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THE PHYSICAL-MECHANICAL PROPERTIES OF EXPERIMENTAL GRANULATED FERTILIZERS FROM POULTRY MANURE WITH BIOFUEL ASH AND BIOCHAR SUPPLEMENT

Ramūnas Mieldažys, Eglė Jotautienė, Algirdas Jasinskas, Aloyzas Gaudutis

Vytautas Magnus University Agriculture Academy Faculty of Engineering Department of Agricultural Engineering and Safety

Introduction

Intensive agriculture and chemical farming deplete the soils recently. The growing demand for organic agricultural products encourages the use of natural materials used for soil fertilization. Many farmers are already using granular organic fertilizers made from manure, meat-and-bone meal and others. Granular organic fertilizers are easier to handle, transport, store and spread in soils using standard fertilizers application machinery. Poultry manure contains all identified essential plant nutrients and its fertilizer value is widely researched. Biochar and biomass ash is also intensively researched as a substance for improving soil quality, plant growth and reducing greenhouse gas emissions from soil. Various studies of biomass ash used as fertilizer have shown beneficial effects. The ash improves the soil structure and supplies plants with nutrients. The benefits of biochar are known for the physical properties of the soil, which manifests itself in changes in soil density and water holding capacity. However, the preparation of poultry manure, biomass ash and biochar for granulation has significant differences compared to other organic materials, due to the moisture, density, fractional composition and other parameters of the granulated material. This requires the determination of the physical and mechanical properties of the raw material and the final product. The article deals with the physical and mechanical properties of granular fertilizers made from poultry manure, biochar and biomass ash. Moisture of different raw organic materials was determined, which is important for the granulation process. The density, bulk density, fractional composition, moisture and compressive strength properties of manure with biochar, biomass ash raw material and granules made from it, produced in different technological regimes, were experimentally investigated. The obtained results showed that it is expedient to enrich manure granules with biochar and biomass ash.

Methods

The poultry manure used in this study was obtained from an industrial poultry farm in Lithuania (*Antalgės paukštynas*). A total of 12 kg of pure poultry manure samples and 6 kg manure with litter were collected from different places in the poultry farm. As litter was used wood sawdust in farm. Manure has been stored for 3 weeks inside the building. Biochar made from wood was submitted by company *Cocos LT* in Lithuania. Biomass ash was collected from the industrial burner unit of a power plant of an energy company in Lithuania, which used biomass as a fuel. The biomass burned was comprised of forest residues and wastes from the wood processing industry, in the form of sawdust and chips. Manure samples were dried for 24 hours in ventilation canal with slow heated air flow. The manure material was placed to the hammer mill GMM-1 (Lithuania), where it was grinded in fine powder like form. Biochar and ash was not milled. Poultry manure, biochar and biomass ash samples material was mixed thoroughly to achieve homogeneity. There was prepared samples of 1.5 kg each for granulation proportions and mixing ratios (weight to weight) are presented in Figure 1. Mass fraction composition of raw materials types was determined using sieve shaker Retsch AS 200 (Germany) and sieves with holes of various diameters: 0.25 mm, 0.5 mm, 0.63 mm, 1 mm, 2 mm, 3.15 mm, 4 mm and 5 mm. The mass remaining on sieves is weighted, and sample part of every fraction in percentage is calculated. *Density* of mill were determined in the 6 dm^3 cylinder vessel, which were fulfilled by mass till the upper edge and weighted. Moisture of mill is determined according to the standard methodology (EN 12048:1996). For granules production was used the low-power (7.5 kW) granulator ZLSP200B (Poland) with a horizontal 6 mm matrix. .The *bulk density* was determined according to the standard methodology (EN 1237:2002). *Moisture content* was determined according to the standard methodology (EN 12048:1996). The samples were weighted and dried for 24 hours in a laboratory drying chamber in the temperature of 105 ºC. *Granule strength te*sts were performed with a 5 kN capacity Instron 5965 test machine (USA). The received parameters were saved to the Instron Bluehill test control software. The cylindrical granules were horizontally placed between two anvils and a compressive force was applied to the side of the granule. The tester was run at a compression rate of 20 mm min^{-1} and was stopped after the granule had broken. Each test was performed 5 times per granule type sample. Statistical methods were used for processing the obtained data. The average values and their confidence intervals (CI) were calculated at a probability level of 95%.

Results and discussion

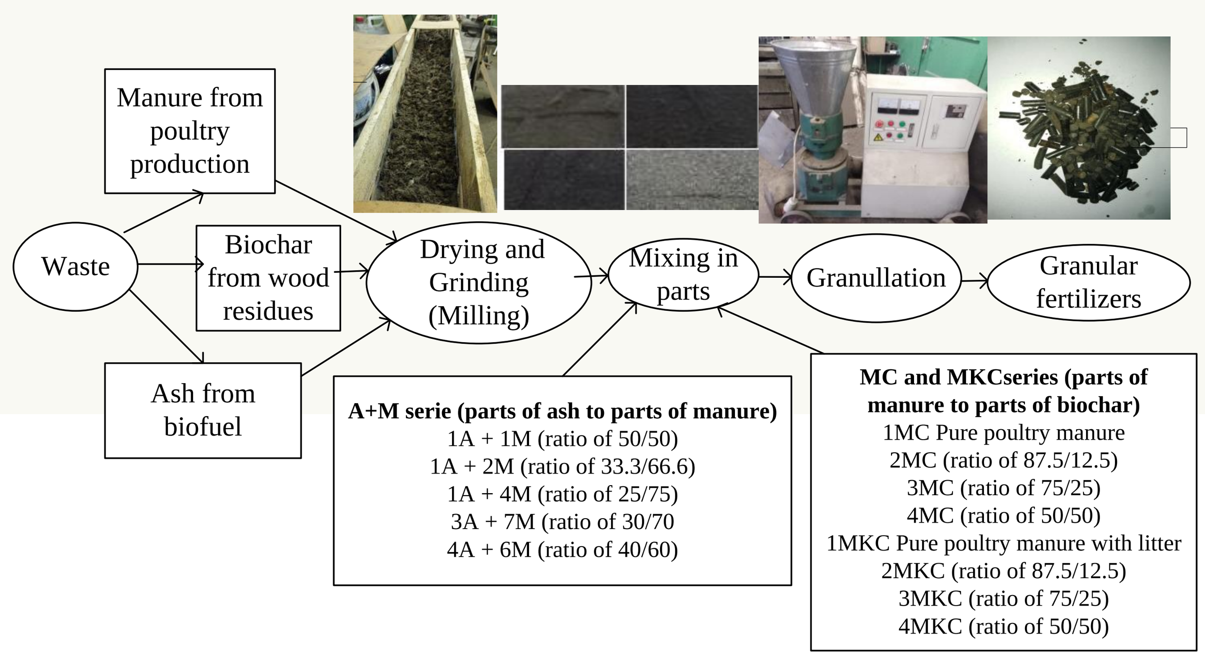

Fig 1. Technological scheme of poultry manure, biochar and ash mixture fertilizers production

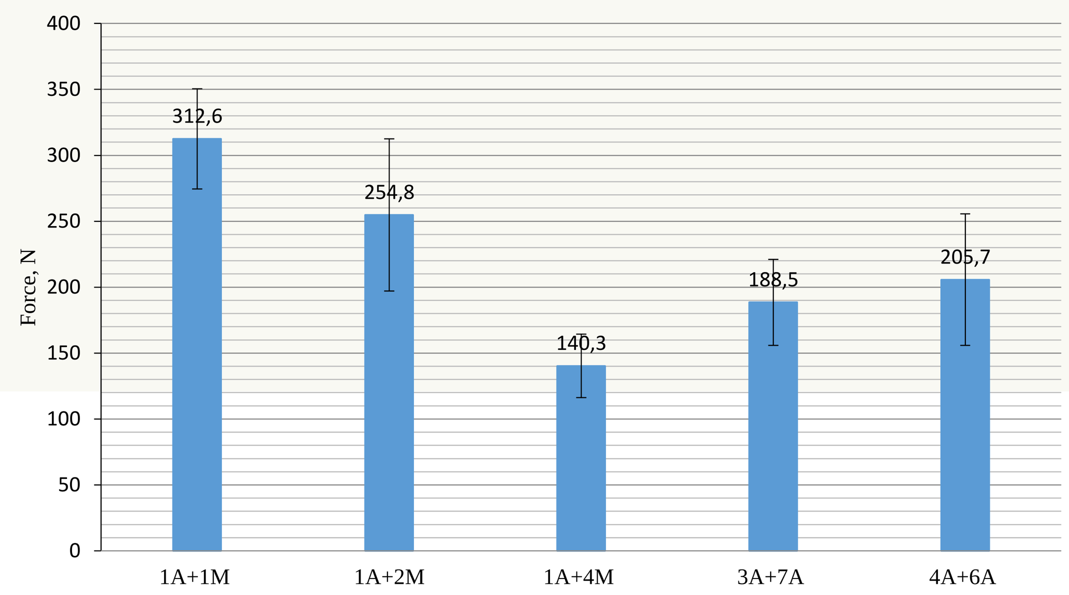

Fig. 3. Poultry manure and biomass ash granules strength test in horizontal orientation: 1A + 1M (ratio of 50/50); 1A + 2M (ratio of 33.3/66.6); 1A + 4M (ratio of 25/75); 3A + 7M (ratio of 30/70; 4A + 6M (ratio of 40/60).

Table 1. Fractional composition of mixtures samples mill.

Sample Code, %	Diameter Range of Sieve Holes, mm								
	0–0.25	0.25–0.5	0.5–0.63	0.63–1.0	1.0–2.0	2.0–3.15	3.15–4.0	4.0–5.0	<5.0
1A + 1M	39.77 ± 7.07	17.60 ± 2.95	8.27 ± 1.81	11.83 ± 0.70	18.33 ± 1.22	3.57 ± 0.74	0.43 ± 0.11	0.20 ± 0.01	-
1A + 2M	31.20 ± 4.81	21.00 ± 0.32	12.47 ± 0,64	19.77 ± 1,38	15.37 ± 3,02	0.20 ± 0.18	-	-	-
1A + 4M	16.40 ± 1.29	20.03 ± 1.96	12.37 ± 0.85	18.53 ± 0.46	21.57 ± 1.22	4.60 ± 1.10	1.37 ± 0.59	1.13 ± 0.11	4.00 ± 2.23
3A + 7M	23.87 ± 4.44	18.07 ± 3.73	11.27 ± 1,04	16.43 ± 0.56	25.37 ± 5.57	4.40 ± 1.63	0.50 ± 0.32	0.10 ± 0.18	-
4A + 6M	30.13 ± 2.27	17.60 ± 4.42	9.83 ± 0.64	15.03 ± 0.70	22.93 ± 1.33	3.80 ± 0.55	0.50 ± 0.18	0.17 ± 0.11	-
MC serie	40.48 ± 2.11	21.71 ± 1.90	8,90 ± 0,37	12,22 ± 0,74	13,54 ± 2,04	2,62 ± 0,84	0,33 ± 0,23	-	-
MKC serie	14,33 ± 1,42	17,10 ± 2,62	11,60 ± 2,11	18,91 ± 1,05	33,53 ± 5,29	4,05 ± 1,85	0,29 ± 0,13	-	-
Biochar	16,07 ± 2,86	15,37 ± 8,46	7,88 ± 1,37	16,05 ± 7,81	35,80 ± 17,16	6,44 ± 1,09	1,39 ± 0,21	0,60 ± 0,23	0,39 ± 0,14

Table 2. Main physical-mechanical characteristics of milled raw material and produced granules

Raw material sample code	Raw material moisture Content, %	Raw material Bulk density, kg·m⁻³	Produced granules density, kg·m⁻³
1MC	9.39±3	635.7±18.66	1609.01±79.57
2MC	8.15±1.9	555.2±15.20	1555.65±80.34
3MC	8.62±0.1	534.7±5.57	1470.22±69.00
4MC	9.16±1.64	457.4±11.85	1369.43±108.80
1MKC	17.50±2.78	410.9±24.95	1300.57±31.27
2MKC	16.76±2,42	406.8±16.65	1350.16±35.78
3MKC	15.80±1.5	398.1± 27.15	1220.29±112.57
4MKC	15.40±0.98	390.8± 9.72	1189.73±50.71
1A + 1M	16.42 ± 0.36	485.7 ± 0.92	1694.61 ± 118.70
1A + 2M	26.32 ± 1.54	437.6 ± 3.82	1483.35 ± 182.43
1A + 4M	30.53 ± 1.00	456.7 ± 2.36	1384.51 ± 86.13
3A + 7M	27.57 ± 2.79	415.0 ± 0.73	1386.45 ± 79.46
4A + 6M	24.23 ± 1.31	438.2 ± 12.31	1315.01 ± 108.6

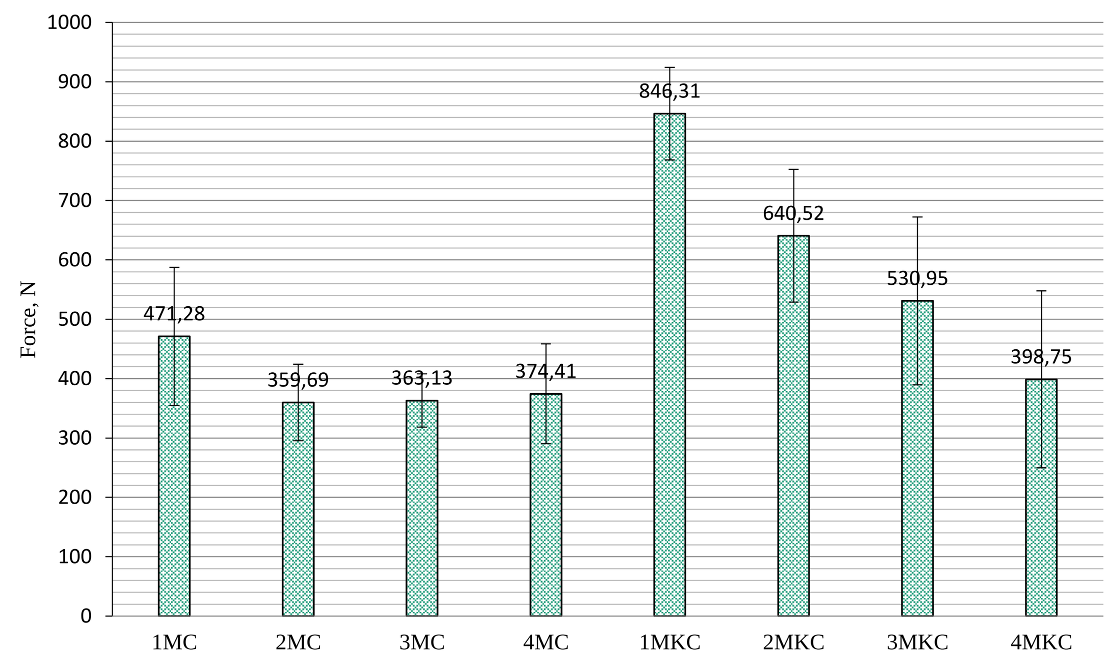

Fig. 4. Poultry manure and biochar granules strength test in horizontal orientation: 1MC pure poultry manure; 2MC manure and biochar (ratio of 87.5/12.5); 3MC manure and biochar (ratio of 75/25); 4MC manure and biochar (ratio of 50/50); 1MKC pure poultry manure with litter; 2MKC manure and biochar (ratio of 87.5/12.5); 3MKC manure and biochar (ratio of 75/25); 4MKC manure and biochar (ratio of 50/50).

Conclusions

The biggest mill fraction was accumulated on 0.25 mm sieves 40.48 ± 2.11 in the case of sample pure poultry manure (MC serie). The largest amount of 1A + 1M was also accumulated on the 0–0.25 mm diameter sieve (39.77% ± 7.07%) while the MKC serie and biochar mill samples accumulated mostly on the 1.0–2.0 mm diameter sieve. The particle distribution was larger in samples with higher manure quantities. The character of biochar dispersion on a sieve is similar like poultry manure with litter dispersion, big amount of biochar fraction accumulated on a sieve with round holes 2 mm diameter (35.80±2.6%).
There was no significant amount of fraction on a sieve with holes 3.15 mm diameter in all variants.

The determined initial moisture content of the raw materials ranged in 62.81±2.48% in pure poultry manure, 56.06±0.58% in manure with litter and 27.35±3.68% in biochar.
After drying and material mixing moisture content varied from 8.15±1.9% to 30.53 ± 1.00%. The bulk density of the raw material was the lowest in the 4MKC sample case (390.8± 9.72%) and the bulk density of 1MC was the highest (635.7±18.66 kg·m^{-3}). The granule density after granulation was obtained from 1384.51 ± 86.13 kg m^{-3} (in the 1A + 4M case) to 1609.01±79.57 kg m^{-3} (in the 1MC case). Increases in ash content, from 25%–50% in the raw material granules, led to strength increases; from 140.3–312.6 N on average in the horizontal direction. increasing biochar content in poultry manure raw material, from 0 till 50% in the raw material, led to strength decrease; from 471.2 to 359.6 n on average in MC series case. increasing biochar content in poultry manure with litter raw material led to strength decrease; from 846.3 to 398.6 N on average in MKC series case.

The results of this study suggest that the granulation of a manure/ash/biochar mixture using biomass granulators with horizontal matrix produces granules of high density and granular strength. It can be argued that the materials of poultry manure, biochar and biomass ash can be granulated, but better strength results is possible to achieve with lower biochar and ash additives.

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