STRAW PELLETS UTILIZATION FOR REDUCTION OF LIQUID MANURE HARMFUL GAS EMISSIONS

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Abstract
Integrated pollution prevention and control systems are necessary to reduce the environmental impact of pollution from livestock farms and to prevent the transfer of pollutants from one environment to another. In intensive livestock farms, various technological and administrative measures should be taken in order to reduce environmental pollution, as the compatibility of these measures avoids the risk of contamination of the environment. The work was performed in Vytautas Magnus University Laboratory of Thermal Energy Processes and Emissions in 2018. The paper analyses the physical properties of wheat and rapeseed straw pellets and their application possibilities for liquid manure reservoir covering and the impact of straw granules on ammonia emission reduction. It has been found that ammonia emissions from liquid manure are reduced by 72-78% when coated by rapeseed pellets.

Keywords: *wheat; rapeseed; straw pellets; pollution; liquid manure; harmful emissions.*

INTRODUCTION

In livestock farms, the accumulation of manure is the main source of ammonia emissions. Evaporating chemicals enter the atmosphere and return to the soil with precipitation. Therefore, in order to solve such problems as climate change, soil erosion, air and environmental pollution, biodiversity loss, we must ensure that the development of livestock farming is based on the principles of sustainable development (*Aleknavičius, 2008*; *Maciukas, 2015*).

There are no reliable measures to protect the environment from harmful pollutants; however, ammonia emissions are decreasing in a loose cow barn, with more cattle shed and manure spreading (*Prakupimaite, 2009*). The impact of livestock farming reduces biodiversity, soil depletion, and water and air pollution. The most important greenhouse gases emitted from manure during anaerobic digestion are methane (CH_4) and nitrous oxide (N_2O) released during storage and use for fertilisation (*Bleizgys & Cesna, 2008*; *Juska, 2010*). Additional gas from manure is ammonia (NH_3) and nitrogen oxides (NO_x), which have an effect on odour generation and are an indirect source of nitrous oxide.

Ammonia is an atmospheric pollutant that promotes acidification of soil and surface water, eutrophication, deforestation (*Pereira et al., 2010*). It is formed by dropping manure, urine, and feed residues. It has been determined that 40% of all nitrogen (N) compounds polluting the atmosphere is ammonia. Another important source of ammonia release is liquid manure and slurry manure (*Mendes & Pieters, 2017*). Liquid manure is usually stored in metal or concrete reservoirs, less often in ponds, and slurry manure is kept in manure storages. To reduce ammonia release, manure storage is covered with various coatings (thick manure, chopped straw, wooden, plastic, clay granules, 2-3 mm thick oil layer, etc.) or roofing. All coatings have their own advantages and disadvantages that need to be assessed when choosing the method of covering the store (*Environmental requirements, 2011*).

The article analyses the use of straw granules for coverage of slurry manure reservoir. Pellets from wheat and rapeseed straw were selected for this purpose; physical properties of the pellets were evaluated, and their influence on ammonia emissions was measured. The aim of this article is to analyse the physical properties of straw pellets and their application possibilities for liquid manure reservoir coating and to evaluate the influence of straw pellets on ammonia emission reduction.

MATERIALS AND METHODS

The research was carried out at Vytautas Magnus University, Agricultural Academy, Faculty of Agricultural Engineering, Laboratory of Thermal Energy Processes and Emissions. Liquid manure was used for the investigation of harmful gas emissions. The tested manure was taken from a 50-seat cowshed where manure was removed by a wheeled mini-loader, pushing it out of the manure removal path.

Firstly, pellets of wheat and rapeseed straw with the diameter of 9 mm were produced, using a small capacity granulator with a horizontal granulator matrix. Before the plants entered the granulator, they were mixed thoroughly to achieve homogeneity and moistened if were too dry for granulation. Using the dosage unit, the mixture was supplied to the press chamber, where it was moved by rollers through the matrix holes and pressed to form 9 mm pellets. When the pellets cooled, their biometric and physical-mechanical parameters (dimensions, moisture content, volume and density) were evaluated. The parameters of 10 pellets were determined by measuring their height and diameter (accurate to 0.05 mm), and pellet density was calculated.

Pellet moisture was determined by using a special drying oven. The pellets of both straw types were weighed before and after drying. The average humidity of the straw pellets was calculated.

Later, pellet strength (compression strength) was measured by using a physical-mechanical test instrument *Instron 5960*. Pellet strength properties are important for pellet transportation, storage and spreading on the manure surface, etc. Five repetitions with both types of pellets were performed. The test data was stored on the computer, then processed and analysed.

In order to determine which sort of straw pellets were the most suitable for liquid manure surface coating, pellet swelling properties and the optimal pellet layer were investigated. Pellets were immersed into water, and it was observed as they expand. The tests were performed 50 times with each type of granule, marking each pellet in a separate vessel with water and waiting for the pellet to swell. The length and diameter of the bead were measured after swelling. Subsequently, by comparing the granule expansion results and density, one type of bead was selected to cover the surface of the plastic container filled with liquid manure.

When determining the optimal pellet layer, four different pellet layers were tested. Each layer was weighed in order to calculate what amount of granules would be needed for slurry coverage. Tests were performed with 10 mm, 20 mm, 30 mm and 40 mm wheat straw and rapeseed straw granules. The layers were measured every two hours.

To determine the emissions and their variations, liquid cow manure was poured into separate plastic vessels. During the test, the first vessel was not mixed and in no way affected; the second and other containers were covered with straw pellets, increasing the coverage with every container. The emission changes were observed in each container, every minute; the data was collected by a meter-analyser.

RESULTS AND DISCUSSION

Firstly, physical-mechanical properties of produced wheat and rapeseed straw pellets were determined. Moisture content of wheat straw granules was 12.58 ± 0.53%, and moisture content of rapeseed straw was about 20% lower and reached 10.08 ± 0.17%. The average density of investigated wheat straw granules was 1074.6 ± 60.05 kg m^{-3}, and the average density of rapeseed straw granules was very similar and reached 1013.6 ± 47.42 kg m^{-3}. If compared to the results of other researchers, which have investigated biofuel and fodder pellets and briquettes, the density of pellets was-high enough and exceeded 1000 kg m^{-3} (*Siaudinis et. al., 2015; Kakitis et. al., 2011*).

The compression resistance of both types of granules was determined by using the Instron 5960 physical-mechanical test equipment. The results obtained by compressing the wheat straw pellets are presented in Fig. 1, and the results of the rape straw granules are presented in Fig. 2.

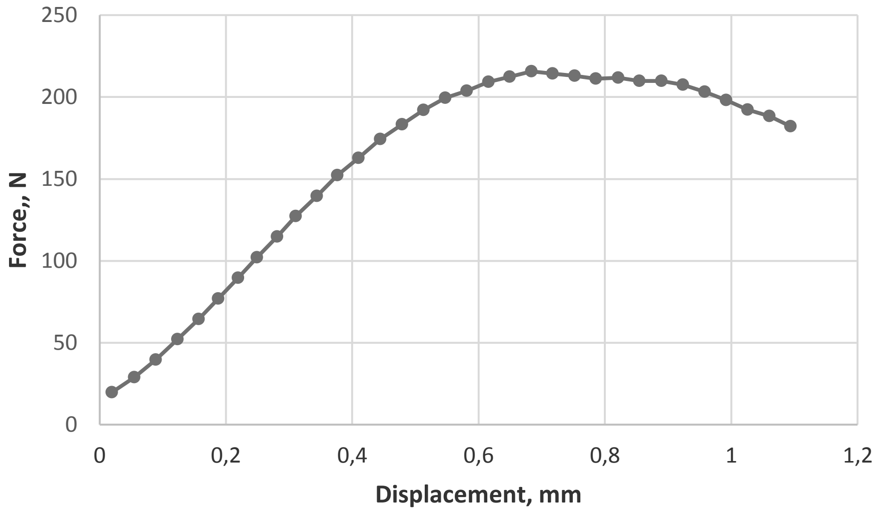

Fig. 1. Research results of wheat straw pellets strength

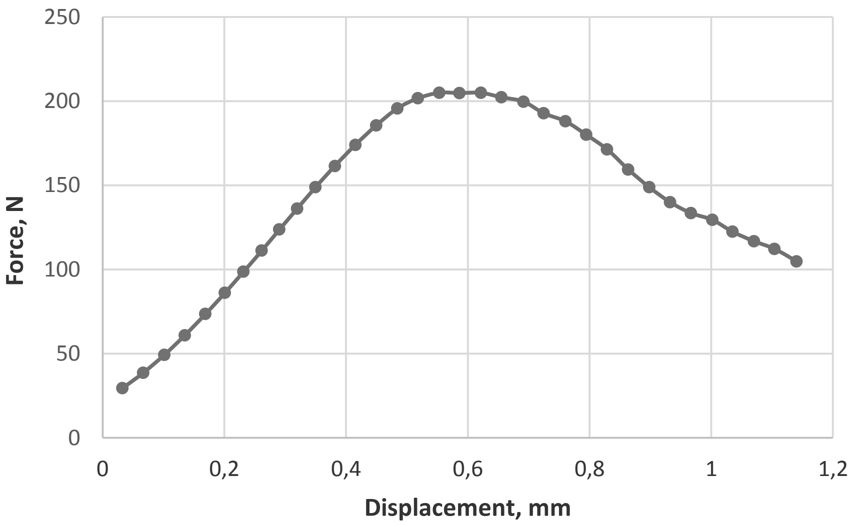

Fig. 2. Research results of rapeseed straw pellets strength

From the results presented in the graphs, it can be seen that–the strength of wheat straw pellets (average force is N, 215 N) is a little higher than that of rapeseed straw – the average force of 205 N is required for crushing rapeseed straw pellets. Therefore, wheat straw granules are more resistant to compression.

It can be noted that the investigated granule properties – moisture content, density, length, diameter and strength – meet the quality requirements for pellets made from plant biomass of the Ministry of Energy of the Republic of Lithuania. Therefore, further research is possible with the selected wheat straw and rapeseed straw pellets (*LAND 43-2013; Siaudinis et. al., 2015)*.

After the investigation of the optimal pellet layer for liquid manure surface coating, it was detected that at the beginning, when pellets are filled with water, they float on the surface, but then settle down quickly on the bottom and then rise again. The tests of swelling duration of 10 mm and 20 mm pellet layers showed that the rapeseed pellets swelled up faster and formed a maximum protective layer approximately 12 hours after the start of the test, which changed slightly during the period of the observation hours (Fig. 3, Fig. 4).

To conclude, rapeseed straw pellet swelling duration is higher than that of wheat straw pellets, thus rapeseed straw pellets are more recommended for liquid manure surface coating.

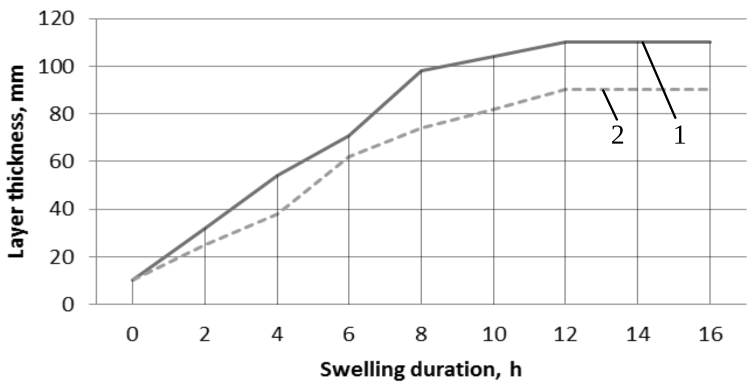

Fig. 3. Swelling duration of 10 mm pellet layer: 1 – rapeseed straw pellets; 2 – wheat straw pellets

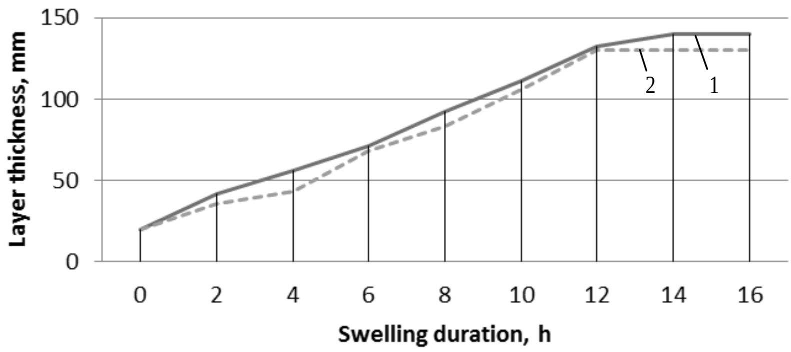

Fig. 4. Swelling duration of 20 mm pellet layer: 1 – rapeseed straw pellets; 2 – wheat straw pellets

The expansion of the rape straw granules layer was determined irrespective of the thickness of the deposited layer, which was always higher than that of the wheat straw pellets. On the average, wheat straw granule lengthens by 3.57 times, and the diameter increases by 1.45 times. Rapeseed straw granule lengthens by 3.1 times, but the diameter increases by 1.8 times. Therefore, rapeseed straw pellets were used for further research.

Further studies were carried out to determine the variation in ammonia emissions by comparing the uncovered liquid manure vessel with the vessel filled with rapeseed straw granules. 44 hours after the start of the test, the rapeseed pellets disintegrated.

From the graph presented in Fig. 5 it can be seen that the ammonia concentration in both vessels was similar at the start of the study and reached the 45 ppm in the first 20 hours of testing.

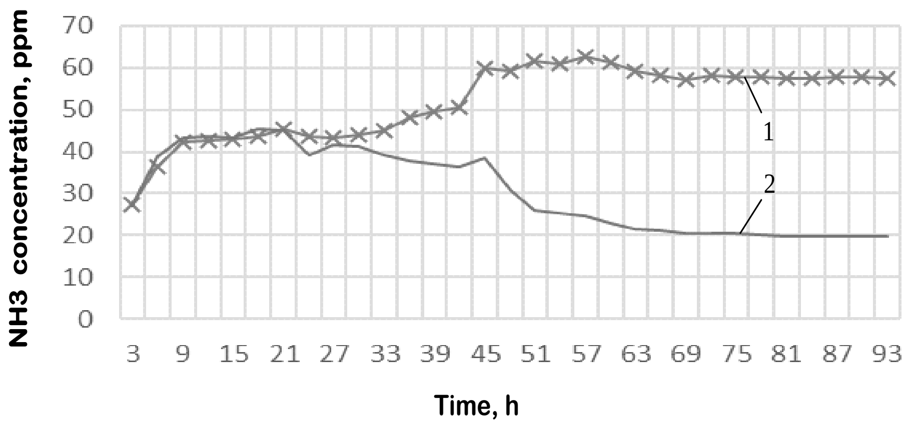

Fig. 5. Variation of ammonia emissions: 1 – liquid manure without coating; 2 – liquid manure with rape-seed straw pellets cover

Later, after 17 more hours, a clearer difference was apparent. In the first vessel, the concentration of ammonia was 50 ppm, and in the second vessel, which had been covered by pellets, the emissions decreased to 36 ppm. At the end of the test, 93 hours after the start of the test, the ammonia concentration in the dish without coating was 59 ppm; and in the container with the rapeseed straw granules it was 19.7 ppm.

Research results showed that a vessel, the surface of which was covered with rapeseed straw pellets, reduced emissions by 75%. Repeated studies showed similar data; emission reduction ranged from 72% to 78%.

These studies shall be continued and will evaluate other plant materials pressed to granules. The content of material and chemical analysis will be evaluated.

Based on the results of our research and other existing studies, it can be said that rape straw pellets are better suited for covering of liquid manure surface, because these plants contain more oil that better retains the emission of noxious gases (*Bleizgys & Cesna, 2008*; *Juska, 2010*).

CONCLUSIONS

Having analysed the main physical-mechanical properties of the produced wheat and rapeseed straw granules, it has been determined that the moisture of the granules varied from 10.08±0.17% to 12.58±0.53%; the average densities of investigated wheat and rapeseed straw granules were very similar and varied from 1013.6 ± 47.4 kg m^{-3} to 1074.6 ± 60.0 kg m^{-3}; the average critical compression resistance force of rapeseed straw reached 204.9 N and was smaller than the critical compression resistance force of wheat straw (215.8 N). Having performed granule swelling tests, it has been determined that the layer of swelled rapeseed straw is always higher than the layer of wheat straw. The impact of rapeseed straw granules on reduction of emissions was observed after 4 hours after the covering; the emission concentration varied from 43.5 ppm in a vessel without coating to 39 ppm in a vessel with rapeseed straw coating. After 93 hours, the emissions stabilised; the emissions of harmful gases were 75% lower in a vessel covered with rapeseed straw granules, comparing to the emissions of the vessel without coating.

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