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PRELIMINARY RESEARCH CONCERNING THE POTENTIAL USE OF POULTRY MANURE AS AN AGRICULTURAL FERTILIZER

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Abstract

Poultry manure management is a major technological, agronomic, and environmental challenge in intensive poultry production. The amount and characteristics of manure are influenced by feed composition, water quality, housing system, bird age, and microclimatic conditions. In Romania, poultry are mainly reared either on litter-based floor systems or in cage systems, and these systems strongly affect manure moisture, handling, storage, and final use. This study examines the relationship between poultry housing systems and manure flow, with emphasis on the energetic recovery of poultry litter through combustion and the agricultural use of the resulting ash. The experimental part included the chemical characterization of soil, poultry litter, ash obtained by combustion at different temperature, and soil–ash mixtures prepared at different rates. The results indicate that poultry litter ash can be considered a valuable secondary fertilizer resource within a circular economy framework, provided that application rates are adjusted to crop requirements, soil properties, and salinity risk.

Key words*: poultry manure, agricultural fertilizer, chemical characteristics, heavy metals contents.*

INTRODUCTION

Intensive poultry production generates large quantities of manure, whose amount and composition depend on feed type, digestibility, water quality, bird age, housing system and microclimatic conditions. These factors directly influence manure moisture content, nutrient concentration, handling, storage and environmental impact. In modern poultry complexes, manure management is therefore an essential component of both production efficiency and environmental protection (Williams, 2013; Bernal et al., 2024).

In Romania, poultry are mainly reared in two systems: floor-based systems with permanent litter and cage systems used especially for laying hens. In floor systems, excreta are mixed with litter material and remain inside the house until the end of the production cycle. During this period, fresh manure with high moisture content gradually dries and becomes solid poultry litter. In cage systems, manure is removed more frequently, usually two times per week and therefore retains a higher moisture content, resulting in a semi-solid material requiring covered storage before final use.

The concentration of poultry production units, the restrictions imposed by environmental regulations, especially those related to nitrate pollution and the increasing need for renewable energy and nutrient recycling have stimulated interest in alternative manure management pathways. Traditionally, poultry manure has been used as an organic fertilizer, either directly or after composting. More recently, it has also been considered a resource for biogas production, thermal energy generation, and combustion for heat and electricity. Combustion is particularly attractive because it significantly reduces manure volume, destroys pathogens, decrease, and produces ash rich in mineral nutrients, especially phosphorus and potassium.

Recent studies have highlighted the potential of poultry litter ash as a fertilizer or soil amendment within the circular economy concept. However, its agronomic value depends on combustion temperature, ash chemistry, nutrient availability, pH, salinity, and heavy metal content. The aim of this study was to analyse manure flow and maintenance systems in poultry complexes and to evaluate the chemical characteristics and agricultural potential of poultry litter ash obtained by combustion.

MATERIALS AND METHODS

The study considered the main poultry categories and management systems used in Romania, including broilers, replacement pullets, laying hens, breeder hens, turkeys, ducks, and geese. Poultry production is organized into cycles that include both the productive phase and sanitary downtime. These cycles vary depending on the species and category of birds.

Fresh poultry excreta generally contain 75-90% water. In floor-based systems, manure is mixed with bedding material and remains in the house until the end of the cycle. During this period, moisture decreases from approximately 75% to 20-30%, depending on the season. In autumn and winter, litter moisture is usually higher, around 30-33%, whereas in summer it may decrease to about 20%. In cage systems, manure is removed twice a week, and its moisture decreases only to approximately 55-60%, resulting in a pasty material (Cempa et al., 2022).

Permanent litter protects birds from direct contact with the floor and manure and facilitates cleaning at the end of the production cycle. It consists of a layer of absorbent material, usually 10-30 cm thick, placed on the floor and not replaced until the end of the cycle. The material used for litter must have high hygroscopic capacity, good gas absorption, softness, porosity, and low moisture content.

Suitable materials include cereal straw, industrial wood shavings, and sunflower husks (Van, 2025).

Based on BAT (Best Aviable Techniques) recommendations, the average amount of litter material used was estimated at 6.7 g/bird/day for broiler chickens, 12.98 g/bird/day for turkeys, 73.4 g/bird/day for ducks, and 7.3 g/bird/day for replacement pullets (Santonja et al., 2010).

The soil used in the experiment was a commercial flower-soil substrate analysed in triplicate. The mean values were: pH 7.37, organic carbon 21.15% dry matter, total nitrogen 1.092% dry matter, available phosphorus 140 mg/kg dry matter, available potassium 319 mg/kg dry matter, and electrical conductivity residue 232 mg/100 g. Heavy metal concentrations were also determined, with mean values of 0.16 mg/kg Cd, 39 mg/kg Cu, 37 mg/kg Cr, 689 mg/kg Mn, 28 mg/kg Ni, 49 mg/kg Pb, and 121 mg/kg Zn.

Poultry litter samples were analysed in triplicate. Mean values were: 51.86% moisture, 48.14% dry matter, 85.26% organic matter, pH 6.45, 4.89% total nitrogen, 115 mg/kg dry matter nitrate nitrogen, 11,244 mg/kg dry matter ammonium nitrogen, 1.56% phosphorus, 1.81% potassium, and electrical conductivity residue of 4,369 mg/100 g. Heavy metal concentrations were 0.46 mg/kg Cd, 40 mg/kg Cu, 28 mg/kg Cr, 325 mg/kg Mn, 19 mg/kg Ni, 9.6 mg/kg Pb, and 280 mg/kg Zn.

Poultry litter was incinerated at three temperatures: 400°C, 600°C, and 800°C. The resulting ash samples were analysed for moisture, dry matter, organic matter, pH, organic carbon, total nitrogen, phosphorus, potassium, electrical conductivity residue, and heavy metals.

A pot experiment was established using soil mixed with poultry litter ash at rates of 5, 15, and 25%. Separate mixtures were prepared for ash obtained at 400°C, 600°C and 800°C, resulting in ten experimental treatments, including the untreated control. The mixtures were analysed for pH, available phosphorus, available potassium, electrical conductivity residue, total nitrogen, organic carbon, and heavy metals.

RESULTS AND DISCUSSIONS

Manure flow in poultry complexes is directly influenced by the housing system. In floor-based systems, the poultry house functions both as a production space and as a temporary manure storage unit. During the cycle, fresh excreta are progressively transformed into solid litter through drying and mixing with bedding. This

reduces moisture and facilitates transport, storage, and subsequent use as fertilizer, compost feedstock, briquetting material, or combustion fuel.

In cage systems, manure is removed more frequently and remains wetter, which makes covered storage necessary and increases the need for careful management because of ammonia emissions, and nutrient losses. These differences show that manure handling cannot be separated from the housing technology itself. According to FAO data, manure production is approximately 80 kg/day per 1,000 broilers, 120 kg/day per 1,000 laying hens, 200-350 kg/day per 1,000 turkeys, and 150 kg/day per 1,000 ducks. These large volumes justify the development of efficient recovery pathways, particularly in areas where land available for direct manure application is limited (Tables 1-4).

The poultry litter used in this study had a medium moisture content and a high organic matter concentration, indicating good potential both as an organic fertilizer and as an energy source. The concentrations of total nitrogen, phosphorus, and potassium were substantial, confirming its agronomic value (Popescu et al., 2024; BAT, 2010; Ehlert, 2017; Bernal et al., 2024). The moderate acidity and the high ammonium content suggest that unmanaged poultry litter may also pose environmental risks, especially through ammonia volatilization and nitrate losses.

Heavy metal concentrations in poultry litter were below the agricultural acceptance limits. The relatively higher contents of zinc, manganese, and copper may be associated with feed supplementation and bedding material. At the same time, these elements can act as useful micronutrients when litter is used in agriculture. Combustion considerably altered the chemical properties of the material. The ash showed very low moisture content, high dry matter, and alkaline pH. The pH increased with combustion temperature and reached the highest level at 800°C. Phosphorus and potassium were concentrated in the ash due to the removal of organic matter during combustion (Codling et al., 2002; Ervin et al., 2019; Kan et al., 2024).

Table 1. Chemical characteristics of the soil used in the experiment

Experimental soil	pH	Organic C	Nt	P_{AL}	P_{AL}*	K_{AL}	Conductometric residue
		%			mg kg^{-1} d.w.		mg/100 g
Mean of three repetitions	7.37	21.15	1.092	184	140	319	232

Table 2. Heavy metals content of the soil used in the experiment compared with heavy metal normal contents and alert threshold according to Order no. 756/1997

Experimental soil	Cd	Cu	Cr	Mn	Ni	Pb	Zn
				mg kg^{-1} d.w.			
Mean of three repetitions	0.16	39	37	689	28	49	121
Normal content	< 1.00	< 21	< 31	< 500	< 21	< 21	< 100
Alert threshold	> 3.00	> 100	> 100	> 1500	> 50	> 100	> 300

Table 3. Chemical characteristics of the poultry manure used in the experiment

Poultry manure	Umidity	Dry weight	Organic matter	pH	Nt	N-NO3*	N-NH4*	P	K	Conductometric residue
		%			%	mg kg^{-1} d.w.		%		mg/100 g
Mean of three repetitions	51.86	48.14	85.26	6.45	4.89	115	11244	1.56	1.81	4369

Table 4. Heavy metals content in poultry manure used in the experiment compared with heavy metal loading limits to be accepted in agriculture according to Order no. 344/2004

Poultry manure	Cd	Cu	Cr	Mn	Ni	Pb	Zn
	mg/kg d.w.						
Mean of three repetitions	0.46	40	28	325	19	9.6	280
Heavy metal loading limits to be accepted in agriculture	10	500	500	-	100	300	2000

Ash obtained at 800°C showed the highest pH, phosphorus, potassium, and electrical conductivity values. This suggests that higher combustion temperatures increase nutrient concentration but may also raise the risk of excessive alkalinity and salinity when ash is applied to soil. The literature also indicates that poultry litter ash contains significant amounts of phosphorus, potassium, calcium, and magnesium and may therefore act as both a fertilizer and a liming material, especially on acidic soils.

Heavy metal concentrations in the ash increased compared with raw poultry litter because combustion reduced the original mass. However, even after this concentration effect, the values remained below the accepted limits for agricultural use. This is important because heavy metal accumulation is one of the major constraints for waste-derived fertilizers.

The addition of poultry litter ash increased soil pH, available phosphorus, available potassium, and electrical conductivity. These effects were more pronounced as the application rate increased from 5 to 25% and were strongest for ash obtained at 800°C.

The untreated soil had a pH of 7.42 (Table 5). After ash application, pH values increased up to 8.25 in the treatment with 25% ash obtained at 800°C. Available phosphorus increased from 184 mg/kg in the control to 469 mg/kg in the same treatment, while available potassium increased from 302 mg/kg to 9,400 mg/kg. Electrical conductivity residue also increased markedly, from 233 to 1,523 mg/100 g.

These findings demonstrate that poultry litter ash is highly effective in enriching soil with phosphorus and potassium. However, the strong increase in potassium and electrical conductivity at high application rates indicates a possible risk of salinity and phytotoxicity, particularly for seedlings and salt-sensitive crops. Therefore, ash should be applied in agronomic doses based on crop phosphorus demand, soil fertility status, and the chemical characteristics of the soil.

Table 5. Chemical characteristics of the soil samples from the experimental variants

Experimental variants	pH	P_{AL}	K_{AL}	Conductometric residue	Nt	Corg
		mg/kg d.w.		mg/100 g	%	%
V1 - Control	7.42	184	302	233	1.288	22.27
V2 - soil+5% ash obtained at 400°C	7.38	318	2220	532	1.445	20.43
V3 - soil+15% ash obtained at 400°C	7.46	367	3780	728	1.619	20.33
V4 - soil+25% ash obtained at 400°C	7.74	380	6920	1250	1.651	19.97
V5 - soil+5% ash obtained at 600°C	7.41	215	1460	431	1.398	21.77
V6 - soil+15% ash obtained at 600^{0}C	7.49	254	2600	548	1.293	21.61
V7 - soil+25% ash obtained at 600°C	7.62	398	4240	768	1.625	22.01
V8 - soil+5% ash obtained at 800°C	7.57	299	2420	457	1.246	19.49
V9 - soil+15% ash obtained at 800°C	7.86	403	5960	877	1.397	20.53
V10 - soil+25% ash obtained at 800°C	8.25	469	9400	1523	1.398	21.88

Table 6. The concentration of total heavy metals (cadmium, lead, zinc and copper) in soil samples from the experimental variants

Experimental variants	Cd	Cu	Cr	Ni	Pb	Mn	Zn
	mg/kg d.w.						
V1 - Control	0.177	41	37	30	66	900	125
V2 - soil+5% ash obtained at 400°C	0.256	53	34	30	63	830	177
V3 - soil+15% ash obtained at 400°C	0.296	59	35	27	47	758	204
V4 - soil+25% ash obtained at 400°C	0.374	70	33	26	33	742	227
V5 - soil+5% ash obtained at 600°C	0.215	47	37	29	48	825	160
V6 - soil+15% ash obtained at 600°C	0.258	43	34	28	47	822	143
V7 - soil+25% ash obtained at 600°C	0.223	45	35	29	54	843	155
V8 - soil+5% ash obtained at 800°C	0.300	50	35	32	44	800	181
V9 - soil+15% ash obtained at 800°C	0.319	54	34	28	41	769	205
V10 - soil+25% ash obtained at 800°C	0.500	66	35	28	33	765	280

The increase in pH may be beneficial on acidic soils, where ash could function both as a fertilizer and as a liming amendment. On neutral or alkaline soils, however, high or repeated applications may be problematic. This agrees with previous studies showing that poultry litter ash performs best when carefully matched to soil type and crop requirements.

Heavy metal concentrations in the soil-ash mixtures remained below alert and acceptance thresholds. Although Cd, Cu, and Zn values increased with ash rate, the final concentrations did not indicate an immediate pollution risk (Table 6). For example, Cd increased from 0.177 mg/kg in the control to 0.500 mg/kg in the highest ash treatment, while Zn increased from 125 mg/kg to 280 mg/kg. These values are still far below the cited limits for agricultural use.

This result supports the view that poultry litter ash can be safely used as a fertilizer material, provided that the original manure is monitored and the combustion process is controlled. Nevertheless, long-term field experiments are still needed to assess cumulative effects under repeated use.

From an agronomic perspective, poultry litter ash is especially valuable as a phosphorus- and potassium-rich fertilizer. Compared with raw poultry litter, ash has a lower mass, reduced volume, no biological hazard, lower potential, and easier transport and storage. In addition, combustion provides thermal energy or electricity and therefore contributes to both waste reduction and energy recovery.

From an environmental perspective, combustion decreases the biological risks associated with raw manure and substantially reduces total residue volume. The use of ash in agriculture also supports nutrient recycling and reduces dependence on conventional mineral fertilizers. However, its successful use depends on efficient combustion, appropriate chemical characterization, nutrient-based application planning, and control of salinity, pH effects, and trace element concentrations.

CONCLUSIONS

Poultry manure management is closely linked to housing system and production cycle. In floor-based systems, manure is transformed into solid litter through mixing with bedding and drying during the cycle, whereas in cage systems it remains wetter and requires frequent removal and covered storage.

The poultry litter analysed in this study had high organic matter content and relevant concentrations of nitrogen, phosphorus, and potassium, confirming its dual value as a fertilizer resource and as an energy substrate. Combustion produced ash with low moisture, alkaline pH, and concentrated phosphorus and potassium contents.

Application of poultry litter ash to soil increased pH, available phosphorus, available potassium, and electrical conductivity. These effects demonstrate strong fertilizer potential, particularly on acidic soils and in phosphorus-deficient conditions. Heavy metal concentrations in poultry litter, ash, and soil–ash mixtures remained below the limits accepted for agricultural use.

Overall, poultry litter ash can be considered a valuable secondary fertilizer material within a circular economy approach. Its agricultural use should be based on controlled combustion, chemical characterization of the ash, and application rates adapted to crop nutrient requirements, soil properties, and salinity sensitivity.

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