CHARACTERISTICS OF DRYING PROCESS OF POULTRY MANURE AT VARIOUS TEMPERATURES*

R. Liška, P. Kic

Czech University of Life Sciences Prague, Faculty of Engineering, Department of Technological Equipment of Buildings, Prague, Czech Republic

The main objective of this work was to investigate the evolution of the role of temperature during drying of poultry manure. The following is a description of common treatment methods of poultry manure. The experiments were carried out in a laboratory of Czech University of Life Sciences Prague. The samples were dried by different drying methods. During the drying process the temperatures varied between 21.5°C to 110°C. From the tested samples, by using a pre-drying method, the lowest rate of 16.84% of dryness of the manure matter was achieved. The lowest rate of dry matter as measured in an environment approximating working conditions was 33.65%. These values were gained in two cases and whole drying procedure lasted 48 hours. The samples were compared according to the type of breeding system. The measurement demonstrates that different design of drinking system significantly influenced the moisture content ($P < 0.05$) of the manure. Spillage causes excessive manure moisture. It was observed that higher moisture content was measured for laying hens using nipple drinkers compared to those equipped with downspout accessories. Results from this study provide new data for updating standards that could be used in design and operation of laying hen houses.

dry matter content; moisture content; drying temperature; air oven

INTRODUCTION

Pollution by animal wastes has become a great problem in many countries. The great problem of animal waste management is well known. Poultry manure can be a valuable resource as it contains a significant amount of nitrogen, phosphorus, potassium, calcium and many other macro and micro minerals (Sistani et al., 2001). The rapid growth of the poultry industry in recent years and the application of poultry waste to agricultural land have resulted in excessive phosphorus content in the soil in many locations. The welfare of poultry and environmental protection can be increased by reduction of ammonia emissions from housing buildings (Codling et al., 2002).

Manure can be classified as solid, slurry and wastewater (Haga, 2001). On the basis of the poultry rearing system, there are two kinds of poultry manure:

(1) Deep litter: poultry is reared on the floor of a building with sufficient bedding materials (sawdust, rice husk or wood shavings, etc.). The excrement with bedding materials is removed from the building and considered as litter. It contains less water and it is easy to handle.

(2) Layer manure: poultry is reared in the case housing system, the excrement is called manure. Layer manure is a semi-solid mass and falls directly onto the concrete floor and needs to be cleaned daily. There is a heavy accumulation of flies and insects and it also produces bad odor if not cleaned or racked daily. Layer manure produces comparatively more odor than broiler litter (Mukhlesur, 2009).

The following treatment methods relevant for land application of poultry manure are currently being used: drying, composting, anaerobic digestion, combustion, pasteurization and palletizing (Roeper et al., 2005).

Direct fertilizing using fresh excrement is strictly limited by its consistence, which does not allow for uniform spreading. Another limitation is the seasonality of application – it can be used only in a specific timeframe and is limited by quantity. If straw was used as opposed to sawdust in deep litter production, fertilizing would be possible. The high rate of lignin in sawdust complicates composting, which is more complicated compared to straw (Hutla, Kosar, 1995).

The average production of manure per hen/day is 170 g. Some proposals have shown the application of 5–7 t per ha of arable land (Hutla, Kosar, 1995). In the case of two spreading yearly, it could be realized on the same field. For example, 5000 hens on an area of 45 ha means 100 000 hens would require an area of 900 ha for regular application. In light of the huge amount of produced manure, this cannot be considered a sustainable solution for problematic exploitation and treatment of poultry excrements.

An application without treatment or non-appropriate disposal can become risky for environment and humans

* Supported by the CIGA (CULS Grant Agency), Project No. 20093001 and IGA (Internal Grant Agency – Faculty of Engineering), Project No. 31170/1312/3106.

as such application might lead to the spread of diseases and may pollute soil and groundwater (Roepet et al., 2005). Direct land application of untreated manure is the most common utilization option, but it can result in environmental pollution of waters, odor nuisance and hygienic problems, which can result in the spread of diseases (Glenn et al., 1998).

Composting is an effective and safe way for reduction of the manure's mass and volume, destruction of pathogens, and stabilization of nutrients and the organic matter in it (Michel et al., 1996; Tiquia et al., 2000). Composting is one of the natural processes capable of stabilizing organic wastes. The stabilization process considerably reduces odor emissions, and dries up the waste making it easier to handle and transport. Also, proper composting effectively destroys pathogens and weed seeds due to high temperature (55–65°C) achieved through the metabolic heat generated by microorganisms. As the animal waste possibly contains viral, bacterial, and protozoan pathogens, the application of untreated livestock wastes could be a hygienic risk for humans (Petric et al., 2008).

Biogas technology is next option of treatment with manure. This is becoming more and more common nowadays. The process of biogas production appears to be a progressive, economically viable method of ultimate disposal and hygienic process (Babička et al., 2007).

One of the most serious consequences of manure's moisture content is not just the method of treatment mentioned above but also of handling. It is directly affected by the selection of the proper operating sequence and technological equipment (Kosar, 1994).

One of the most important drawbacks of housing systems is the high concentration of ammonia in the building. As a result of the damaging effects of ammonia deposition on the environment (eutrophication and acidification) (Heij, Schneider, 1991), governmental regulations prescribe a substantial reduction of the emissions ammonia from livestock husbandry (Voorburg, 1993; Lekkerkerk et al., 1995). Emission rates, processes and influencing factors of the emission of ammonia from poultry houses were reviewed by Groot Koerkamp (1994).

One of interesting alternatives of manure is its application on a post-fire land. Villar et al. (2004) conducted an experiment to investigate efficiency of a post-fire land management practice, including plant cultivation (*Lolium perenne*) combined with the addition of poultry manure, for restoring the protective vegetation cover in soils degraded by high intensity wildfires. The increase of phytomass and nutrient uptake with the addition of poultry manure revealed the beneficial effects of this soil management practice.

In practice, moisture in manure is also influenced by temperature, drinking system and the management of ventilation during the removal of manure, which is shown further in the results of our experiment. A study was conducted to determine the effect of drying methods and temperature influence on drying characteristics of poultry manure. The results from this study provide useful information for developing cost-effective mitigating techniques.

MATERIAL AND METHODS

The experiments were done at the Faculty of Engineering of Czech University of Life Science Prague (CULS). For measurement proposes three different samples of poultry manure were used. The first (Rak_v1) and the second (Rak_v2) poultry samples were produced on a farm using an intensive breeding system for laying hens. The third one sample originated from the experimental facilities of CULS.

(1) Poultry housing systems

Laying hens (Lohmann white) were housed in 3 different cage designs. The cage units were of three categories:

The first house was equipped with four-tier cages. Manure disposal was by a belt-clean system below each tier. Nipple drinkers were used without downspout accessories.

The second house was equipped with three-tier cages and nipple drinkers with downspout equipment. Ventilation of manure facilities in both systems was provided by fans mounted in the side walls drawing air through inlets in the ridge.

The third house was designed as a simple battery of three cages with a manure belt. There was natural ventilation of manure facilities without special equipment, influenced only by forced ventilation of the room.

(2) Techniques for measuring air temperature and humidity

Temperature and humidity were measured by the Almemo 2590-9 with sensor FHA646-E1C device.

(3) Techniques for measuring moisture content

The moisture content in the manure was identified by gravimetrics using an MEMERT UNB-200 air oven. Samples were weighted on a Kern 440-35N laboratory scale with a range from 0 to 400 g and accuracy to 0.01 g.

The total sample, consisting of about 10 kg, was poured into a clean, dry polythene vessel and mixed thoroughly and closed. Then materials were extracted and used as a sample for analysis. The composite manure samples were stored in a cool environment (8°C) prior to analysis.

Four drying methods were used to dry the fresh poultry (lying hens) manure as follows: oven drying at

65°C with processing pre-dried matter and subsequent drying at 105°C. The next three drying methods were measured by gravimetric methods during oven drying at 70°C, oven drying at 110°C, and drying at 21.5°C. Poultry manure samples were obtained in a school testing laboratory.

(4) Gravimetric method

A representative sample was weighed (M_{WM}) and put into a preheated oven at the required temperature (±3°C). It was dried and continuously weighed till absolute dry state. It was defined as the material remaining after the water was completely evaporated from the sample – dry matter (M_{DM}). The different sample weights did not vary more than 0.01 g with at least 2 h additional drying time. The weights of fresh samples were 5, 10, 15 and 20 g.

Measured values were used for relative (1) and specific (2) moisture content calculation. This data was used to calculate the rate of change in moisture with drying time (3). This was done by calculating the difference in moisture content (M_{H_2O}) between consecutive sampling times and dividing this value by the time interval (h).

$$w = \frac{M_{H_2O}}{M_{WM}} \times 100 \quad (1)$$

$$X = \frac{M_{H_2O}}{M_{DM}} \quad (2)$$

$$M_{H_2O} = M_{WM} - M_{DM}$$

$$N = \frac{dX}{dt} \quad (3)$$

where:
w – moisture content of material (% w. b.)
X – specific moisture (g.g^{-1} d. b.)
M_{H_2O} – mass of water (g H_2O .g^{-1} DM)
M_{WM} – sample mass of manure being dry (g)
M_{DM} – sample manure mass of dry (g)
N – rate of drying in depending on material moisture content (rate curves) (g.g^{-1}.h^{-1})

(5) Pre-dried method

The pre-dried method consists of two different drying processes: pre-drying and drying. As the first step, a fresh sample 150–200 g was taken, and then the sample was pre-dried at 60°C for 8 h. The sample was then taken out and left for 12 h in air. This procedure was necessary to achieve conditioning prior to weighing. The sample consistence became brittle and refracting which allows for easy grinding. From the adjusted sample was taken 5 g and dried for 4 h at 103°C. These values of weighed samples are used for moisture content calculation (4).

$$w = 1 - \frac{M_{WM1} \cdot M_{DM}}{M_{WM0} \cdot M_{WM2}} \times 100 \quad (4)$$

where:
w – moisture content of material (%)
M_{WM0} – sample mass of manure being pre-dry (g)
M_{WM1} – weight of sample after pre-dry (g)
M_{WM2} – sample mass of manure being dry (g)
M_{DM} – sample manure mass of dry matter (g)

The obtained data were processed by statistical methods using a computer program. The results are accepted as reliable when $P < 0.05$.

RESULTS AND DISCUSSION

The specific and relative moisture content as well as the rate (velocity) of drying of all samples were compared. The average data of relative and specific moisture content, their variability and standard deviations are in Table 1.

Generally, drying rates were highest during the first 1 h of drying, when the moisture content was greatest. Manure dried at 70°C showed a constant rate of drying for the first 1.5 h depending on sample averaging 0.85–1.00 g H_2O.g^{-1} DM.h^{-1}. After that time rates declined gradually (Fig. 1).

Drying curves for fresh manure at 70°C and 110°C are shown in Fig. 2. Increasing the temperature from 70°C and 110°C resulted in a higher loss of moisture content with drying time. The temperature 110°C and 70°C resulted in a marginally higher loss of moisture

Table 1. Statistical evaluation of manure samples

t (°C)	Relative/ specific MC	Agro			Rak_v1			Rak_v2		
		avr(x)	σ	s_x^2	avr(x)	σ	s_x^2	avr(x)	σ	s_x^2
110	w (%)	74.514	0.659	0.434	76.012	1.811	3.278	80.472	0.704	0.495
	u (g.g^{-1})	2.891	0.155	0.024	3.020	0.589	0.347	4.127	0.192	0.037
70	w (%)	76.087	1.744	3.043	73.270	0.492	0.242	79.607	0.669	0.474
	u (g.g^{-1})	3.197	0.319	0.102	2.740	0.070	0.005	3.907	0.168	0.028
21.5	w (%)	61.040	11.477	131.725	66.347	6.601	43.577	66.350	9.486	96.948
	u (g.g^{-1})	1.727	0.821	0.674	2.043	0.549	0.302	2.187	1.100	1.210

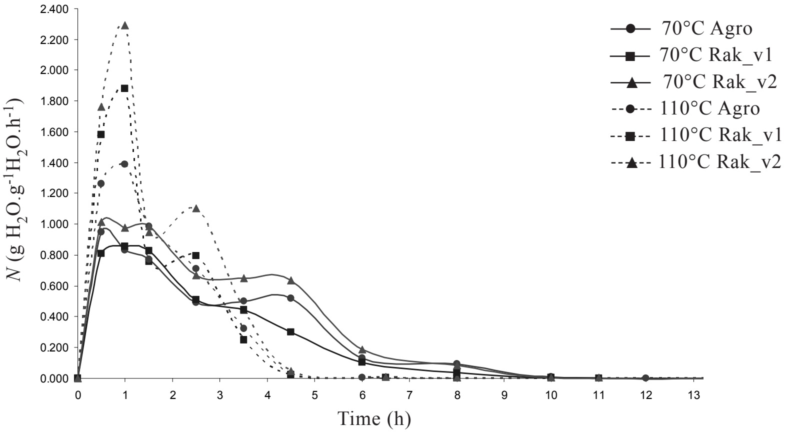

Fig. 1. The rate of drying (dx.dt^{-1}) of manure in different conditions, at (70°C; 110°C)

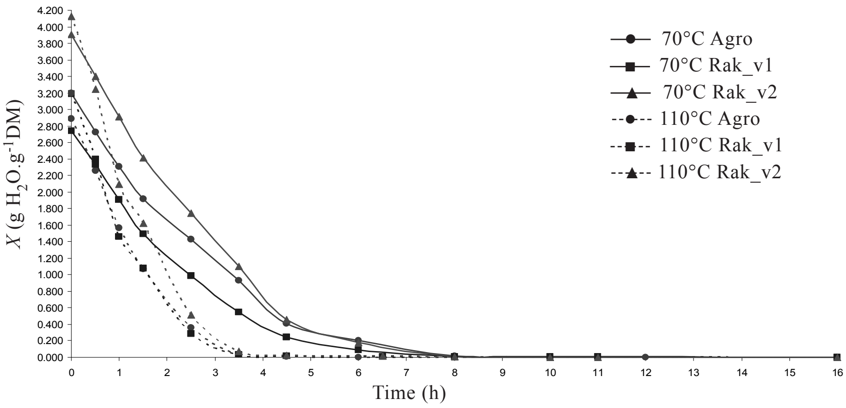

Fig. 2. Drying curves for experiments carried in different conditions, at (70°C; 110°C)

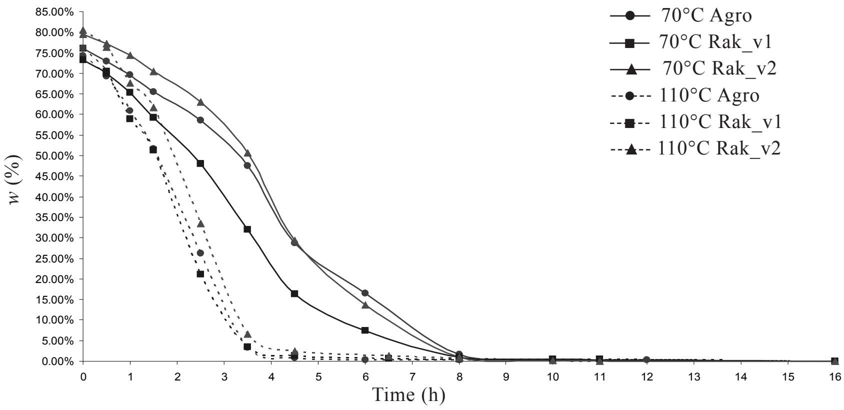

Fig. 3. The moisture content changes in manure during oven drying, at (70°C; 110°C)

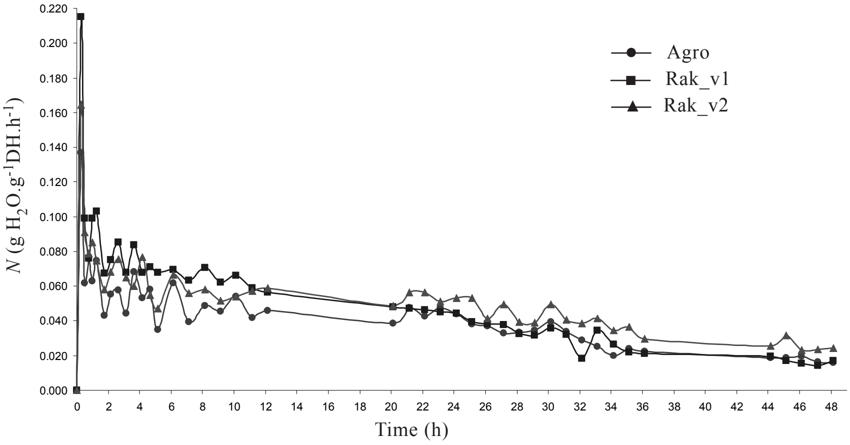

Fig. 4. The rate of drying (dx.dt^{-1}) of manure in an environment approximating conditions, at 21.5°C

Table 2. Measured weight and calculation of relative moisture content

Sample	Pre-drying (60°C)		Drying (103°C)		
	Mass of wet matter M_{WM0} (g)	Mass of wet matter M_{WM1} (g)	Mass of wet matter M_{WM2} (g)	Mass of dry matter M_{DM} (g)	Initial moisture content w (% w. b.)
Agro	199.98	131.83	5.02	1.67	78.07
Rak_v1	150.60	47.23	5.01	3.41	78.65
Rak_v2	150.69	44.14	5.01	2.88	83.16

Table 3. Comparison of values by different measurement methods

Drying stage	Sample	Time of drying t (h)	Final content of dry matter x (% d. b.)
110°C	Agro	16	25.73
	Rak_v1	16	23.99
	Rak_v2	16	19.43
70°C	Agro	16	23.99
	Rak_v1	16	26.73
	Rak_v2	16	20.40
21.5°C	Agro	48	38.94
	Rak_v1	48	33.65
	Rak_v2	48	33.65
Pre-dried matter 60°C/103°C	Agro	24	21.95
	Rak_v1	24	21.31
	Rak_v2	24	16.84

during the first 3 h and 4.5 h of drying. Specific moisture content values after 3 h and 4.5 h of drying averaged 0.035, 0.036, 0.074, 0.521, 0.299 and 0.638 g $H_2O.g^{-1}$ DM for dried at 110°C and 70°C, respectively.

Highest moisture content of untreated manure at 110°C and 70°C was achieved 80.57% and 79.60% wet basis by sample Rak_v2. The highest lost of relative moisture content was reported during the first 3.5 and 4.5 h of drying. In Fig. 3 it may be observed that at 110°C, the time to reduce the moisture content to minimum was 6.5 h, 8.5 h at 70°C, respectively.

Drying rates for fresh manure at 21.5°C are shown in Fig. 4. Manure dried at 21.5°C showed a maximal rate of drying for the first 30 min depending on sample averaging 0.065–0.090 g $H_2O.g^{-1}$ $DM.h^{-1}$. The temperature 21.5°C resulted in a gradually declining loss of moisture content during the whole time of drying. The measurement of the sample has not conducted from 12 to 20 hours and from 36 to 44 hours because a symmetrical loss of moisture content was expected. These results are shown in Fig. 5 and Fig. 6.

Further the methods of pre-drying were chosen to check on data obtained from the gravimetric method (Table 2). Column w (% w. b.) of Table 2 shows initial moisture content of fresh sample.

The analyses of the temperature influence on drying of the poultry manure are shown in Table 3 and Fig. 7. Moisture contents achieved levels of similar values during drying at the temperature 70°C and 110°C. It took 48 h (Table 3) of drying in conditions similar to the ambient to reach about 35% relative moisture.

Moisture content was significantly affected by different designs of drinking systems between samples Rak_v1, Rak_v2 and Agro ($P < 0.05$). The difference between sample Rak_v2 and other samples (Rak_v1 and Agro) was statistically significant.

The influence of initial moisture content on the composting of poultry manure with wheat straw was investigated by Petric et al. (2009). High moisture content can lead to increased losses of ammonia, which should be controlled by the addition of suitable additives. The results of the study suggest that an initial moisture content of approximately 69% can be considered as being suitable for the efficient composting of poultry manure mixed with wheat straw.

Davalos et al. (2002) was aimed at evaluating of the energy by combustion of poultry litter. The energy (heat) value of dry-poultry litter was 14 447 kJ/kg. This value decreases when the water content of the sample increases. Finally, they found that poultry litter with water content less than 9% can burn without extra fuel. Therefore, these samples seem to be suitable for use as a fuel for generation of electrical power.

As mentioned above, the direct application by fresh excrement is also strictly limited if its composition will not allow uniform spreading. Pezzi and Rondelli (2002) evaluated a prototype spreader for the distribution of poultry manure. This prototype was set up for orchard and arable crops. Physical properties of the fertilizers influenced the distribution pattern. The poorest results were observed in the distribution of manure with large particles and high moisture content.

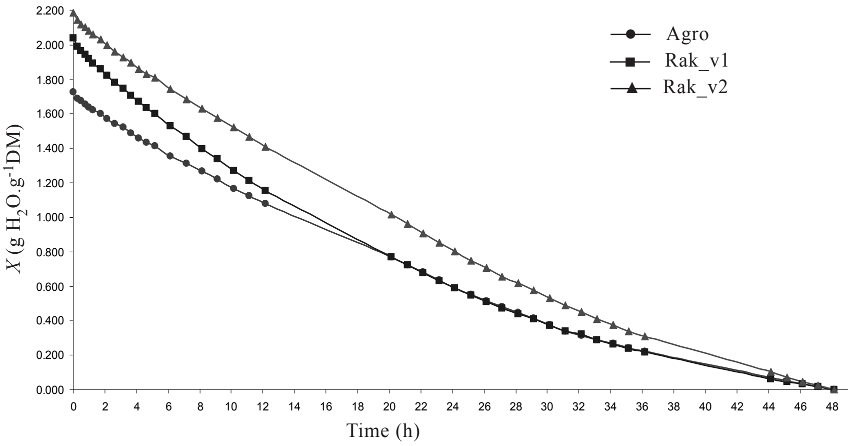

Fig. 5. Drying curves for experiments carried out at 21.5°C

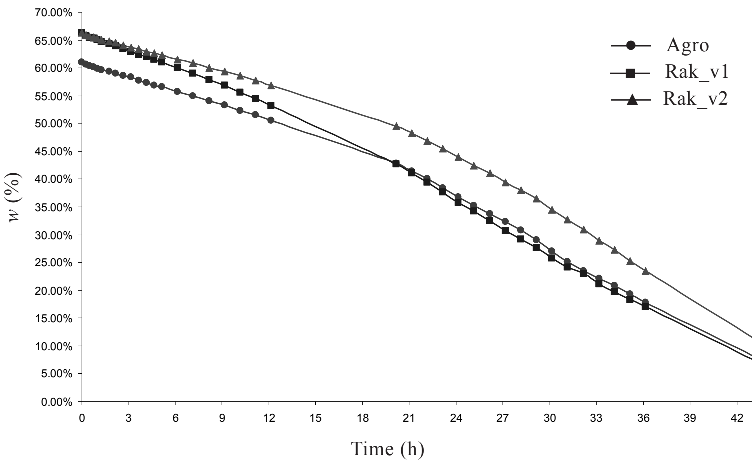

Fig. 6. The moisture content changes in manure during oven drying, at 21.5°C

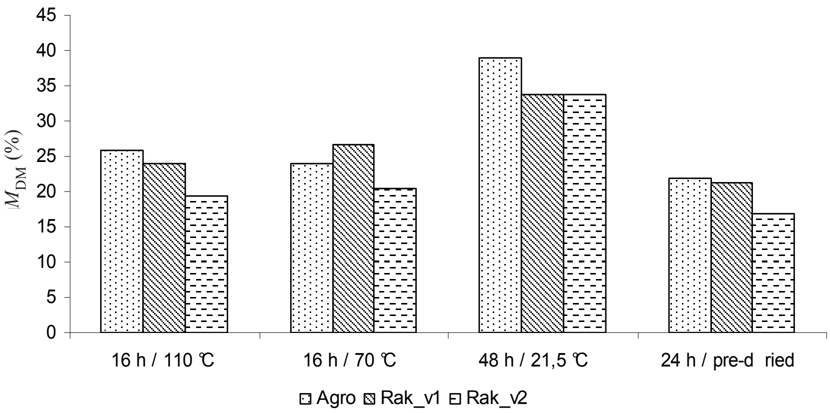

Fig. 7. Comparison of values by different measurement methods

CONCLUSIONS

The lowest rate of dry matter as measured in an environment approximating working conditions was 33.65%. These values were gained in two cases and whole drying procedure lasted 48 h. The measurement demonstrates that different design of drinking system significantly influenced the moisture content ($P < 0.05$) of the manure. It was observed that higher moisture content was measured for laying hens using nipple drinkers compared to those equipped with downspout accessories. As we can see from the results, the drinker with downspout accessories has lower moisture content and we could recommend this system. Results from this study provide new data for updated standards to be used in design and operation of laying hen houses. It concluded that useful knowledge of the evaporation rate of water from the fresh manure was obtained. With this knowledge, the moisture content, and drying time can be used to develop an optimal treatment system of poultry manure. Therefore, the process keyed to drying effects should be taken into consideration in evaluation of manure utilization. In this way, the emission of ammonia from the poultry manure can be minimized. The effect of different drinker types on moisture contents was studied. Design of drinkers influences manure moisture content and the use of water. In two types of tested manure, the different moisture in dependence on drinker types was recognized as statically significant.

Acknowledgements

We are grateful to Lukáš Zita from Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, for his advice.

REFERENCES

BABIČKA, L. – KOUŘIMSKÁ, L.: Biogas Station as a Part of Ecological Farm. In: Proceeding of Conference 'Organic farming 2007', Prague, Czech Republic, 2007, pp. 195–199. (in Czech)

DAVALOS, J.Z. – ROUX, M.V. – JIMENEZ, P.: Evaluation of poultry litter as a feasible fuel. Thermochimica Acta, *394*, 2002: 261–266.

CODLING, E.E. – CHANEY, R.L. – SHERWELL, J.: Poultry litter ash as a potential phosphorus source for agricultural crops. Journal of Environmental Quality, *31*, 2002: 954–961.

GLENN, J.: 300,000,000 tons of manure. BioCycle, *39*, 1998: 47–50.

GROOT KOERKAMP, P.W.: Review on emissions of ammonia from housing systems for laying hens in relation to sources, processes, building design and manure handling. Journal of Agricultural Engineering Research, *59*, 1994: 73–87.

HAGA, K.: Managing manure on Japanese livestock and poultry farms. BioCycle, *42*, 2001: 66–66.

HEIJ, G.J. – SCHNEIDER, T.: Dutch priority programme on acidification, final report second phase Dutch priority programme on acidification. Report 200-09, 1991 RIVM, Bilthoven, the Netherlands.

HUTLA, P. – KOSAR, K.: Utilization of poultry manure. Recommendation 03.02.01, 10/1995, Crop Research Institute, Prague, 8 p. (in Czech)

KOSAR, K. – ZAKOVA, I. – MATOUSEK A. – MATEJKA, J.: Pre-drying of poultry manure. Recommendation 03.02.01,09/1994. Crop Research Institute, Prague, 8 p. (in Czech)

LEKKERKERK, L.J.A. – HEIJ, G.J. – HOOTSMANDS, M.J.M.: Ammoniak: de feiten (Dutch priority programme on acidification, Ammonia: the facts). Stuurgroep Verzuringsonderzoek, 1995, RIVM Report 300-06, Bilthoven, the Netherlands, pp. 15.

MICHEL, F.C.Jr. – FORNEY, L.J. – HUANG, A.J. – DREW, S. – CZUPRENSKI, M. – LINDENEG, J.D. – REDDY, C.A.: Effects of turning frequency, leaves to grass ratio and windrow vs pile configuration on composting of yard trimmings. Compost Science & Utilization, *4*, 1996: 26–43.

MUKHLESUR, R.: Composting Poultry Manure: An Effective Strategy to Reduce Environmental Pollution. Bangladesh News [online]. [ref. 2010-01-05], 2009. Avaliable at: http://www.independent-bangladesh.com/letters/composting-poultry-manure-an-effective-strategy-to-reduce-environmental-pollution.html

PETRIC, I. – SELIMBASIC, V.: Composting of poultry manure and wheat straw in a closed reactor: optimum mixture ratio and evolution of parameters. Biodegradation, *19*, 2008: 53–63.

PETRIC, I. – ŠESTAN, A. – ŠESTAN I.: Influence of initial moisture content on the composting of poultry manure with wheat straw. Biosystems Engineering, *104*, 2009: 125–134.

PEZZI, F. – RONDELOU, V.: Evaluation of a prototype spreader in the distribution of poultry manure. Applied engineering in agriculture, *18*, 2002: 285–291.

ROEPER, H. – KHAN, S. – KOERNER, I. – STEGMANN, R.: Low-tech options for chicken manure treatment and application possibilities in agriculture. In: Tenth International Waste Management and Landfill Symposium, 2005, CISA, Cagliari, Italy, pp. 565–566.

SISTANI, K.R. – ROWE, D.E. – MILES, D.M. – MAY, J.D.: Effects of drying method and rearing temperature on broiler manure nutrient content. Communications in Soil Science and Plant Analysis, *32*, 2001: 2307–2316.

TIQUIA, S.M. – RICHARD, T.L. – HONEYMAN, M.S.: Effects of windrow turning and seasonal temperatures on composting of hog manure from hoop structures. Environmental Technology, *21*, 2000: 1037–1046.

VOORBURG, J.H.: Pollution by animal production in the Netherlands: solutions. Revue Scientific et Technique, Office International de Epizoöties, *10*, 1993: 655–668.

VILLAR, M.C. – PETRIKOVA, V. – DÍAZ-RAVIŇA, M. – CARBALLAS, T.: Recycling of organic wastes in burnt soils: combined application of poultry manure and plant cultivation. Waste Management, *24*, 2004: 365–370.

Received for publication on October 2, 2010
Accepted for publication on February 25, 2011

LIŠKA, R. – KIC, P. (Česká zemědělská univerzita v Praze, Technická fakulta, Praha, Česká republika)

Průběh změny vlhkosti drůbežího trusu během sušení v závislosti na různé teplotě

Scientia Agric. Bohem., *42*, 2011:79–86.

Tento příspěvek popisuje vliv teploty na průběh vysoušení drůbežího trusu. Dále popisuje vybrané způsoby a metody jeho využití a zpracování na základě vlhkosti trusu. Experimenty byly provedeny v laboratoři České zemědělské university v Praze. Vzorky byly vysoušeny různými metodami za různých teplot vysoušení od 21,5 °C do 110 °C. U testovaných vzorků byla zaznamenána nejmenší dosažená vlhkost na hodnotě 16,84 %. Při měření v podmínkách, které se blíží skutečným stájovým podmínkám, bylo dosaženo vlhkosti 33,65 %, a to po 48 hodinách sušení vzorku. Získané vzorky byly navzájem porovnány a byla vyhodnocena jejich vlhkost na základě různých systémů chovu. Zde výsledky prokázaly signifikantní vliv napájecího systému na vlhkost materiálu. Na základě tohoto zjištění a prokázání zvýšené vlhkosti lze doporučit, vzhledem k nižší vlhkosti trusu, napájecí systém se záchytným žlábkem. Výsledky z této studie mohou poskytnout nová data pro vylepšení technologií v chovech nosnic.

obsah sušiny; obsah vlhkosti; sušicí teplota; sušárna

Contact Address:

Ing. Radek L i š k a , Česká zemědělská univerzita v Praze, Technická fakulta, Katedra technologických zařízení staveb, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika, tel.: +420 777 970 571, e-mail: liska.radek@gmail.com