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Original Article

Efficacy of Aluminum Sulfate Addition to Poultry Litter on Productive Performance of Laying Hens, Ammonia Emissions, and Litter Quality

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ABSTRACT

The objective of this research was to examine whether different types of litter (New, used, and mixed) and alum could interfere in litter quality, thereby also influencing the productive performance of laying hens. A total number of 450 Inshas chickens aged 24 weeks were randomly distributed into six groups (5 replicates, each with 15 hens) of floor litter. The groups included (G1) new wheat straw litter, (G2) used wheat straw litter, (G3) mixed wheat straw litter (50% new+50% used) and (4, 5 and 6) the same litter types in groups 1, 2 and 3 supplied with 500g of alum /m^2 litter. The experiment lasted 16 weeks. Laying hens productive parameters, blood parameters, carcass parameters, respiratory rate, coliform count and pH, as well as ammonia emission, litter quality were assessed.

The results showed that the litter type significantly affects the level of ammonia emission, litter characteristics, carcass characteristics, intestinal pH and coliform count, blood characteristics (T3, cholesterol, uric acid, total protein, albumin, globulin, hemoglobin, and PCV), as well as the body weight gain. In general, we found that reused litter followed by the mixed litter without added alum resulted in the lowest efficiency on the studied traits, as compared to the same types of litter treated with alum and the new litter. We therefore conclude that the addition of alum reduces ammonia emission and improves the characteristics of the litter, which is reflected in enhancement of productive performance and properties of blood and carcass.

INTRODUCTION

Fresh litter is treated in a variety of ways to ensure that it fulfills its function while also reducing ammonia volatilization, which has a positive impact on bird performance, producer health, and return. Acidifier additions, particularly Aluminum sulfate [alum; Al2 (SO3) 414H2O], are commonly employed for outstanding results.

Poultry are typically raised on floor litter to absorb moisture from bird droppings, keeping the floor relatively dry and comfortable for the birds. It also provides a perfect platform for feeding, watering, and other management techniques for the birds. To allow litter to perform these tasks properly, it must be kept dry, clean, and at an acidic pH to prevent ammonia volatilization and the spreading of diseases such as necrotic enteritis, coccidiosis, and fungal infections (Williams *et al.*, 2003).

The bacteria in the litter convert uric acid and organic nitrogen (N) in the bird excreta and spilled feed into ammonium (NH4+). Ammonium, a plant-available type of nitrogen, has the ability to bind to litter and dissolve in water. A part of the ammonium in the litter will be transformed into ammonia depending on the moisture content, temperature, and acidity of the litter (NH_3). High temperature and high pH (alkaline conditions) enhance ammonia generation (Ritz *et al.*, 2004). In commercial poultry farms, ammonia (NH_3) is a major airborne pollutant. In poultry farms, 25 parts per million of ammonia should not be surpassed, according to researchers (Kristensen & Wathes 2000). Furthermore, high levels of ammonia in poultry houses can affect chickens by diminishing growth rate, feed efficiency, and egg production, as well as harming the respiratory tract by increasing tracheitis and airsacculitis, and increasing susceptibility to chronic respiratory disease (CRD), E. coli infection, and Newcastle disease, as well as increasing the incidence of kerato conjunctivitis (Tasistro *et al.*, 2007).

Acidic amendments, which make the litter PH acidic and introduce unfavorable medium for ammonia volatilization, are among the approaches employed to maintain high litter quality. Aluminum sulfate [alum; Al2 (SO3) 414H2O] was primarily utilized to minimize ammonia (NH_3) volatilization by converting volatile NH_3 into nonvolatile NH_4-N. Madrid *et al.* (2012) discovered that using alum as a top dressing for new litter (wood shaving) at a rate of 0.25kg/m2 for 5 days (37-42) significantly reduced indoor ammonia concentrations as compared to non-treated groups, and Do *et al.* (2005) obtained similar findings for a multi-flock litter.

The purpose of this research was to examine the impact of adding alum to new, used, and mixed litters in reducing ammonia emission and the possibility of improving productive performance of Inshas chicken, as well as studying the related changes in physiological parameters.

MATERIALS AND METHODS

The current experiment was carried out at the Sakha Animal Research Station, Animal Production Research Institute, Agriculture Research Center. A total number of 450 Inshas (Sina X Plymoth Rock) hens aging 24 weeks were used in this trial. All birds were randomly distributed into six groups (5 replicates each 15 hens) of floor litter, the contents of which being as follows: (G) floor litter; (G1) new wheat straw litter; (G2) used wheat straw litter; (G3) mixed wheat straw litter; (50% new+50% used) and (G4, G5 and G6) the same litter types in treatments 1, 2 and 3 supplied with 500g of alum /m^2 litter, following Taboosha, 2017). The birds were maintained in a 1.5 square meter pen, 1.5 meter long and 1 meter broad (6 bird/1 meter square), with a 5 cm particular height of such litter in each replicate. The alum (aluminum sulfate, $Al_2(SO_4)_3 \cdot 14{\sim}18H_2O$) was obtained from Daejung Chemical & Metals CO (Siheung, South Korea). Alum is a dry acid salt that neutralizes alkalinity.

The used litter was gathered from a chicken farm used to raise one flock of broilers to 6 weeks of age. 2 days after the birds were removed, the moisture level of litter was high, but it was not caked. For one week, the litter was composited with alum to reduce moisture and ammonia levels, then being thoroughly blended and sifted to eliminate any caked pieces. New, used, and mixed litter was strewn on the floor at a depth of 5 cm

The chickens were grown in an open-sided home on the floor under the same management conditionss. Daily photoperiod was 16 hours. During the experiment, birds were given feed and water *ad libitum*. The study took place over a 16-week period. The experimental diets were created using a basal diet that was designed to be isonitrogenous (16.5 percent CP) and isocaloric (2700 Kcal ME/kg diet), while meeting nutrient requirements set forth by the Agriculture Ministry Decree (1996).

Measurements

Ammonia Emission

Ammonia emission was measured using a digital ammonia measuring equipment (Drager Pac 7000) supplied by Alltech India Pvt. Ltd. The ammonia level was measured monthly. The digital ammonia measuring equipment was placed on the four corners and center on the litter material of each pen and the readings were taken in ppm unit.

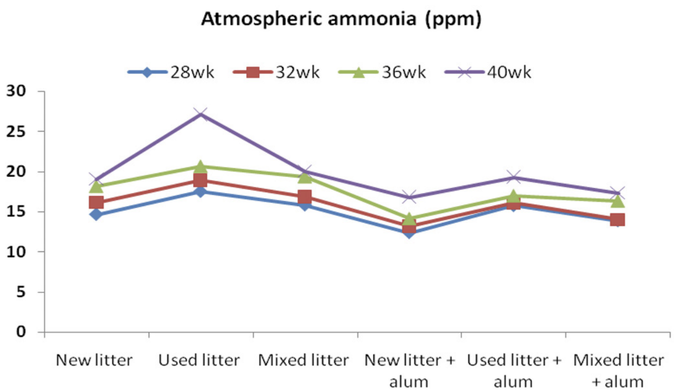


Figure 1 – Effect of alum addition to litter types on atmospheric ammonia for Inshas chickens at 28, 32, 36 and 40 week of age.

Productive performance traits

The body weight gain (BWG) of the chickens was determined by weighing them at the start and end of the trial. Feed consumption was recorded weekly. Every day, the weight and number of eggs were recorded.

The average egg weight was multiplied by the number of eggs to obtain egg mass. The amount of feed used to generate a unit (g) of egg mass was calculated using feed conversion values. During the experiment, dead birds were recorded on a daily basis. Daily respiratory rate of the birds was calculated as the number of breaths per minute.

Five birds from each group (one bird from each replicate) were slaughtered at random at the end of the trial (40 weeks of age) to assess features such as carcass, giblets, and edible parts relative to body weight. During slaughter, samples of intestinal feces from 5 birds from each treatment, as well as 150 samples of litter, were taken for Coliform count and pH determination.

1 gram of digesta was blended with 9 mL of sterile peptone water and stirred for 1 minute on a vortex blender to measure the Coliform count in intestinal contents. Viable counts of bacteria in intestine digesta contents were estimated by plating serial ten-fold dilutions onto violet red bile agar (Merck, Germany) plates to isolate coliform bacteria. Plates were then incubated at 37°C for 24-48 h anaerobically and colonies were counted. After counting the colonies on each plate, the colony numbers were multiplied by the inverse of the dilution to determine the number of colony-forming units (CFU) in 1 g of the sample.

A portable pH meter was used to measure pH after 1 gram of fresh intestinal contents was put into a tube filled with 2 ml distilled water and the pH was measured (SevenEasy pH, Schwerzenbach, Switzerland).

Litter sampling and analysis

Litter samples were collected from three random locations from each partition at the end of each experimental month, and litter samples were then thoroughly mixed for analysis. Moisture and pH were measured in five in litter samples. The difference in the weight of the litter sample before and after drying for 48 hours at 65 degrees Celsius was used to calculate the percentage of moisture content in the litter. The pH of the litter was tested by combining 20 g of litter with 400 mL reverse-osmosis water, shaking vigorously for 20 minutes, and measuring using a pH meter (SevenEasy pH, Schwerzenbach, Switzerland).

Blood parameters

Whole blood samples were gathered from 5 birds from each treatment at 40 weeks of age in heparinized tubes centrifuged at 4000 rpm for 10 minutes in order to obtain the plasma to estimate hemoglobin (Hb), hematocrit (PCV percent), total protein, albumin, globulin, uric acid, cholesterol, T3 and T4 levels were calculated according to Darras *et al.* (1992).

Statistical analysis

Using the SPSS software program package, the data were subjected to an analysis of variance (SPSS, 2005, version 16.0). All data were evaluated with a one-way ANOVA and reported as means standard errors. To find significant differences across groups, Duncan's multiple range test was used (Duncan, 1955).

RESULTS AND DISCUSSION

Ammonia Emission

Table (3) shows that there were high (p<0.05) significant differences in ammonia emission among all groups. In general, however, there was a trend of increasing ammonia emission from 28 week to 40 week in all the litter types. Regardless of alum, ammonia emission was reduced for new litter as compared to those for used or mixed litter. The addition of aluminum sulfate (Al2(SO4)314H2O; alum) to chicken litter has been found to be a cost-effective method of lowering ammonia production (Moore *et al.*, 1995; Moore *et al.*, 1999). Alum is an acid-producing substance that lowers the pH of the litter, preventing ammonia synthesis. Alum dissolution produces hydrogen ions, which mix with ammonia to make nonvolatile ammonium (NH4+), which then combines with sulfate to form ammonium sulfate (Moore *et al.*, 2000; DeLaune *et al.*, 2004). Alum decreased ammonia volatilization by up to 99 percent and quadrupled N retention in the litter, according to Moore *et al.* (1995).

Productive performance

Table 1 shows that there are no significant differences between the treatments on the productive traits of laying hens, except for body weight gain. In general, numerically, the final body weight, number of eggs, and egg weight of the groups reared using different types of litter without treatment was less than the groups raised on the same types of litter treated with alum. These productive traits improved with alum addition, so there were no significant differences between the treatments at the end of the experiment. These findings are in line with Younis *et al.* (2016) who reported that there were no significant differences in body weight of broilers reared on fresh and reused type of litter. There was no significant difference in feed conversion ratio between groups. The results in Table (1) testify that feed conversion ratio for birds raised on used litter

Table 1 – Effect of alum addition to litter types on productive performance for Inshas chickens throughout the experimental period.

Treatments	Body weight			Productive performance				
	IBW	FBW	BWG	EM/h/d	AEW	EP%	FI/h/d	FCR
New litter	1487.3	1673.5	186.2b	30.84	50.15	61.50	94.80	3.07
Used litter	1482.5	1630.0	147.5e	30.06	50.10	60.00	95.80	3.19
Mixed litter	1484.3	1650.2	165.9d	30.47	50.12	60.80	95.00	3.11
New litter + alum	1480.0	1680.0	200.0a	31.12	50.20	62.00	94.60	3.04
Used litter + alum	1478.9	1655.0	176.1c	30.64	50.15	61.10	95.60	3.12
Mixed litter + alum	1483.6	1670.0	186.4b	30.90	50.17	61.60	95.20	3.08
SEM	2.41	2.38	2.75	0.170	0.059	0.316	0.043	0.059
p-value	0.524	0.062	0.001	0.714	0.822	0.525	0.245	0.724

Means in the same column having different letters means they are significantly different ($p \leq 0.05$). IBW= initial body weight, FBW= final body weight, BWG= body weight gain, EM= egg mass, AEW= average egg weight, EP= egg production, FI= feed intake, FCR= feed conversion ratio.

was numerically higher compared with other groups. These findings are in line with Kalita *et al.* (2012) and Yamak *et al.* (2016) who found that feed conversion ratios did not vary significantly between birds raised on new and used litter. Non-significant differences in the feed conversion ratio of broilers reared on fresh and reused litter were also stated by Malone *et al.* (1990) and Lien *et al.* (1992). Moore *et al.* (1996) attributed the improvement in productive performance caused by alum treatment to a decrease in ammonia emission levels or a change in litter microbiology, both of which are linked to variations in litter pH. Furthermore, Rothrock *et al.* (2008) stated that alum reduced litter pH, which resulted in pathogen decrease and, ultimately, improved productive performance.

Litter characters of different litter type

Figure 2 showed there were significant differences among all types of litter at 24 and 40 weeks. Moisture content for new litter was higher than ideal at the end of the experimental time. Meanwhile, moisture contents observed in all litter types without or with alum were ideal, at 20 - 25% at 40 weeks of age.

These findings are harmony with Senaratna *et al.* (2007) who found that moisture contents observed in his experiment, irrespective of the type of litter, were greater than the ideal moisture content (20 - 25%). Excess moisture in the litter can cause growth depression, disease susceptibility, and induce severe discomfort in the form of contact dermatitis in broiler chickens (Dawkins *et al.*, 2004). Controlling litter moisture is also the most critical step in avoiding ammonia problems, as wet litter has been linked to high ammonia levels (Fidanci *et al.*, 2010).

Dry litter helps control the ammonia level, providing a healthy flock environment, and reducing condemnations due to hock, footpad burns, and breast blisters Lonkar, *et al.* (2018). Similar to the present findings, Sahoo *et al.* (2017) reported that the litter moisture content for the control group was higher than that of both sodium bisulphate and alum treated groups. Many other researchers used, aluminium sulfate and sodium bisulfate (Nagaraj *et al.*, 2007) to reduce litter moisture.

Figure 2 shows that the type of litter significantly affects the pH: it was higher in the different types of litter without treatment as compared to the same types of litter treated with alum during the beginning and end of the experiment, and in general, the used and mixed litter had higher pH than other types of litter.

It is advantageous if litter material has a low pH because the conversion of excretory uric acid into ammonia is inhibited at acidic pH values (Moore *et al.*, 1995). Furthermore, as pH rises above 7, ammonia changes from an ionized to a unionized state, making it more volatile (Elliott & Collins, 1982).

Furthermore, Line (2002) demonstrated that aluminum sulfate treatments resulted in a decreased pH for a long time. The alum action was characterized by Moor (1996), with a pH reduction in the litter as a result of alum addition, resulting in a more acidic litter and providing a source of hydrogen ions (H+), which have 6 moles of protons per mole of alum and react with ammonia to create ammonium (NH4+).

The findings of diminishing litter total bacterial counts by alum addition in litter types are in line with those reported by Cook *et al.* (2008), who reported that litter treated with alum significantly reduced litter total bacterial counts. Reduced pH generated by alum application could be a mechanism for reducing pathogen populations, and total bacterial count, having dramatic effect on urease-producing bacteria, as well as reducing production and volatilization of ammonia (Moor *et al.*, 1999, Line, 2002 and Cook *et al.*, 2008).

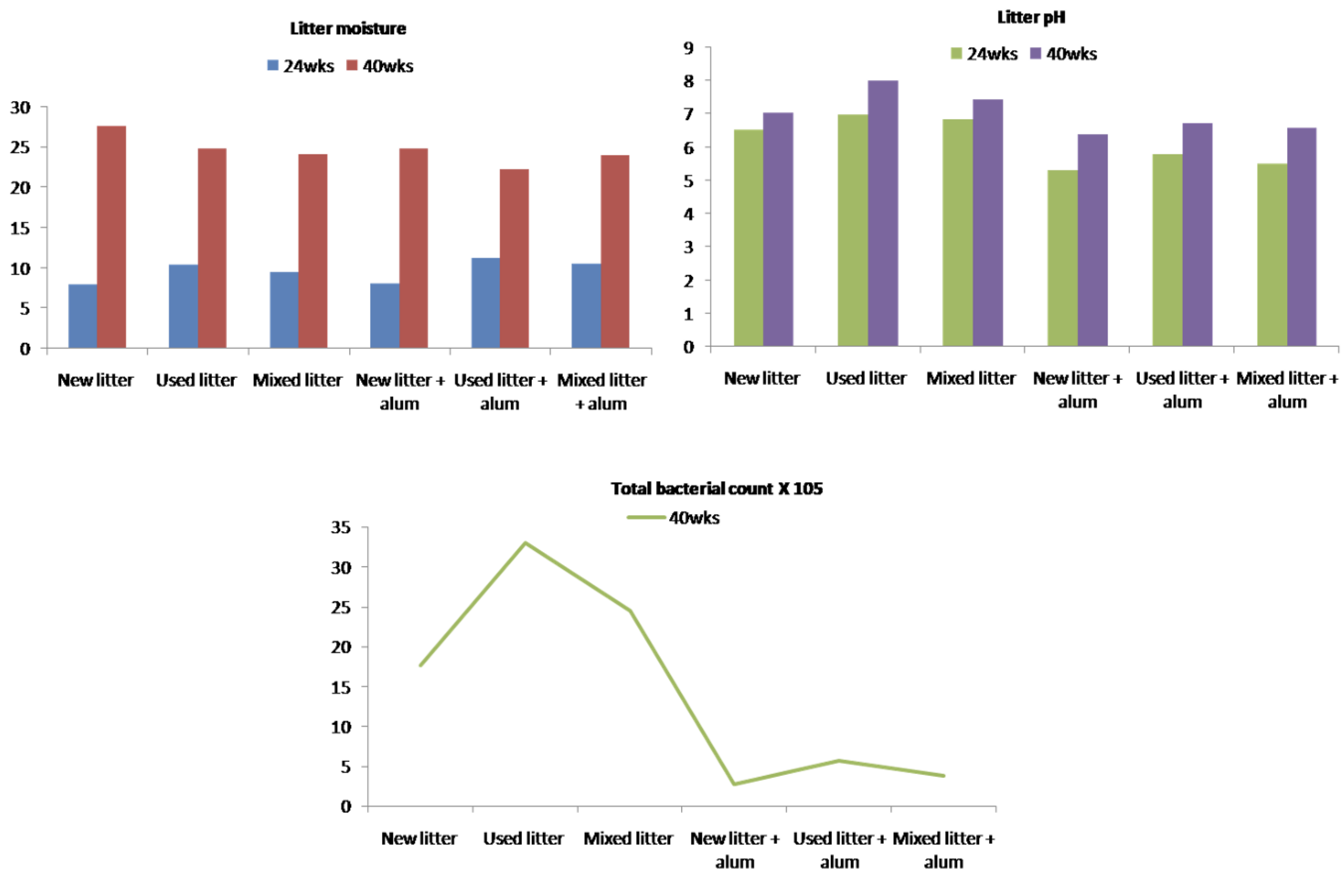


Figure 2 – Effect of alum addition to litter types on litter (moisture, pH and total bacterial count) for Inshas chickens at 24 and 40 wks of age.

Blood parameters

Table 2 shows that there is a significant effect of the treatments on all blood measurements except T4 at 40 weeks of age. It is clear that in the groups raised on different litter types (new, used, mixed) without alum treatment, the lowest levels were in T3, protein, total protein, albumin, globulin, hemoglobin, and PCV. On the other hand, there was an increase in uric acid and cholesterol compared to groups raised on the same litter types treated with alum. It is also worth noting that there are no significant differences between the types of litter (new, used or mixed) when adding alum.

The findings in the present research concerning plasma T3 and T4 supported the findings of Fidanci *et al.* (2010), who observed that plasma T3 concentrations was significantly reduced by ammonia treatment compared with control, while no significant differences were found for plasma T4 between ammonia treatment and control. Also, the same authors suggested the reasons linking low plasma T3 concentrations to ammonia emission. Firstly, the excretion rate and activity of the thyroid gland may be reduced as ammonia level raises in poultry farms. Secondly, there may be greater clearance of T3 from

Table 2 – Effect of alum addition to litter types on some blood constituents for Inshas chickens at 40 wks of age.

Treatments	Blood parameters								
	T3 (ng/ml)	T4 (ng/ml)	Uric acid (mg/dl)	Cholesterl (g/dl)	T.protein (g/dl)	Albumin (g/dl)	Globulin (g/dl)	Hb (g/dl)	PCV %
New litter	2.65b	15.00	6.80b	108.10b	6.30b	3.25b	3.05bc	12.30^{b}	34.5b
Used litter	2.36b	14.50	7.15a	120.15a	6.14b	3.21b	2.93c	11.70b	34.64b
Mixed litter	2.40b	14.60	7.00a	110.80b	6.20b	3.25b	2.95c	12.00b	34.58b
New litter + alum	3.20a	14.80	5.50b	80.85d	6.75a	3.58a	3.17a	16.80a	42.69a
Used litter + alum	3.34a	14.08	5.97b	95.25c	6.80a	3.47a	3.33a	15.80a	40.58a
Mixed litter + alum	3.30a	14.50	5.35b	82.15cd	6.78a	3.48a	3.30a	16.20a	41.60a
SEM	0.12	0.33	0.56	1.52	0.32	0.10	0.12	0.30	0.41
p-value	0.025	0.328	0.0001	0.012	0.005	0.025	0.032	0.001	0.025

Means in the same column having different letters means they are significantly different ($p \leq 0.05$).

the blood. Thirdly, the low retinol concentration in the blood resulting from the raised oxidative stress related to ammonia raise in poultry farm may cause hypothyroidism.

There is few actual published data to support diminishing plasma uric acid and cholesterol concentrations through alum supplementation, but Beker (2004) observed that uric acid with ammonia emissions raise. In birds, uric acid is the principal end product of amino acid and nitrogen metabolism and the chief hormones involved in controlling protein metabolism are insulin and thyroid hormones (Oliveira, 2007).

The decrease in plasma cholesterol concentration through alum addition in this study is in harmony with those cited by Fidanci *et al.* (2010), who reported that accumulated ammonia level in poultry farms significantly raised cholesterol concentration. The significant reduce of cholesterol concentration in the present research may be relative to the raise of plasma T3 concentration as suggested by Shin & Osborne (2003).

The findings of alum impact as an acidic compound on increasing certain parameters are maintained by Enaiat *et al.* (2009), who observed that adding aluminum chloride to poultry litter significantly raised total protein as compared to the control group. This finding is in line with those reported by Arzour-lakehal *et al.* (2013), who mentioned a significant correlation between plasma T3 and plasma total protein. Moore *et al.* (2008) also stated that ammonia levels as low as (20ppm) compromised the immune system of chickens. Also, Amina *et al.* (2010) found that using aluminum chloride in litter significantly enhanced antibody titer, assuming that globulin is a part of immunity. Also, Fidanci *et al.* (2010) have reported that ammonia treatment diminished plasma hemoglobin as carrier of oxygen. The results of raising PCV% by alum supplementation are in line with those stated by Beker et al, (2004), who reported that ammonia emission diminished PCV% for broiler chicks. Additionally, the decrease in PCV% for litter types without treatment may be related to the decrease in plasma T3 level. Bilezikian *et al.* (1980) observed that hypothyroid significantly reduced PCV% when compared with hyperthyroid.

Carcass Characteristics

Figure 2 shows that birds raised on new, used, and mixed treated litter with alum were significantly higher in carcass and giblets % than birds raised on the same litters without alum. Kalita *et al.* (2012) and Yamak *et al.* (2016) found non-significant differences of dressing % between fresh and used litter treatments.

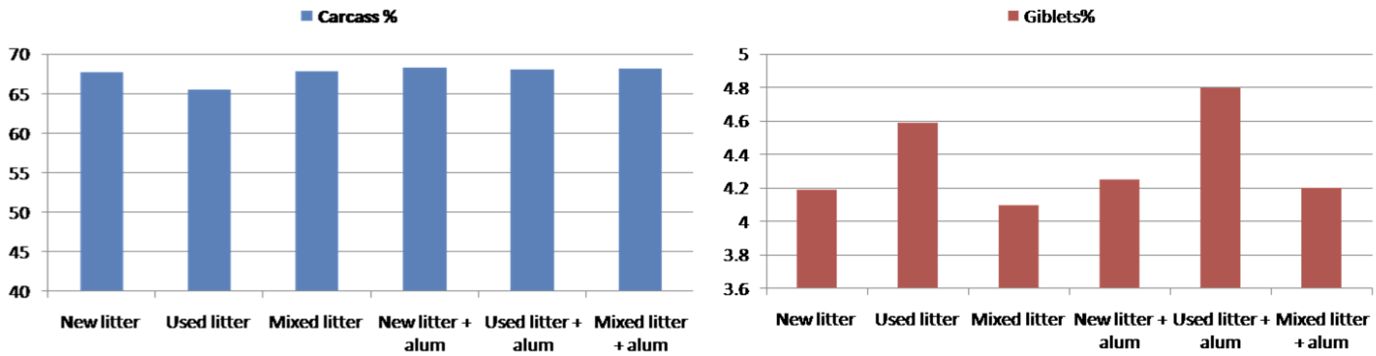


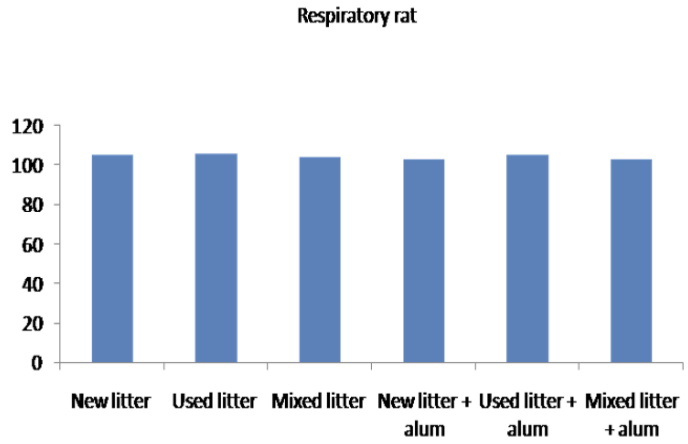
Figure 3– Effect of alum addition to litter types on carcass % and giblets% for Inshas chickens at 40 wks of age.

Respiratory rate, Intestinal pH, and total Bacterial count

There were no significant ($p>0.05$) differences in respiratory rate of birds reared on all litter types at the end of the experimental time (Figure 3). Different litter types had different intestinal pH and Coliform count, these differences were ($p<0.05$) significant among all litter types at 40 weeks (Figure 3). Intestinal pH and Coliform count observed in mixed and used litter were increased compared with new litter. intestinal pH and Coliform count for litter types treated with alum were lower than the same litter types without treated with alum. These results are in line with those reported by Line (2002) who found that the addition of aluminum sulfate and sodium bisulfate for broiler litter significantly diminished their cecal pH and pathogenic microbes.

CONCLUSION

Reused litter treated with alum induced better productive performance for laying hens and litter



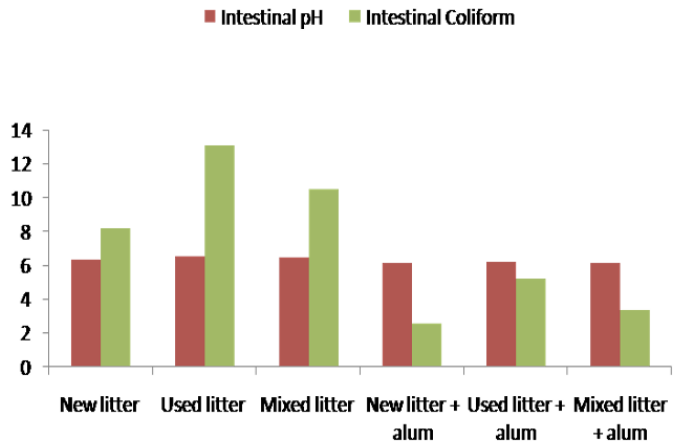


Figure 4 – Effect of alum addition to litter types on respiratory rate, intestinal pH and intestinal Coliform count for Inshas chickens at 40 wks of age.

quality than new non-treated litter. Addition of alum to new, used, or mixed litters decreased litter pH, which reduces ammonia emission in the poultry house. Therefore, litter (especially used and mixed) treated with alum could be recommended for diminishing ammonia emission and improving chicken performance.

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