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EFFECTS OF TREATED POULTRY LITTER ON POTENTIAL GREENHOUSE GAS EMISSION AND FIELD AGRONOMIC PERFORMANCE

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Abstract
A study was conducted to evaluate the effects of different treatments of poultry faecal waste on potential greenhouse gas emission and inherent agronomic potentials. Sugar solution at 100g/l salt solution at 350g/l and oven-drying were the various faecal treatments examined using a completely randomized design. The experiment was conducted for eight weeks. Salt treatment had significantly lower nitrogen content (1.70%; $p<0.05$), and highest nitrogen depletion percentage (1.34%; $p<0.05$) while sugar treatment showed superiority in nitrogen trapping tendency, with depletion rate of -0.6%. Moisture content tends to increase significantly in sugar treatment (86.67%; $p<0.05$) and lowest with samples oven-dried (57.33%; $p<0.05$). Sugar treatment had a mildly acidic pH of 5.66, which was significantly lower ($p<0.05$) than was observed in Salt treatment (6.35). Salt treatment increased in weight over the 8weeks in storage (2.52kg, $p<0.05$), Sugar treatment weighed 2.28kg, heavier than oven-dried and control treatments ($p<0.05$), largely due to the process of fermentation. Baseline microbial assay studies shows no difference ($p>0.05$) in microbial count across all treatments, as was observed up till the 8^{th} week. By the 4^{th} week oven-dried faeces was lower ($p<0.05$) in fungal count (0.33×10^3cfu/ml) compared to other treatments, and completely devoid of Fungi by the end of the 8^{th} week. On agronomic performance test, maize planted using sugar treatments had a 40% germination percentage (GP) after two weeks, oven-dry treatment and the control had mean GP of 65% and 75% respectively. The Sorghum plot attained 100% GP with the control and oven-dry treatments, sugar treatment recorded 88% GP. In both cases, germination was nil on salt treatment. By the third week ending, maize stands on control treatment were averagely 48cm tall, 19cm on oven-dried treatment and10cm on sugar treated pots. This trend persisted on sorghum plots with oven-dry treatment showing superiority to other treatments, averaging a plant height of 28cm after 21days.

Key Words: *Sugar, Salt, Oven-drying, Germination, Faecal waste, Fungal count.*

Introduction

The poultry industry is one of the largest and fastest growing agro-based industries in the world resulting in production of increasingly greater volumes of litter materials (Millner, 2009). This litter represents a valuable energy and nutrient source, with uses as livestock feed, crop fertilizer, and a potential bio-fuel source (Williams *et al.*, 1999). However, one of the major problems encountered is the accumulation of large amount of faecal wastes generated by intensive production which tends to pose disposal and pollution problems unless, environmentally and economically sustainable management

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technologies are evolved (Power and Dick, 2000). Dust, odours and bio-aerosols (e.g. microbes, endotoxins and mycotoxins suspended in air) generated at production, manure storage facilities and during land spreading of poultry litter constitute the most frequent source of complaints against animal-based industries (Millner, 2009).

Uncontrolled decomposition of manure produces odorous gases, including amines, amides, sulphides, and disulphide, these noxious gases can cause respiratory diseases in animals and humans. Ammonia volatilisation from manure also creates odour formation (Williams, 1995; Wheeler *et al.*, 2006), and it may also contribute to atmospheric deposition and acid rain (Walker *et al.*, 2000a; 2000b). Emission of ammonia ranges from 0.034- 0.384 kg NH_3/bird/year for various layer systems (Koerkamp, 1994; Yang *et al.,* 2000) and this could adversely affect the health and welfare of the flock (Dawkins *et al.*, 2004; Ritz *et al.*, 2004), resulting in lower feed efficiencies and increased costs due to the need to remove ammonia, usually through ventilation of the house (Moore *et al.*, 1995). Extended exposure (8 to 10 h) to high ammonia levels have also been shown to negatively affect the welfare of human operators (Ritz *et al.*, 2004; Kirychuk *et al.*, 2006). In addition to health issues, ammonia can also be a major source of pollution (Koerkamp, 1994; Williams, 1995), causing eutrophication of surface waters (Edwards and Daniel, 1992; Paerl and Fogel, 1994), and acidification of soils (Williams *et al.*, 1999). Addition of poultry manure to soils not only helps to overcome the disposal problems but also enhances the physical, chemical and biological fertility of soils (Friend *et al.*, 2006; McGrath *et al.*, 2009) and likewise increasing the organic matter content, water holding capacity, oxygen diffusion rate and the aggregate stability of the soils (Mahimairaja *et al.*, 1995a; Adeli *et al.*, 2009). However, pollution and nuisance problems can occur when manure is applied under environmental conditions that do not favour agronomic utilisation of the manure-borne nutrients (Casey *et al*., 2006; Kaiser *et al*., 2009). It is quite expedient, therefore, to explore several treatment mechanisms for poultry manure in order to improve its storage and handling and to minimize the risks of disease transmission and environmental pollution.

This study was conducted to investigate the influence of various poultry litter treatment on green house gas emission and post-treatment field application performance of maize and sorghum.

Materials and Method

Experimental Materials and Design

The study was carried out at the Animal Pavilion, Department of Animal Production, University of Ilorin, Nigeria. Ilorin is located on latitude 08 29′N and Longitude 004 35′E. Annual temperature range is 22-34°C and annual precipitation is 80-120mm (World Climate, 2013). Fresh faecal samples used in this study were collected randomly from laying birds at the Teaching and Research farm, University of Ilorin, over a three hour period. The samples were subjected to four different treatments each replicated five times using the Completely Randomized Design (CRD). The treatments were; faecal sample treated with Sugar solution, faecal sample Oven-dried (at 60°C), faecal sample treated with salt solution and the Control (untreated). One kilogram of the faecal waste was weighed into separate pots before subjecting to the various treatments; Salt solution at 350g/L of water was used as salt treatment while Sugar at 10% of faecal weight (100g) was used as Sugar treatment (Moore *et al*., 1995). Samples were placed under a shed for eight (8) weeks and subsequently mixed with soil during agronomic evaluation of maize and sorghum performance. Three seeds were planted per potting medium while the plant height and number of leaves was taken weekly.

Parameters Tested

Parameters measured include; Nitrogen retention, moisture content, weight, temperature, pH, and microbial load. Nitrogen retention test was carried out bi-weekly by subjecting the samples to acid digestion and distillation (AOAC, 1990), the temperature range was determined using a thermometer and pH determined bi-weekly using a manual pH meter. The microbial count and identification were carried out fortnightly at the Microbiology Laboratory, University of Ilorin.

Microbial Population and Identificaton Procedure

Potato Dextrose Agar (PDA)

Thirty-nine grams of Potato dextrose Agar powder was weighed and suspended in 1 liter of distilled water. It was shaken properly and heated to dissolve the powder completely. After heating, the flask was plugged with cotton wool and wrapped with aluminum foil, sterilized in the autoclave at the temperature of 121°C for 15 minutes and allowed to cool to about 45°C after which 1% streptomycin powder was added before pouring aseptically into the Petri-dishes.

Serial Dilution Technique

This method was used for the enumeration of all bacteria and fungi.1ml of each of the samples was transferred to 9mls of sterile distilled water in a test tube. Serially, 1ml was taken from the 10^{-1} tube to another tube which make 10^{-2} this was done up to 10^{-6} dilution. Then 1ml was taken from the 10^{-5} dilutions respectively into a sterile Petri-dish and the molten agars that has been prepared earlier for bacterial growth were allowed to cool to about 45°C before pouring into each of the sterile Petri-dishes and allowed to solidify, 10^{-2} dilution was taken for the growth of fungal. These steps were followed for the fungal growth, after solidification each of the plates was incubated at 37°C for bacteria and at room temperature for fungi. Incubation period was between 24-48 hours and 72 hours for fungi. After incubation period, each of the plates were examined and counted.

Characterization and Identification of bacteria isolates

The isolates were characterized and identified after obtaining pure culture of isolates through repeated sub-culturing by using their colonial morphology such as colony shape, edge, surface texture elevation, pigmentation, consistency and optics; Cellular morphology tests including Gram staining and motility test and Biochemical reactions on the bacteria isolates for possible identification, which includes catalase test, coagulate test, oxidase test, indole test, starch hydrolysis and sugar fermentation test (Fawole and Oso, 2007).

Statistical Analysis

Data obtained from the experiment were subjected to Analysis of variance using the SPSS package; significant means were separated using the Duncan Multiple Range Test (Duncan, 1955).

Results and Discussion

Table 1: Effects of Treatments on Nitrogen content, Moisture, pH, Temperature and Weight of Poultry faecal samples

Parameters	Control	Salt solution	Sugar solution	Oven-dry	SEM
Nitrogen (%)	2.20^{b}	1.70^{a}	2.56^{c}	2.42^{c}	0.03
Moisture (%)	66.74^{b}	75.36^{c}	86.67^{d}	57.33^{a}	1.05
pH	7.37^{c}	6.35^{b}	5.66^{a}	7.36^{c}	0.07
Temperature (°c)	28.95^{a}	29.06^{a}	29.05^{a}	60.20^{b}	0.05
Weight (kg)	0.79^{b}	2.52^{d}	2.28^{c}	0.41^{a}	0.01

Means bearing different superscript across the rows are significant ($p<0.05$)

There were significant differences ($p<0.05$) in Nitrogen content across the treatments. Salt treatment was significantly lower in nitrogen (1.70%; $p<0.05$), however sugar treated and oven-dried samples were similar ($p>0.05$) in mean Nitrogen concentration, though higher ($p<0.05$) than the observed value for the other treatments. Lower N_2 content in Salt treated feaces implies high ammonia volatilization and litter quality deterioration (Griffin, 1981; Elliot and Collins, 1983). Raymond and Harris (1954) reported a 5-10% loss of faecal nitrogen in conventional oven dried material compared to levels in fresh faeces, This is consistent with the present study, hence indicative of its nitrogen trapping tendencies. Similarly, moisture content tends to increase significantly in sugar treatment (86.67%; $p<0.05$) and lowest with samples oven-dried (57.33%; $p<0.05$). Litter moisture content has been shown to affect ammonia release (Elliot and Collins, 1983) and although there is limited numerical information about the release rate, earlier studies (Elliot and Collins, 1983) indicated microbial growth in chicken manure with aerobic decomposition or anaerobic process as optimal between 40 and 60% moisture. An increase in moisture content would therefore enhance ammonia release, as the growth of microbes depends on water.

pH test shows that the control and Oven-dried treatments were neutral ($p>0.05$), Sugar treatment had a mildly acidic value of 5.66, which was significantly lower ($p<0.05$) than was observed in Salt treatment (6.35). The implication of acidic faecal pH is that at low pH, ammonification is inhibited and therefore leads to reduction in ammonia emissions to the atmosphere (NRCS, 2007). Consequently, treating poultry faecal waste with sugar solution during storage does not completely stop the processes that result in gaseous nitrogenous emissions (that is, denitrification and ammonification) but may slow it down. Derikx *et al*. (1994) noted that during the drying of poultry, cattle and pig manure, all ammonia was volatilized when the pH was above 8 and the fatty acids evaporated when the pH was below 5. Broiler litter pH has an important role on the volatilization of ammonia, as it tends to increase when the pH increases. The pH value is the main factor regulating the equilibrium between NH_4^+ ions and NH_3 gas in the manure solution. The degradation of uric acid and undigested protein in the poultry manure increases their breakdown rates at pH 5.5 or higher, with an optimum pH of 9 for uricase. Practically, below a pH of 7 nearly all ammonia is bound as ammonium and not available for volatilization (Weast *et al.*, 1986).

Oven-dried treatments were also observed to record higher temperature ($p<0.05$) in excess of 60°C, almost doubling the figures observed in other treatments. Ghaly and MacDonald (2012a) reported that drying of poultry manure over the temperature range of 40-60° achieved reductions in odor intensity and offensiveness of 65 and 69%, respectively. Thermophilic bacteria have high growth rates growth rate in media with high temperature (e.g. *Bacillus substilis)* because temperature of poultry faeces is determined by the microorganism's growth phase. Higher temperatures, therefore, lead to higher rates of nitrification, denitrification and decomposition of organic material, but also to foster crop growth and the associated uptake of nutrients from manure. Nitrates are formed faster and are therefore more susceptible to leaching, but are also taken up faster by plants if a crop or vegetation is present. At higher temperatures and under reduced conditions NO_3 will, be denitrified more rapidly and N_2O, (harmful to the ozone layer), will be formed more quickly (Ghaly and MacDonald, 2012a). These observations were found to corroborate with the significantly lower weight drop (410g; $p<0.05$) of oven-dried faeces. Salt treatment was heaviest after eight weeks in storage (2.52kg, $p<0.05$) while Sugar treatment recorded a mean weight of 2.28kg, heavier than both Oven-dried and Control treatments ($p<0.05$). This is largely due to the process of fermentation.

Table 2: Rate of Nitrogen Depletion

Parameter	**Control**	**Salt solution**	**Sugar solution**	**Oven-dry**	**SEM**
Nitrogen %	0.57^{b}	1.34^{c}	-0.60^{a}	0.54^{b}	0.02

Means bearing different superscript across the rows are significant ($p<0.05$)

Table 2 shows the trend, at which nitrogen depleted from the treated poultry faecal samples. Samples Oven-dried and the control were similar ($p>0.05$) in rate of depletion. Salt solution had the highest nitrogen depletion percentage (1.34%; $p<0.05$) while sugar solution showed superiority in nitrogen trapping tendency, recording a negative index of N_2 depletion.

Microbial Population and Identification

Table 3: Effect of treatments on faecal microbial population

Parameters (cfu/ml)	**Control**	**Salt solution**	**Sugar solution**	**Oven-dry**	**±SEM**
Baseline					
TVC (10^6)	4.53	3.53	2.37	2.77	0.44
TCC (10^6)	3.47	0.97	1.40	0.47	0.55
FCC (10^6)	0.33	0.00	0.33	0.00	0.14
FC (10^3)	1.73	1.40	1.47	1.33	0.15
Week 4					
TVC (10^6)	2.37	3.80	3.57	4.50	0.40
TCC (10^6)	1.70	3.13	2.40	3.20	0.34
FC (10^3)	2.07^{b}	1.67^{b}	2.20^{b}	0.33^{a}	0.18
Week 8					
TVC (10^6)	4.33	4.23	4.10	4.70	0.33
TCC (10^6)	3.07	3.73	2.83	3.40	0.28
FC (10^3)	1.47^{b}	1.23^{ab}	2.10^{b}	0.00^{a}	0.23

Means bearing different superscript across the rows are significant ($p<0.05$). TVC- Total Viable Count, TCC- Total Coliform Count, FC- Fungal Count.

The following bacteria were identified during the sugar fermentation of the faecal samples, *Staphylococcus aureus, Enterobacter aerogenes, Proteus vulgaris, Escherichia coli, Bacillus substilis.* Identified fungiincludes; *Aspergillus niger, Neurospora crazza, Penicillium chrysogenum, Aspergillus flavus, Saccharomyces cerevisae, Rhizopus stolonifer.*

Table 3 above shows the microbial properties of the various treatments. Baseline studies shows no difference ($p>0.05$) in microbial count across all treatments, as was observed up till the 8th week. By the 4th week, Oven-dried Samples had lower ($p<0.05$) Fungal count (0.33×10^3cfu/ml) compared to other treatments. This sample was completely devoid of Fungi by the end of the 8th week. This might be due to the higher internal temperature observed in the oven dried samples which is unfavorable to fungal growth. However, some bacteria, identified in the microbial assay are known to be resistant to high temperature, some of which includes *Bacillus substilis and Saccharomyces cerevisae*. The results indicated that the higher the drying temperature and/or the thinner the manure layer, the more destruction of microorganisms there is in the dried manure. The killing actions of heat appeared to be time-temperature dependent. Several researchers reported that 90% of microorganisms in manure will be destroyed in a few days at temperatures in the range of 20-40°C and a few weeks at temperatures of 4-10°C (Himathongkham and Riemann, 1999; Placha *et al*., 2001). Larney *et al*. (2003) noted that a period of 7 days was necessary to eliminate *Escherichia coli* in beef cattle manure at temperatures in the range of 33.5 - 41.5°C. As earlier stated, ammonia volatilization results from the mineralization of organic nitrogen in the poultry litter (uric acid and urea) and more than half of the nitrogen in poultry litter is lost as ammonia due to microbial activity (Moore *et al*., 1996).

Agronomic Evaluation of Treated Feacal Samples

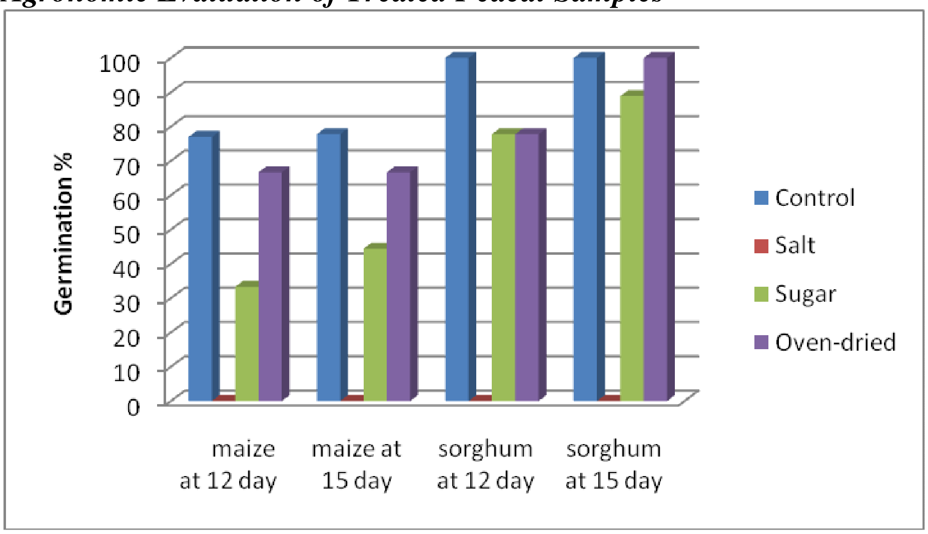

Figure 1: Germination Percentage of Maize and Sorghum cultivated using the various Treatments.

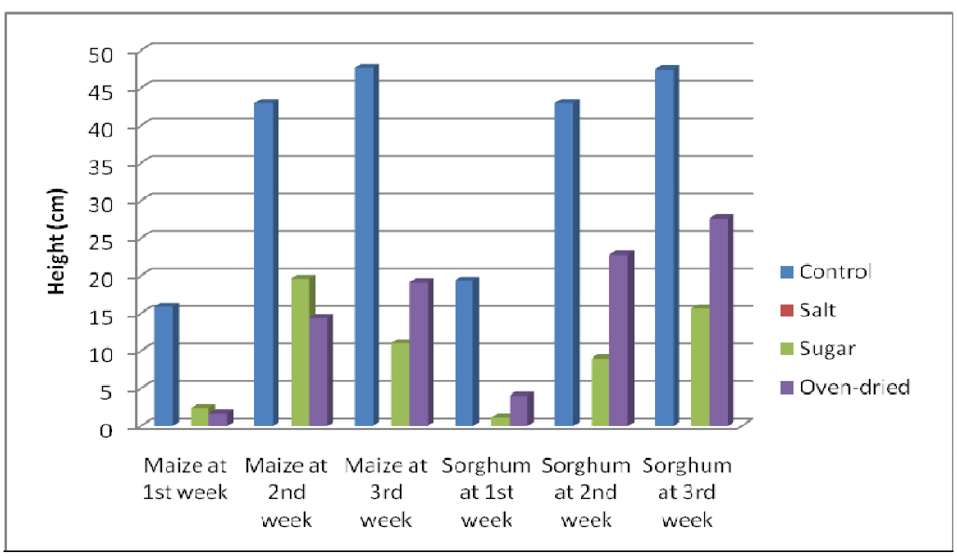

Figure 2: Average height of Maize and Sorghum cultivated using the various Treatments

Figure 1 shows the germination rate of Maize and Sorghum cultivated using the various treatments. Maize planted on sugar treatments had an average germination percentage (GP) of 40% after two weeks, while Oven-dry treatment was head to head with the control with mean GP of 65%. This trend was also observed in the Sorghum plot, with the Control and Oven-dry attaining 100% GP after two weeks, and Sugar treatment recording an impressive 88% GP. In both cases, seed germination was nil on Salt treatment. Sugar acts by drawing out water from the bacteria and other microorganisms, which either kills the bacteria or inhibits their growth, once the oxygen is exhausted, only anaerobic organisms can survive in the potting medium, thus allowing the growth of acid forming and proteolytic bacteria. This causes a decrease in pH in the faecal waste which kills both yeast and molds. The acidity in the soil continues to increase to such a level where the acid producing organisms themselves are killed. After the death of both the aerobic and anaerobic organisms, deterioration of the waste stops and this might takes two to three weeks. (Atteh, 2002). Figure 2 shows the mean height of Maize and Sorghum planted using the various treatments. Sugar treated and Oven-dried faecal matter produced an average Maize height of 3cm after 7 days, this been in sharp contrast to the control which recorded Maize stands 15cm tall after 7days. By the third week ending, Control treatment were averagely 48cm tall, 19cm on Oven-dried and10cm on sugar treated plots. This trend persisted on Sorghum plots with Oven-dry treatment showing superiority to other treatments, averaging a height of 28cm after 21days of planting. It has been reported that dried poultry manure can be used as a fertilizer source for plants because of its high nitrogen, phosphorus and potassium contents which are essential for plant growth, including its higher rate of oxidation and pathogen destruction (Cummings and Jewell, 1977; Ghaly and MacDonald, 2012b).

Conclusion

The study suggests that the potentiality for denitrification and ammonification is better suppressed in Oven-dried faecal matter, thereby reducing the tendency for ammonia volatilization. This was also buttressed in its relatively superior agronomic performance. However, Sugar treatment is equally effective in preventing faecal nitrogen depletion hence mechanisms for improving its overall agronomic performance could be an area of research.

References

Adeli, A., Tewolde, H., Sistani, K.R. And Rowe, D.E. (2009). Broiler litter fertilization and cropping system impacts on soil properties. *Agronomy Journal*, 110: 1304-1310.

Atteh J.O. (2002). Principles and practice of livestock feed manufacturing. Adlek Printers. Ilorin Kwara State Nigeria, Pp: 27-28.

Casey, K.D., Bicudo, J.R., Schmidt, D.R., Singh, A., Gay, S.W., Gates, R.S., Jacobsen, L.D. and Hoff, S.J. (2006). Air Quality and Emissions from Livestock and Poultry Production/Waste Management Systems, In: Rice, J.M., Caldwell, D.F. & Humenik, F.J. (Eds.) Animal Agriculture and the Environment: National Center For Manure and Animal Waste Management White Papers, Publication No 913c0306, Pp. 1-40 (St. Joseph, Mi, Asabe).

Cummings, R.J. and Jewell, W.J. (1977). Thermophilic Aerobic Digestion Of Dairy Waste. In: Food, Fertilizer and Agricultural Residues, Loehr, R.C. (Ed.), Ann Arbor Science Publishers Inc., Michigan. Illinois.

Dawkins, M.S., Donnelly, C.A. and Jones, T.A. (2004). Chicken Welfare is Influenced More by Housing Conditions than by Stocking Density. *Nature,* 427: 342–344. Crossrefmedlineweb Of Science

Derikx, P.J.L., Willers, H.C. and Ten Have, P.J.W. (1994). Effect of pH on the behaviour of volatile compounds in organic manures during dry-matter determination. Bioresou. Technol., 49: 41-45. DOI: 10.1016/096-8524(94)90171-6

Edwards, D.R., and Daniel, T.C. (1992). Environmental impacts of on-farm poultry waste disposal—A review. *Bioresource Technology*, 41: 9–33.

Elliot, H.A. and Collins, N.E. (1983). Chemical Methods For Controlling Ammonia Release from Poultry Manure. *Asae.*Paper 83-4521, P. 17.

Fawole, M.O and Oso B.A (2007). Laboratory Manual of Microbiology pp 30-34.

Friend, A.L., Roberts, S.D., Schoenholtz, S.H., Mobley, J.A. and Gerard, P.D. (2006). Poultry Litter Application to Loblolly Pine Forests: Growth and Nutrient Containment. *Journal of Environmental Quality*, 35: 837-848.

Ghaly, A.E. and K.N. Macdonald, (2012a). Drying of Poultry Manure for Use as Animal Feed. *Am. J. Agricultural Biological Sci*., 7: 239-254. Doi :10.3844/Ajabssp.2012.239.254

Ghaly, A.E. and K.N. Macdonald (2012b). An Effective Passive Solar Dryer For Thin Layer Drying Poultry Manure. *Am. J. Eng. Applied Sci*., 5: 136-150. Doi: 10.3844/Ajeassp.2012.136.150

Griffin, D.M. (1981). Water and Microbial Stress. In: Advances in Microbial Ecology, New York: Plenum Press. Pp. 91-136.

Himathongkham, S. and Riemann, H. (1999). Destruction of *Salmonella* typhimurium, Escherichia coli O157:H7 and Listeria monocytogenes in chicken manure by drying and/or gassing with ammonia. FEMS Microbiol. Lett., 171: 179-182. PMID: 10077842

Kaiser, D.E., Mallarino, A.P. and Haq, M.U. (2009). Runoff Phosphorus Loss immediately after Poultry Manure Application as influenced by the application rate and tillage. Journal of Environmental quality 38: 299-308.

Kirychuk, S.P., Dosman, J.A., Reynolds, J.S., Willson, P., Senthilselvan, A., Feddes, J.J.R., Classen, H.L. and Guenter, W. (2006). Total Dust and Endotoxin in Poultry Operations: Comparison between Cage and Floor Housing and Respiratory Effects in Workers. J. Occup. Environ. Med. 48:741–748.Cross Refmedlineweb of Science

Koerkamp, P.W.G. (1994). Review Of Emission Of Ammonia From Housing Systems For Laying Hens In Relation To Sources, Processes, Building Design And Manure Handling. *Journal of Agricultural Engineering Research*, 59: 73-87.

Larney, F.J., Yanke, L.J., Miller, J.J. and McAllister, T.A. (2003). Fate of coliform bacteria in composted beef cattle feedlot manure. *J. Environmental Quality*, 32: 1508-1515. DOI: 10.2134/jeq2003.1508

Mahimairaja, S., Bolan, N.S. and Hedley, M.J. (1995a.) Agronomic Effectiveness of Poultry Manure Composts. *Communications in Soil Science and Plant Analysis*, 26: 1843-1861.

Mcgrath, S., Maguire, R.O., Tacy, B.F. and Kike, J.H. (2009). Improving soil Nutrition with Poultry Litter application on Low input forage systems. *Agronomy Journal,* 102: 48-54

Millner, P.D. (2009). Bioaerosols Associated With Animal Production Systems.

Bioresource Technology, 100: 5379-5385.

Moore, P.A., Daniel T.C., Edwards, D.R. and Miller, D.M. (1995). Effect of Chemical Amendments on Ammonia Volatilization from Poultry Litter. *J. Environ. Qual.*, 24:2 93–300.

Moore Jr, P.A., Joern, B.C., Edwards, D.R., Wood, C.W. and Daniel, T.C. (2006). Effects Of Manure Amendments on Environmental and Production Problems, In: Rice, J.M., Caldwell, D.F., & Humenik, F.J. (Eds) Animal Agriculture and the Environment: National Center For Manure and Animal Waste Management White Papers, Publication No 913c0306, Pp. 1-40 (St. Joseph, Mi, Asabe).

National Resources Conservation Service (NRCS), (2007). Manure Chemistry Nitrogen, Phosphorus, and Carbon. *Manure Management Information Sheet*, 7: 1-4.

Paerl, H.W., and Fogel, M.L. (1994). Isotopic characterization of atmospheric Nitrogen inputs as sources of Enhanced Production on coastal Atlantic Ocean Waters. *Mar. Biol*., 119: 635

Placha, I., Venglovsky, J. Sasakova N. and Svoboda, I.P. (2001). The effect of summer and winter seasons on the survival of Salmonella typhimurium and indicator micro-organisms during the storage of solid fraction of pig slurry. J. Applied Microbiol., 91: 1036-1043. PMID: 11851811 Poultry Science, 75:315-320.

Power, J.F. and Dick, W.A. (2000). Land Application of Agricultural, Industrial, and Municipal By-Products. Soil Science Society of America Inc., Madison, WI

Raymond, W.F., and Harris, C.E. (1954). The laboratory drying of herbage and faeces, and drying matter losses possible during. J. Brit. Grassl. Soc. 9:119-130

Ritz, C. W., B. D. Fairchild, and M. P. Lacy. (2004). Implications of Ammonia Production and Emissions from Commercial Poultry Facilities: A Review. J. Appl. Poult.Res.13:684–692.

Walker, J., Nelson, D. and Aneja, V.P. (2000b). Trends In Ammonium Concentration In Precipitation And Atmospheric Ammonia Emissions At A Coastal Plain Site In North Carolina, U.S.A. *Environmental Science And Technology,* 34: 3527-3534.

Walker, J.D., Aneja, V.P. and Dickey, D.A. (2000a). Atmospheric Transport and Wet Deposition of Ammonium in North Carolina. *Atmospheric Environment,* 34: 3407-3418.

Wheeler, E.F., Casey, K.D., Gates, R.S. Xin, H., Zajaczkowski, J.S., Topper, P.A., Liang, Y. and Pescatore, A.J. (2006). Ammonia Emissions from Twelve U.S. Broiler Chicken Houses. Trans. Asae 49:1495–1512.

Williams, C. M., J. C. Baker, and J. T. Sims (1999). Management and Utilization of Poultry Wastes. Rev. Environ. Contam. Toxicol. 162:105–157 Medline Web of Science

Williams, P. E.V. (1995). Animal Production and European Pollution Problems. *Anim. Feed Sci. Technol*., 53: 135–144.

World Climate, (2013). http://www.climate-charts.com/ Locations/n/NI65101.php. Retrieved 10/09/2013.

Yang, P., Lorimor, J.C. and Lin, H. (2000). Nitrogen Losses From Laying Hen Manure In Commercial High-Rise Layer Facilities. American Society of Agricultural engineering, 43: 1771-1780.