yucca inclusion rate; nonrec. rate = nonrecommended yucca inclusion rate.

$^2$Mean difference = recommended rate mean − nonrecommended rate mean (mean ± SE of the difference).
the manure belt from damage by the excessive weight of accumulated manure. During the first, second, and third days, the 100-ppm treatment had 220 mg/d per kilogram of manure (44%), 154 mg/d per kilogram of manure (28%), and 72 mg/d per kilogram of manure (14%) lower NH3 emission, respectively, with a cumulative 3-d reduction of 30%, when compared with the average NH3 emission for the 0-, 50-, and 200-ppm regimens. A regression analysis was conducted on the data in Table 2, and the results are shown in Figure 3. Although yucca at a dosage of 100 ppm significantly reduced NH3 emission in the first and second days of manure storage, the manure thereafter tended to release NH3 at a much faster rate, as shown by the greater slope of the 100-ppm regimen when compared with that of the averaged 0-, 50-, and 200-ppm regimens (80 vs. 6.7, respectively). Thus, the question of how the feed additive would affect NH3 emissions during long-term manure storage (e.g., 6 mo) typical of commercial operation remains to be addressed. Data from the current study are not adequate to answer such a question.

Manure properties for the different diet regimens are shown in Table 3. Compared with the 0-, 50-, and 200-ppm regimens, the manure of the 100-ppm regimen had most of its N existing in the organic form (10.2 ± 0.9 g/kg), which was conducive to lower NH3 emission. Under anaerobic conditions, organic nitrogenous materials would ferment and release NH3, CH4, CO2, H2S, and volatile fatty acids [28]. The ammonium N (NH4-N) is the dominant inorganic or mineral form of N in poultry manure over nitrate N (NO3-N) and nitrite N (NO2-N) [29]. The NH4-N would release NH3 gas through the aerobic and anaerobic microbial transformation processes [30].

Manure of the 100-ppm regimen had lower MC (65.8 ± 4.7%) than that of the other treatments. The MC affects microbial activity, and thus NH3 volatilization [31], and NH3 generation from stored manure decreases when MC falls below 30% [32]. Moisture is required for both dissolution of solid urea forms and subsequent urea hydrolysis, and these processes must occur before NH3 volatilization [30]. The figure 3. Ammonia emission vs. storage time of laying-hen manure for diets containing 0, 50, 100, or 200 ppm of yucca.
pH of manure in all the regimens was above 7.0 (neutral pH), which was favorable for aerobic N decomposition and NH$_3$ release. Ammonium (NH$_4^+$) is the predominant form of N under acidic and neutral conditions, whereas NH$_3$ gas is the predominant form at higher pH levels [33]. The higher MC in the 0-, 50-, and 200-ppm treatments coupled with above-neutral pH may have contributed to higher NH$_3$ ER in these regimens when compared with the 100-ppm regimen.

**CONCLUSIONS AND APPLICATIONS**

1. *Yucca schidigera* powder in the laying-hen diet at a dosage of 50, 100, or 200 ppm did not affect the production performance of laying hens when compared with the 0-ppm dosage.

2. Measured with an NH$_3$ emission vessels system, hen manure from the 100-ppm dosage treatment emitted significantly ($P < 0.05$) lower NH$_3$ in the first day (44% lower) and second day (28% lower) of manure storage when compared with the other yucca inclusion levels. On the third day, NH$_3$ emission was 14% lower but was not significantly different from the other treatments. Adding 50 or 200 ppm of yucca in the diet did not reduce NH$_3$ emission.

3. Field verification studies are warranted, considering the promising results with the 100-ppm dosage and the observation that after 3 d of manure storage, NH$_3$ emission increased at a faster rate for the 100-ppm dosage than for the other dosages. The field studies need to quantify the impact of the 100-ppm inclusion rate on cumulative NH$_3$ emissions over an extended (e.g., 3 to 6 mo) manure storage period.

**REFERENCES AND NOTES**


16. A variable-speed exhaust fan provided the required VR, with the inlet baffle situated on the ceiling of the chamber. A thermostat-controlled 1,500-W heater/fan (Model 3VU37A, Dayton Electric Mfg. Co., Niles, IL) was used to maintain the desired temperature. A portable humidifier (Model V745A, Kaz Inc., Hudson, NY) was used to provide the desired RH.

17. Hy-Line W36 laying hens, West Des Moines, IA.

18. S. C. Johnson & Son, Racine, WI.

19. The Gaseous Emission Vessels System is composed of 8 emission vessels. The vessels were placed in an environmentally controlled room with a constant temperature of 21°C at Livestock Environment and Animal Physiology Laboratory II of Iowa State University. The vessels were made of 19-L (5-gal) plastic containers. To prevent potential interference of the vessel material with NH3 emission measurement, each vessel was lined with Teflon FEP 100 film (200A, DuPont Teflon Films, Wilmington, DE). The air inlet and outlet were located in the airtight lid. Teflon tubing (1/4 in. diameter) and manifold, along with polyvinyl chloride compression fittings, were used in constructing the emission vessel system. The vessels were operated under positive pressure. A diaphragm pump (Model DOA-P104-AA, Gast Manufacturing Inc., Benton Harbor, MI) was used to supply fresh air to the emission vessels. Flow rate of the fresh supply air was controlled and measured with an air mass flow controller [0 to 30 L/min (LPM), stainless steel wetted part, Aalborg Instruments and Control Inc., Orangeburg, NY]. The supply air was connected to a distribution manifold in which air was further divided via 8 identical flow meters (0.2 to 4 LPM, stainless steel valve, VFB-65-SSV; Dwyer Instruments Inc., Michigan City, IN). A flow rate of 3 LPM was introduced into each vessel, resulting in an air exchange of 11 air changes/h. Each vessel was equipped with a small stirring fan (12VDC, Radio Shack, Fort Worth, TX) located 6 cm below the lid for uniform mixing of the headspace. Exhaust air of the vessels was connected to a common 5-cm polyvinyl chloride pipe that was routed to the building vent outlet. Samples of the exhaust air from each of the 8 vessels, the supply air, and the room air were sequentially taken at 6-min intervals, with the first 4 min used for stabilization and the last 2 min for measurement. This yielded a measurement cycle of 1 h for each vessel. The sequential sampling was achieved by controlled operation of 8 solenoid valves (Type 6014, 24 V, stainless steel valve body, Burket Contrromatic USA, Irvine, CA). A Teflon filter was placed in front of each solenoid valve. An advanced photacoustic multi-gas analyzer (Model 1314, Innova, Ballerup, Denmark) was used to measure the NH3 concentrations. The digital signal from the Innova analyzer was converted into an analog signal by the NH3 analog module (Model J1210HW Type 4X, California Analytical Instruments Inc., Orange, CA), which was in turn connected to the measurement and control module (Model CR10, Campbell Scientific Inc., Logan, UT) that logged the data.


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