THE EFFECT OF STOCKING DENSITY AND LITTER TYPE ON AMMONIA, DUST, CARBON DIOXIDE CONCENTRATIONS AND BROILER PERFORMANCE

By

A. Al Homidan and, J.F. Robertson*

College of Agric. and Veterinary Med., Dep. Of Animal Prod. & Breeding, Qassim Univ., Buriedah P.O. Box 1482, Saudi Arabia.
*School of Sciences, University of Aberdeen, Scotland, UK.

Received: **25/9/2005** Accepted: **19/2/2007**

Abstract: *A total of 2778 Hybro broiler chickens were grown over a 49-d period. Two replicates of a 3x2 randomized block design were used. Chicks were wing-banded, weighed individually and allocated randomly into the treatments. Three bedding materials were used: wood shavings, ground chopped straw and chopped straw with sand. There were two stocking densities of 10 and 15 birds/m^2. Birds were fed a commercial diet, and feed and water were supplied ad libitum. Individual body weights were recorded at 1, 28 and 42 days of age. Food consumption and mortality were recorded on a weekly basis. Ammonia and carbon dioxide concentrations were measured daily at bird height at two locations in each room from week 3, and inspirable dust concentrations from week 4.*

In weeks 4-6 the chopped straw litter gave significantly ($P<0.05$) higher mean concentrations of ammonia (17.3ppm) compared with chopped straw and sand (13.4ppm) and wood shavings (11.9ppm). No specific trend was observed for carbon dioxide concentrations in different litter types. The chopped straw litter gave significantly lower mean inspirable dust concentrations than chopped straw with sand or wood shaving litter (4.29 mg/m^3 vs. 6.35 or 5.97 mg/m^3 respectively ($P<0.05$)).

The average ammonia concentration in the air was always higher in rooms with the higher number of birds (15 birds m^2), and this increase was highly significant in week 5 (15ppm vs 5ppm, $P<0.01$) and week 6 (26ppm vs 9ppm, $P<0.001$). There were significant differences in the mean inspirable dust concentrations between stocking densities in week 5 (6.07mg/m^3 vs 4.28mg/m^3, $P<0.01$)), although the significant differences *were not maintained through week 6. Carbon dioxide concentrations were always significantly higher at the higher stocking densities ($P<0.05$).*

INTRODUCTION

In closed poultry houses, the concentration of most aerosol particles increases during the production period, while ammonia with other volatile gases tend to increase exponentially. Ammonia is a colourless, highly irritant gas, which is produced during the decomposition of faeces and urine. Ammonia can adversely affect birds' performance at concentrations of up to 50 ppm during the first 28 days of growth (Reece *et al*, 1980). The problem of elevated concentrations of ammonia has been most common in laying-hen houses and in the grow-out phase of poultry meat production. Therefore, It has become increasingly necessary to ascertain those factors that increase ammonia concentration, their relative importance and interaction, and thereafter to determine the most effective control methods.

Dust in the atmosphere of broiler houses has deleterious effects on broiler performance. (Willis et al, 1987). Therefore, It is important to study the origin, production and control of dust. The dust found in poultry houses is entirely organic and originates from bedding, feed, broken feathers, skin debris and feaces (Koon *et al*., 1963). It is correctly referred to as an aerosol due to its fine particulate nature and the fact that it is dispersed in the atmosphere. Inspirable dust can exacerbate respiratory problems in birds (Willis *et al.,* 1987), and the dust particles carry a proportion of the odorous volatile compounds which many people find offensive, especially if they live nearby.

Webster (1990), in a discussion on the role of housing in respiratory disease, observed that a 10-fold increase in ventilation rates is only two-thirds as effective as halving stocking density in reducing the challenge from contaminants in the air. There is evidence to suggest, therefore, that it is important to ensure that adequate floor space is available for each bird, especially since growth rates and mortality rates can be affected by very high stocking densities. (Proudfoot *et al.,* 1979; Weaver *et al.,* 1982; Shanawany, 1988; and Webster, 1990).

As the broiler industry continues to expand, the availability and cost of conventional litter materials, particularly sawdust and wood shavings, has become a major concern in many areas of the world. Farmers may increasingly have to re-use old litter or use one of the alternative substrates.

Many studies were carried out in the last decade to investigate the effect of litter type on broiler performance (Andrews *et al*., 1993; Martinez and Gernat 1995; Anisuzzaman and Chowdhury 1996; and AL-Homidan, 2001). The principle requirements are that the litter remains dry and friable, and that the water holding capacity of the material is suitable to maintain these conditions.

The present study was conducted to examine some of the above mentioned interrelationships in a systematic manner. The aim was to determine the effect of litter type and stocking density on the broiler growth performance, as well as their effects on ammonia, dust and carbon dioxide concentrations.

MATERIAL AND METHODS

The experiment was carried out at the Poultry Farm of the Agricultural Experimental Station, College of Agriculture and Veterinary Medicine Qassim University, Saudi Arabia. The experiment utilized a total of 2778 Hybro mixed sex broiler chickens grown over a 42-d period. A factorial experiment of randomized block design (2 replicates of 3 bedding materials x 2 stocking densities) was used in six identical adjacent rooms. Three bedding materials were used: wood shavings, chopped straw and chopped straw (4 cm deep) with sand (3 cm deep) to a depth of 7 cm, while the two stocking densities were 10 and 15 birds/m^2. Chicks were wing-banded, weighed individually and allocated randomly into the treatments with 185 and 278 chicks/ replicate. Birds were fed a commercial diet. Starter crumbs containing 22.0 CP % and providing 12.6 MJ ME/kg were fed from hatch to 28 days, followed by a finisher diet containing 18.0% CP and 13.4MJ ME/kg from 28 to 42 days,. Individual body weights and sex were recorded on day 1, and 28 and 42 days of age. The feed offered to each pen was recorded daily. Feed and water were supplied *ad libitum*. Food consumption and mortality rate were recorded on a weekly basis.

Ammonia and carbon dioxide concentrations

Ammonia and carbon dioxide concentrations were measured at bird head height within each room using an air sampling pump (Kitigawa, Japan, Model AP 5). A fixed volume of ambient air was drawn through a glass tube containing indicator reagents that are sensitive to the gases. The measurement accuracy is stated to be ± 10%. The tubes used during the experiment were: 0.2 - 20 ppm (*part No.105 SD*) and 5 - 260 ppm for ammonia (*part no.105 SC, Komyo Rikagaku Kogyo K.K. Japan*) and 0.1-2.6% for carbon dioxide (*part no.126SA*).

Inspirable dust

Inspirable dust concentrations were measured using air sampling pumps (*CasellaUK, Model VORTEX Standard 2*), which ran for 24 hours, attached to total dust sampling heads (*Model T 13087*) (*SKC Ltd. WIMBORINE. DORSET*) containing Whatman *GF/A 25 mm* glass microfibre filters. The filters retain all particles larger than 1.6 µm. The sampling head was located approximately 0.5 m above the floor in the middle of the broiler rooms. Fresh and used filter papers were kept in a desiccator for at least 24 hours before weighing to 0.01 mg accuracy. The difference between the weight of the filter paper with and without dust (before and after sampling) was transformed to give dust concentrations in mg/m^3 for each sampling period.

Ventilation

Ventilation, air conditioning and heating in each of the 6 rooms was controlled by a Dicam FSC2.2M master unit (*Farm Energy and Control Services Ltd. (FARMEX), Pingewood, Reading RG30 3VR*). The unit contains an integrated processor, process timers, and serial ports. Each room had a dedicated temperature sensor leading to the Dicam unit. The unit controlled the temperature to preset limits, and induced preset minimum ventilation rates, which were increased with increasing age of the birds. Thus ventilation rates were variable above the set minimum rates, and a function of bird age and performance, and external weather conditions. Routine adjustments to the individual room requirements were carried out on a daily basis by reconfiguring the system at the Master unit.

Statistical analysis:

Data were analysed using the **GLM** procedure of the SAS program (SAS, 1996).

RESULTS AND DISCUSSION

Bird performance

Mortality during the experimental period was very reasonable, with a mean of 2% across all treatments .There were expected significant differences between male and female liveweights at 42 days, with mean weights of 2025g and 1752g. The corresponding mean of daily growth rates to 42 days were 47.3 and 40.8g/day respectively. .

1- Stocking density

The most prevalent and widely held conclusion to emerge from the numerous literature on stocking density is that increasing stocking density can influence body weight gain by the end of the production cycle. This has not been a unanimous conclusion, however, and studies on the effect of stocking density on other performance indicators such as mortality rate, feed intake and feed conversion, have shown much less agreement. High stocking densities may carry higher risks of disease, and Webster (1990) has demonstrated at an experimental level that manipulation of stocking density is a more effective method of reducing the challenge from infectious organisms than substantial increases in ventilation rates.

The higher stocking density treatment of 15 birds/m^2, in the present study as shown in Table 1 and 2, was associated with a significant ($P<0.05$) decrease in mean body weight of 102g at 42 days, mean daily weight gains reduced by 2.43g/d and mean feed consumption reduced by 8.5g/d. Feed conversion was not significantly affected, although it was lower for birds at the higher stocking density, at 1.76 compared with 1.85. Similar results have already been reported by Heishman *et al*. (1952), Hartung (1955), Hanson and Becker (1960); Moreng *et al.* (1961); Proudfoot *et al*. (1979); Elwinger (1995) and AL-Homidan (2001).

Also, the ammonia concentrations were significantly higher from week 3 to week 6 in the rooms at a stocking density of 15 birds/m^2 compared to rooms with 10 birds/m^2 (Table 3). Averages NH_3 concentration in weeks 5 to 6 were 26ppm and 9.5ppm respectively. Previous studies using the same range of stocking densities have reported similar results, indicating that stocking density had a significant effect on ammonia concentrations (AL-Homidan et al., 1998). The increase in ammonia concentrations in these rooms may be explained by the fact that an increase in the number of the birds will increase the amount of feaces, and the moisture content of litter. The greater concentration of faeces will increase the quantity of nitrogen available for release, and the moisture increases the microbial activity in the litter and hence will cause an increase in ammonia emission (Gustavsson and Mårtensson, 1990). Stanley (1981) indicated that the moisture content of the litter increased progressively as the bird stocking density increased.

There were significant differences in the inspirable dust concentrations between the two stocking densities during the interval of 4-5 weeks of age (Table 4) Greater inspirable dust concentrations were observed in the rooms with higher stocking density. For the period of 5-6 weeks of age, the amounts of inspirable dust was slightly higher in the rooms with higher stocking density but the differences were not significant (Table 4). Bird stocking density may also affect bird activity and temperature; this increase in stocking density leads to an increase in the concentrations of airborne micro-organisms, thereby increasing the risk of disease (Sauter *et al.*, 1981). The main source of dust is bedding, which is disturbed by animal movement and air turbulence. The feed is another potential source of dust, although the quantities of feed dust emitted to air are heavily influenced by feeder design and physical attributes of the feed such as fineness of milling and the use of binding agents (AL-Homidan et al, 2003). The birds themselves contribute to airborne dust through the shedding of skin particles and feathers. An increased stocking density would be expected to increase bird activity and hence lead to a greater production and disturbance of dust.

Meanwhile, stocking density had a small but significant effect ($P<0.05$) on carbon dioxide concentrations (Table, 4). This suggests that the expected increase in CO^2 production within the room from the larger number of birds per unit area was not matched by a proportional increase in ventilation rates.

2- Litter type

Whilst litter type is of less importance than stocking density in terms of broiler performance it may still have significant effects on certain aspects of the production system. Wood shavings were associated with significantly heavier body weights, and increased daily weight gains compared with straw based litters, although feed conversion ratios were similar at 28 and 42 days (Table1&2). Similarly, Anisuzzaman and Chowdhury (1996), using sawdust, paddy straw, sand and rice husk, found that birds reared on rice husk litter showed the greatest feed consumption (3161, 3078, 2967 and

3353g, respectively), greatest weight gain (1520, 1466, 1393 and 1634g, respectively), and the best feed conversion 2.08, 2.10, 2.13 and 2.05, respectively, from 4-56 days of age. These significant differences between the effect of litter types on broiler performance are most likely to be caused by the indirect influence of litter type on the poultry house environment, including air quality.

Ammonia concentrations were significantly affected by litter type during weeks 4 to 6 (Table 3). Ammonia concentrations in the present study were mostly below the suggested animal threshold limit value (TLV) for ammonia of 20 ppm (Scottish Farm Building Investigation Unit, 1984). Concentrations of ammonia in the rooms with chopped straw were generally higher than chopped straw with sand or wood shavings, the concentrations being significantly higher ($P<0.05$) towards the end of the growth period (4-6 weeks). However, high ammonia concentrations may be due to the inadequate amount of substrate available, combined with the different physical properties of the different litter types.

Ammonia is released from poultry fasces by the action of the enzyme urease present in uric acid, on the nitrogen held within the faeces. The emission rate of ammonia from poultry manure is strongly influenced by the moisture content, and will peak at 40-60% moisture (Elliot and Collins, 1983). Thus a dry litter will release less ammonia to the atmosphere than a damp litter. It is suggested that, in the current experiment, the superior water holding capacity of the woodshavings would have maintained a dryer litter than the straw based systems, and thereby limited the release of nitrogen as ammonia. The inclusion of sand with straw may be a useful practical benefit for managing air quality in broiler housing, as it appears to have produced a litter that releases less ammonia to atmosphere than straw alone. Again, this may be associated with an improved water holding capacity.

In the litter there is a continual process involving microbial action that utilises the nutrients in the wood shavings (or other litter materials) and the available nitrogen of the faeces. This process leads to the partial breakdown of wood shavings and faeces to produce a huge number of bacterial cells. The mean carbon: nitrogen ratio (C: N) of microbial cells is about 5: 1 and their growth process involves the nitrogen from the faeces being incorporated into the cellular material (Lynch, 1979). When the C: N ratio of the substrate falls below 20, the microorganisms often became inactive, and in the litter this would be shown by a build-up of faeces, and would indicate that the litter needs to be replenished. Sawdust has a C: N ratio of 400: 1, and straw 80: 1 (Lynch, 1979), which suggests that sawdust or any similar wood based product would provide a suitable litter substrate for longer than straw in an environment where nitrogen is continually being added to the surface. When there is an inadequate source of carbon from the litter, or it is poorly distributed (for example when capping occurs), the microbial growth declines. At this point the nitrogen in the litter becomes preferentially available for aerobic decomposition to ammonia.

Litter type also had a significant effect on dust production (Table 4). The inspirable dust concentrations were lower in those rooms with chopped straw during weeks 4 to 5 and 5 to 6 (3.64 mg/m^3 and 4.29 mg/m^3 respectively) compared to those with chopped straw with sand (6.45 mg/m^3 and 6.35 mg/m^3) or wood shavings (5.45 mg/m^3 and 5.97 mg/m^3). It is suggested that this was probably due to variations in the moisture content of the litter types, with an inverse relationship between moisture content and dustiness. This also fits the association in the current work between litter type and ammonia concentrations, with chopped straw associated with higher concentrations of airborne ammonia, and higher ammonia emission rates being associated with increased moisture levels in the litter.

The threshold limit value (TLV) for long-term (8 hours) exposure of animals to organic dust is 10 mg/m^3, as proposed by The National Board of Agriculture (1988) and the National Swedish Board of Occupational Safety and Health (1987). The mass concentrations of inspirable dust in the rooms with chopped straw with sand, chopped straw or wood shavings ranged from 3.64 to 6.45 mg/m^3 (Table 3). Results of the present study are acceptable and fall below the recommended levels for organic dust of 10 mg/m^3 for animals. Litter type had no significant effect on carbon dioxide concentrations (Table 4).

3- Interaction between litter-type and stocking density:

Ammonia, carbon dioxide and dust concentrations as affected by interaction of litter-type (**LT**) by stocking density (**SD**), are presented graphically in Figures 1&2&3. At 4 and 5 weeks of age, ammonia and carbon dioxide concentrations were significantly affected by LT x SD interaction. The intersecting lines in Figures 1 and 2, indicate that litter-type act jointly (non-independent) with stocking density on ammonia and carbon dioxide concentrations during the 4^{th} and 5^{th} weeks of growth. At the 6^{th} week of growth, lines in curves are nearly parallel to each other; indicating that litter-type and stocking density act independently on ammonia and carbon dioxide concentrations.

At the higher density of birds per pen (15 birds/m^2), wood shavings gave the lowest concentrations of ammonia (1.0 and 10.72 ppm at 4 and 5 weeks, respectively) and carbon dioxide (0.108 and 0.124 % per 100 ml at 4 and 5 weeks, respectively) compared with the other two types of litter of chopped straw supplemented with sand and chopped straw not supplemented with sand (Figures 1&2). Therefore, wood shavings could be used efficiently to decrease the concentrations of ammonia and carbon dioxide in the pens when the stocking density was increased to 15 birds/m^2. However, at six weeks of age the litter of chopped straw and sand gave the least concentrations of ammonia (23.3 ppm) and carbon dioxide (0.104 % per 100 ml) at a stocking density of 15 birds/m^2. Whilst it is not logical to change litter types during a crop of birds, the results suggest that chopped straw supplemented with sand could be used efficiently as a litter at the later stages of broiler growth.

With respect to airborne dust concentrations, the litter of chopped straw not supplemented with sand recorded the lowest concentrations of inspirable dust (4.45 and 4.54 mg/m^3 at 5 and 6 weeks of age, respectively) when the density of birds was 15 birds/m^2 (Figure 3). However, any benefit in bird health and performance that occurs from this relationship with reduced dust concentrations may well be offset by the significantly higher concentrations of ammonia from the chopped straw system. Overall the birds kept on wood shavings gave an average increased body weight at 42 days of at least 63 g per bird compared with the other litter systems.

There were no publications found to compare the current results with other work that has investigated the effect of litter type and stocking density interactions on dust and ammonia concentrations or bird performance.

In conclusion, these results indicate that wood shavings could be used efficiently to limit the concentrations of ammonia in the pens when the stocking density was increased to 15 birds/m^2. Wood shavings also produced significantly higher growth rates in the birds, compared with chopped straw or chopped straw and sand, which will have commercial benefits. Chopped straw supplemented with sand could be used as a litter for the later stages of the broiler production cycle to limit ammonia concentrations.

Table 1: Least square mens and their standard errors (SE) for broiler body weights (g) and daily weight gains (g) as affected by stocking density, litter type and sex.

	Body weight (g)		Daily weight gain (g)	
Weeks	**4**	**6**	**0-4**	**0-6**
Litter types				
Chopped straw with sand	956 ± 3.79[b]	1862 ± 6.44[b]	32.76 ± 0.13[b]	43.41 ± 0.15[b]
Chopped straw	945 ± 3.86[c]	1870 ± 6.57[b]	32.35 ± 0.13[c]	43.62 ± 0.15[b]
Wood shaving	1040 ± 4.04[a]	1933 ± 6.87[a]	35.79 ± 0.14[a]	45.13 ± 0.16[a]
Stocking density				
10 birds/m^2	987 ± 3.44[a]	1939 ± 5.84[a]	34.00 ± 0.12[a]	45.27 ± 0.13[a]
15 birds/m^2	973 ± 2.91[b]	1837 ± 4.94[b]	33.37 ± 0.12[b]	42.84 ± 0.11[b]
Sex				
M	1041± 3.64[a]	2025 ± 6.19[a]	35.82 ± 0.13[a]	47.30 ± 0.14[a]
F	919 ± 2.65[b]	1752 ± 4.50[b]	31.45 ± 0.09[b]	40.80 ± 0.10[b]

Means within columns with no common letters are significantly different ($P<0.05$)

Table 2: Least square means and their standard errors (SE) for feed consumption (g) and daily feed conversion ratio (g) as affected by stocking density and litter type.

	Daily feed consumption (g)		Daily feed conversion ratio (g)	
Weeks	**0-4**	**0-6**	**0-4**	**0-6**
Litter types				
Chopped straw with sand	53.50 ± 0.61[b]	79.75 ± 2.0[a]	1.65 ±0.03[a]	1.83 ± 0.04[a]
Chopped straw	52.25 ± 0.61[b]	78.25 ± 2.0[a]	1.62 ± 0.03[a]	1.78 ± 0.04[a]
Wood shaving	56.75 ± 0.16[a]	81.25 ± 2.0[a]	1.58 ± 0.03[a]	1.80 ± 0.04[a]
Stocking density				
10 birds/m^2	56.00 ± 0.50[a]	84.00 ± 1.64[a]	1.65 ± 0.03[a]	1.85 ± 0.03[a]
15 birds/m^2	52.33 ± 0.50[b]	75.50 ± 1.64[b]	1.58 ± 0.03[a]	1.76 ± 0.03[a]

Values are means ± SE.
Means within columns with no common letters are significantly different ($P<0.05$)

Table 3: Least sguare mens and their standard errors (SE) for ammonia concentration (PPM) as affected by stocking density and litter type.

	Ammonia concentration (PPM)		
Weeks	**3-4**	**4-5**	**5-6**
Litter types			
Chopped straw with sand	2.74 ± 0.18a	10.37 ± 1.09c	16.35 ± 1.19b
Chopped straw	2.59 ± 0.18a	13.91 ± 1.09a	20.69 ± 1.19a
Wood shaving	0.95 ± 0.18b	7.06 ± 1.09c	16.79 ± 1.19b
Stocking density			
10 birds/m^2	1.45 ± 0.15b	5.24 ± 0.89b	9.49 ± 0.97b
15 birds/m^2	2.74 ± 0.15a	15.66±0.89a	26.40±0.79a

Means within columns with no common letters are significantly different ($P<0.05$)

Table 4: Least square means and their standard errors (SE) for Inspirable dust concentrations (mg/m^2) and Carbon dioxide concentration (% per 100 ml) as affected by stocking density and litter type.

	Inspirable dust concentrations (mg/m^2)		Carbon dioxide concentration (% per 100 ml)		
Weeks	**4-5**	**5-6**	**3-4**	**4-5**	**5-6**
Litter types					
Chopped straw with sand	6.45 ± 0.49^a	6.35 ± 0.41^a	0.144 ± 0.002^a	0.118 ± 0.004^a	0.102 ± 0.003^a
Chopped straw	3.64 ± 0.49^b	4.29 ± 0.41^b	0.115 ± 0.002^a	0.125 ± 0.004^a	0.105 ± 0.003^a
Wood shaving	5.45 ± 0.49^a	5.97 ± 0.41^a	0.104 ± 0.002^b	0.112 ± 0.004^a	0.112 ± 0.003^a
Stocking density					
10 birds/m^2	4.28 ± 0.40^b	5.48 ± 0.33^a	0.10 ± 0.002^b	0.101 ± 0.003^b	0.100 ± 0.002^b
15 birds/m^2	6.07 ± 0.40^a	5.59 ± 0.33^a	0.12 ± 0.002^a	0.135 ± 0.003^a	0.112 ± 0.002^a

Means within columns with no common letters are significantly different ($P<0.05$)

Figure 1: Interaction between type of litter and stocking density affecting ammonia concentration

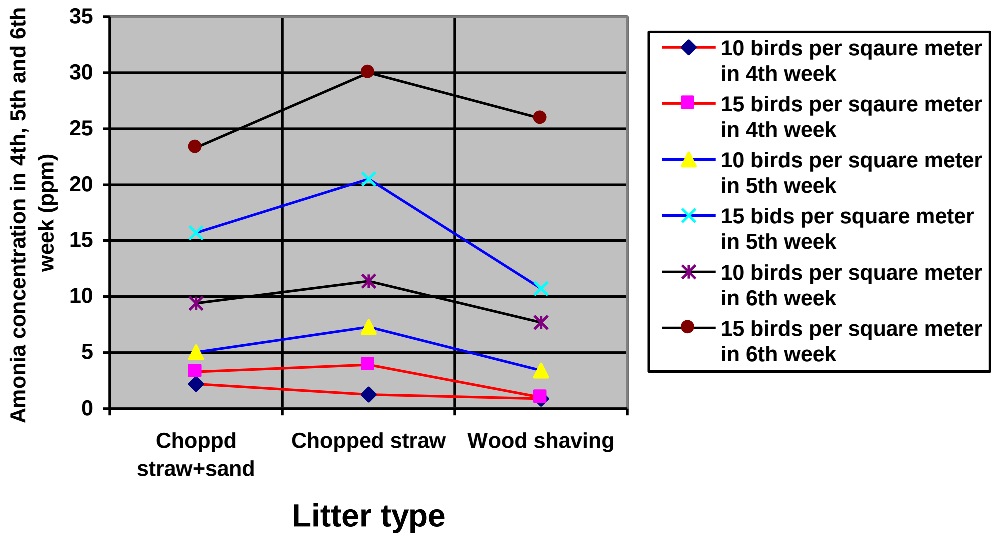


Figure 2: Interaction between type of litter and stocking density affecting carbon dioxide concentration

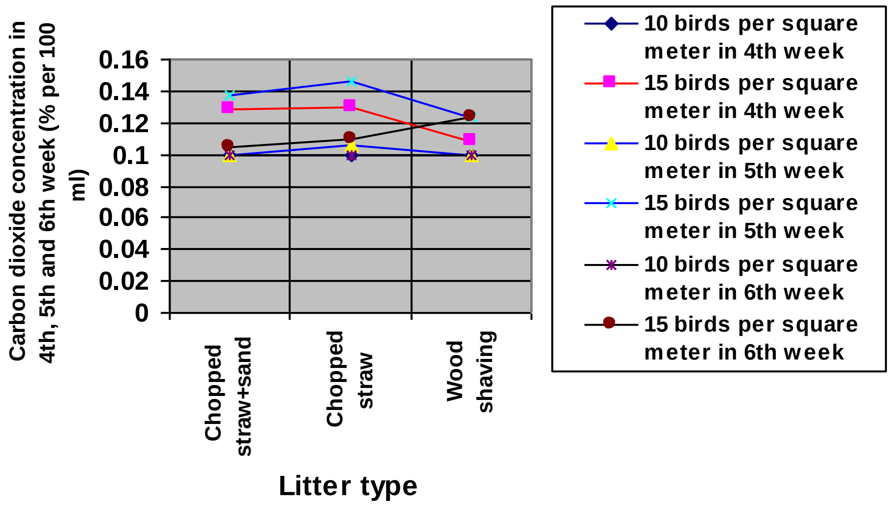
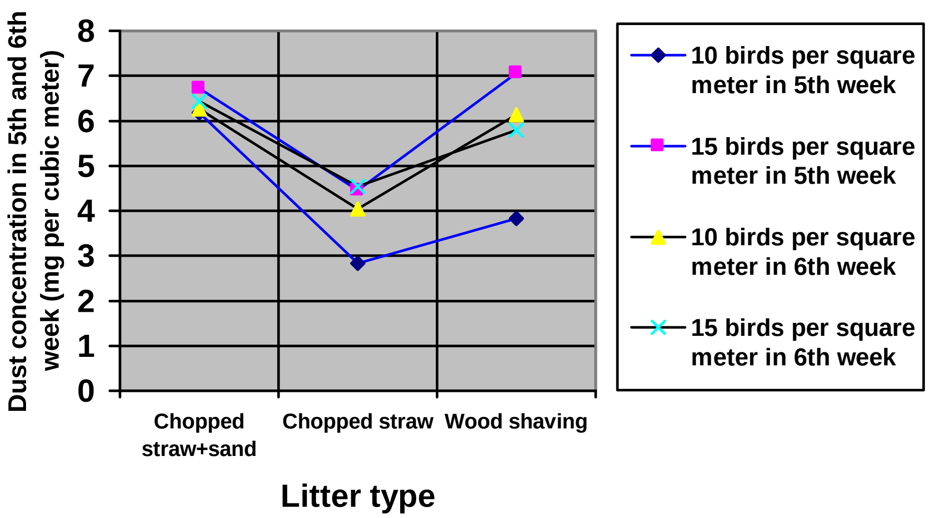


Figure 3: Interaction between type of litter and stocking density affecting dust concentration



REFERENCES

AL-HOMIDAN, A. (2001). *The effect of temperature and stocking density on broiler performance and ammonia production. Egyptian Poultry Science.21: 1121-1137.*

AL-Homidan, A.; Robertson, J.F. and Petchey, A.M. (1998). *The effect of environmental factors on ammonia and dust production and broiler performance. British Poultry Science 39:S9-S10.*

AL- Homidan, A: Robertson J F, Petchey A M. (2003). *Review of the effect of ammonia and dust concentrations on broiler performance. World's Poultry Science Journal, Vol 59, 340-349*

Andrews, L. D., Stamps, L. K., Moore, R. W. and Newberry, L. A. 1993. *Effects of different floor types and levels of washing of waterers on broiler performance and bacteria count of drinking water. Poultry Science, 72 : pp. 1224-1229.*

Anisuzzaman, M. and Chowdhury, S. D. 1996. *Use of four types of litter for rearing broilers. British Poultry Science, 37: pp. 541-545.*

Elliot, H. A., and Collins, N. E., 1983. *Chemical methods for controlling ammonia release from poultry litter. ASAE paper 83-4521, St Joseph, MI.*

Elwinger, K. 1995. *Broiler production under varying population densities a field study. Archiv fur Geflugelkunde, 59 : pp. 209-215.*

Gustafsson, G and Mårtensson, L. 1990. *Gaser och damm i fjäderfästallar. Swedish University of Agricultural Science, Department of Farm Buildings. Report No. 68. Lund.*

Hanson, R. S. and Becker W. A. 1960. *Feeding space, population density and growth of young chickens. Poultry Science, 39 : pp. 659-661.*

Hartung, T. E. 1955. *Floor space for broilers. Poultry Science, 34: pp. 1200.*

Heishman, J. O., Cunningham, C. J. and Clark, T. B. 1952. *Floor space requirement of broilers. Poultry Science, 31: pp. 920.*

Koon, J., Howes, J. R., Grub, W. and Rollo, C. A. 1963. *Poultry dust: Origin and composition. Agriculture Engineers, 44: 608-609.*

Lynch, J. M. 1979. *The terrestrial environmental. In: 'Microbial Biology- A conceptual approach' edited by J. M . Lynch and N. G. Poole. Blackman Scientific Publication, Oxford.*

Martinez, D. F. and Gernat, A. G. 1995. *The effect of chopped computer and bond paper mixed with wood shavings as a litter material on broiler performance. Poultry Science, 74 : pp. 1395-1399.*

Moreng, R. E., Enos, H. L., Buss, E. G. and Hartung, T. E. 1961. *The relationship of floor space to factors influencing broiler growth. Poultry Science, 40: pp. 1039-1044.*

National Board of Agriculture, 1988. *Statutory order on animal protection. Book of Statutes. SFS Jonkoping. Sweden. : pp. 539.*

National Swedish Board of Occupational Safety and Health. 1987. *Occupational exposure limit values. AFS, Solna. Sweden, pp. 12.*

Proudfoot, F. G., Hulan, H. W.and Ramey, D. R. 1979. *The effect of four stocking densities on broiler carcass grade, the incidence of breast blisters, and other performance traits. Poultry Science, 58 : pp. 791-793.*

Reece, F. N. , Lott, B. D. and Deaton, J. W. 1980. *Ammonia in the atmosphere during brooding affects performance of broiler chickens. Poultry Science, 59: pp. 486-488.*

Reece, F. N. and Lott, B. D. 1980. *The effect of ammonia and carbon dioxide during brooding on the performance of broiler chickens. Poultry Science, 59: pp. 59.*

SAS User's Guide, 1989. *Statistical Analysis System. Edition 5. SAS Institute Inc., Box 8000, Cary NC 27 511- 800. U.S.A.*

Sauter, E. A., Petersen, C. F., Steele, E. E. and Parkinson, J. F. 1981. *The airborne microflora of poultry houses. Poultry Science, 60 : pp. 569-561.*

Scottish Farm Buildings Investigation Unit. 1984. *Report of working group on climatization of animal houses. Commission International du Genie Rural. CIGR and SFBIU. Aberdeen, Scotland. ISBN 0 902433 33 4*

Shanawany, M. M. 1988. *Broiler performance under high stocking densities. British Poultry Science, 29: pp. 43-52.*

Stanley, V. G., 1981. *The effect of stocking density on commercial broilers performance. Poultry Science. 60: pp 1737-1738.*

Weaver, W.D (Jr), Beane, W. L. and Cherry, J. A. 1982. *Effect of light, feeding space, stocking density, and dietary energy on broiler performance. Poultry Science, 61: pp.33-37.*

Webster, A. J. 1990. *Housing and respiratory disease in farm animals. Outlook on Agriculture, 19: pp 31-35.*

Willis, W. L., Ouart, M. D. and Ouart, C. L. 1987. *Effect of an evaporative cooling and dust control system on rearing environment and performance of male broiler chickens. Poultry Science, 66: pp. 1590- 1593.*