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VALORIZATION OF LIVESTOCK MANURE AS A MEANS OF ENVIRONMENTAL PROTECTION IN RURAL REGIONS

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ABSTRACT

The study was conducted both to highlight the negative environmental impacts associated with livestock manure and to assess the potential use of manure as a sustainable alternative to chemical fertilizers. To this end, three distinct samples of cattle manure at different stages of fermentation were collected. The main physico-chemical quality parameters analyzed were: pH, moisture content, organic matter, salt content, nitrate and ammoniacal nitrogen, phosphates, and potassium. Livestock manure represents a major source of pollution in rural areas, potentially causing diseases in animals and humans and contributing to the increase of the carbon footprint if storage regulations are not properly followed prior to its use as fertilizer. This research aims to determine the nutritional quality of the studied manure in order to evaluate its applicability as agricultural soil amendment.

KEYWORDS: livestock manure, organic fertilizer, nitrogen, phosphorus, potassium

1. Introduction

Manure is a natural fertilizer obtained through traditional animal husbandry systems, consisting of solid and liquid excreta, along with plant material used as bedding. Its composition varies depending on the species, diet, and rearing conditions, containing significant proportions of nitrogen, phosphorus, and potassium, elements essential for soil fertility [1]. Manure can be a valuable natural fertilizer, but if not properly managed, it becomes a source of pollution for all environmental factors [2]. In rural areas, improper storage can have a significant environmental impact, affecting soil, water, air, and human health [3].

Both storage in non-designated areas (i.e., without impermeable platforms) and excessive application lead to soil imbalance through effects such as soil acidification, nutrient oversaturation, blockage of the absorption of other nutrients, and soil contamination with heavy metals (in cases where animals were fed contaminated fodder) [4].

If manure is stored directly on the ground, nutrients, especially nitrates and phosphates, can infiltrate the groundwater, contaminating drinking water sources. During rainy periods, runoff can carry organic matter, bacteria, nitrates, and phosphates into rivers and lakes, triggering the phenomenon of eutrophication [5,6]. Furthermore, the contamination of drinking water with nitrates, particularly in wells located in rural areas, can cause blue baby syndrome (methemoglobinemia) [7,8]. Manure also contains bacteria, viruses, and parasites that can reach food, water, or soil, leading to gastrointestinal illnesses or infections [9,10].

In addition, a large number of volatile compounds can be produced during the decomposition of animal waste. The most significant gaseous compounds are carbon dioxide, methane, nitrous oxide, ammonia, and other gases with implications for global warming [11]. Optimal manure valorization involves transforming it from a potential pollutant into a valuable agricultural resource through the application of appropriate technologies and practices, in compliance with environmental requirements. The simplest method of manure processing is composting an aerobic process that leads to the production of a stable natural fertilizer [12]. The advantages of composting include volume and odor reduction, as well as the elimination of pathogens [13,14]. Therefore, proper management of animal waste not only reduces pollution through efficient agricultural waste handling but also ensures sustainable agriculture by increasing soil fertility with this natural nutrient solution [15].

The aim of this paper is, on the one hand, to highlight the negative effects that manure has on environmental factors, and on the other hand, to assess the potential for its subsequent use as a sustainable alternative to chemical fertilizers.

Fig. 1. The storage site from which the studied manure samples were collected

2. Materials and Methods

2.1. Sample Collection

For the analyses, three manure samples from cattle were collected. The studied samples were taken from a specially designated storage area belonging to an Administrative Territorial Unit in Buzău County (Fig. 1). The three samples differ according to the storage time and degree of fermentation, as follows:

- Sample 1: storage period under 6 months;
- Sample 2: storage period between 6 and 12 months;
- Sample 3: storage period over 12 months.

Fig. 2. Drying of the analyzed manure samples

Fig. 3. Manure samples after preparation for analysis

The three samples were air-dried (Fig. 2), then ground using a mortar and sieved through a 2 mm mesh (Fig. 3). For the three manure samples, the corresponding aqueous extracts were prepared, as shown in Fig. 4.

3.2. Analyses Performed

For all collected samples, the following parameters were determined:

- pH, by potentiometric method;
- moisture content, by drying at 105°C for 2 hours until constant weight;
- organic matter content, by calcination at 800°C for 3 hours until constant weight;
- salt content, by conductometric method;
-nitrate nitrogen ($N\text{-}NO_3$) content, by photo colorimetric method using a UV/VIS spectrophotometer at a wavelength of 690 nm;
- ammonium nitrogen ($N\text{-}NH_4$) content, by photo colorimetric method using a UV/VIS spectrophotometer at a wavelength of 690 nm;
- phosphate (PO_4^{3-}) content, by photo colorimetric method using a UV/VIS spectrophotometer at a wavelength of 690 nm;
- potassium (K^+) content, by photo colorimetric method using a UV/VIS spectrophotometer at a wavelength of 690 nm.

Fig. 4. Preparation of manure extracts

3. Results and Discussions

The results obtained from the experimental analyses performed on the studied manure samples are presented in Table 1. The following sections will detail the results obtained for each of the analyzed parameters.

3.1. pH Determination

As a result of the manure analysis, it was found that all samples were alkaline, with pH increasing as the storage time increased (Fig. 5). During fermentation, the decomposition of proteins and the release of ammonia can lead to alkalinization.

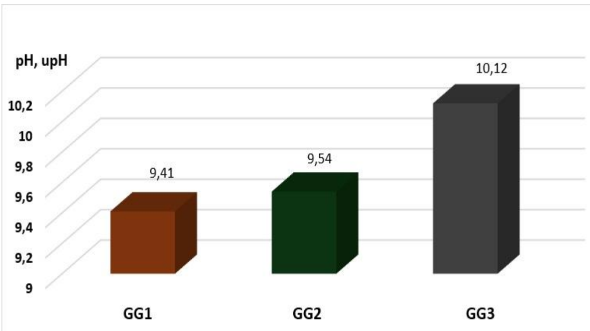

Fig. 5. Values obtained for pH determination in the analyzed manure samples

Tabel 1. Rezultatele analizelor efectuate asupra probelor de gunoi de grajd studiate

Analyzed Parameters	Sample 1	Sample 2	Sample 3
pH, upH	9,41	9,54	10,12
Moisture, %	70,46	54,62	33,41
Organic matter, %	96,76	86,58	93,05
Salts, mg/100 g manure	2360	2265	2485
Nitrate nitrogen ($N–NO_3$), mg/100 g manure	21	54	101
Ammonium nitrogen ($N–NH_4$), mg/100 g manure	30,9	26,4	17,8
Phosphates (PO_4^{3-}), mg/100 g manure	12,5	14,5	25
Potassium (K^+), mg/100 g manure	870	1300	840

A pH value above 9 indicates advanced fermentation, but a pH > 10 (Sample 3) may reduce the availability of certain nutrients in the soil. Nevertheless, all pH values obtained are acceptable for mature compost.

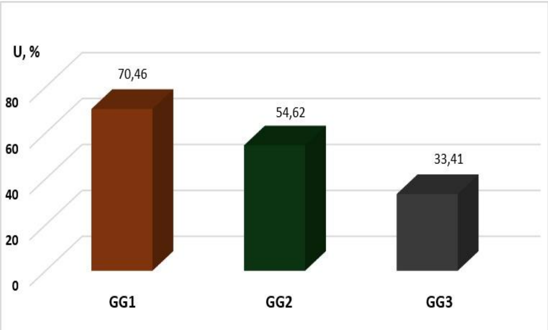

Fig. 6. Values obtained for moisture determination in the analyzed manure samples

3.2. Determination of Moisture

According to the values presented in Table 1 and the diagram in Fig. 6, moisture content decreases with the progression of the fermentation process. Sample 1 is still very moist, indicating that it is fresh and insufficiently matured.

Sample 3 exhibits an optimal moisture level for a stable, mature compost, which is easy to handle and apply. Furthermore, the appearance of this sample (Fig. 2) resembles that of a dark-colored soil rich in nutrients.

3.3. Determination of Organic Matter

Organic matter decreases during fermentation due to decomposition; however, the slight increase observed in Sample 3 may be attributed to water loss (relative concentration).

According to the diagram in Fig. 7, all values are high, indicating a strong fertilizing potential of the studied manure.

3.4. Determination of Soluble Salts

With regard to the salt content, slight variations can be observed (Fig. 8), but all values remain below the critical threshold of approximately 3000 mg/100 g manure [16].

Salt levels increase slightly with maturation (due to dehydration). The recorded values are acceptable for soil application. Although fertilizers can provide essential nutrients to plants, their excessive use may lead to salt accumulation in the soil. It is therefore recommended to develop a crop rotation plan that maximizes yield while minimizing the risks associated with salinity [17].

3.5. Determination of Ammonium Nitrogen and Nitrate Nitrogen

Ammonium nitrogen ($N–NH_4$) decreases over time as it volatilizes or is converted into nitrate. The obtained values confirm the progressive maturation of the studied manure (Fig. 9).

As shown in Fig. 10, nitrate nitrogen ($N–NO_3$) increases significantly with maturation. Ammonium nitrogen is transformed by nitrifying bacteria into nitrates, a form readily available to plants. Therefore, Sample 3 is the most valuable as a fertilizer.

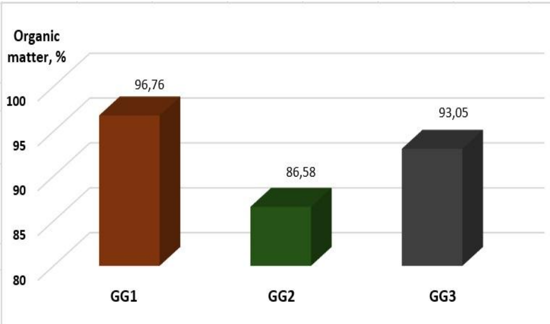

Fig. 7. Values obtained for organic matter determination in the analyzed manure samples

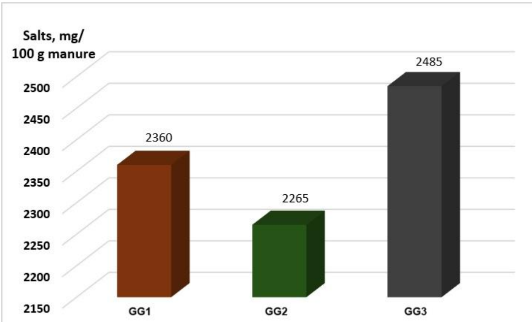

Fig. 8. Values obtained for salt content determination in the analyzed manure samples

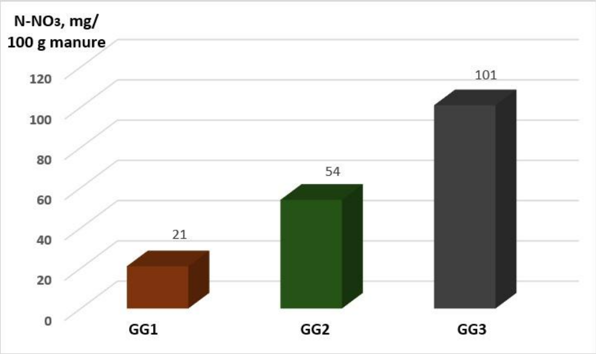

Fig. 9. Values obtained for nitrate nitrogen determination in the analyzed manure samples

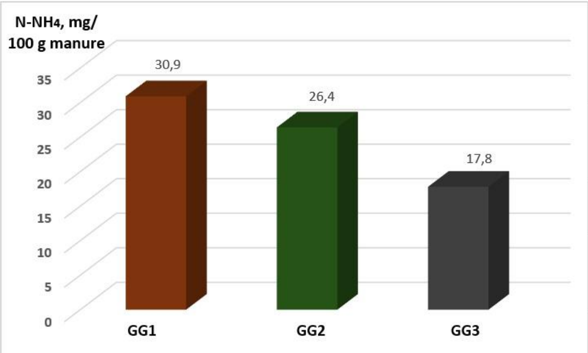

Fig. 10. Values obtained for ammoniacal nitrogen determination in the analyzed manure samples

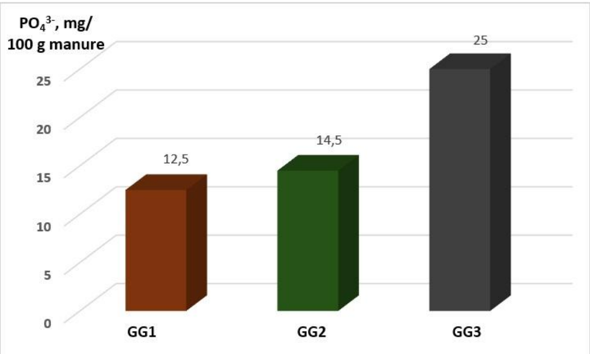

Fig. 11. Values obtained for phosphate determination in the analyzed manure samples

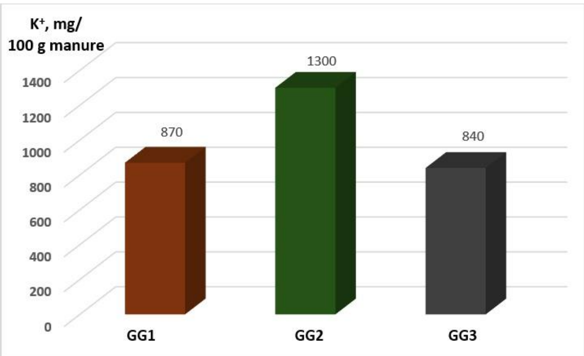

Fig. 12. Values obtained for potassium determination in the analyzed manure samples

3.6. Determination of Phosphates

As shown in Fig. 11, the phosphate content increases with the maturation of manure, as organic substances decompose and release phosphorus [18].

Sample 3 exhibits the highest phosphorus availability, an essential macronutrient for plant roots and flowering [19].

3.7. Determination of Potassium Content

Regarding the analysis of potassium (K^+) content, the highest level was observed in Sample 2 (Fig. 12). Potassium levels may fluctuate depending on the bedding, leaching losses, or variations in moisture. All samples exhibited a good potassium content, which is essential for fruiting and stress resistance [20]. Generally, the potassium content in plants is higher than that of any other major nutrient [21].

Unlike other primary nutrients (nitrogen, phosphorus, sulfur, magnesium, calcium), potassium is not incorporated into the organic constituents of plants; its importance lies in its role in the following plant processes [22]: regulation of water balance, activation of numerous enzymatic systems, and enhancement of resistance to stressful conditions such as cold, pathogens, and various diseases.

4. Conclusions

The comparative analysis of the three manure samples, at different stages of fermentation, highlights the physicochemical transformations occurring during the maturation process. As the manure matures, the following observations can be made (Table 2):

- Decrease in moisture and ammoniacal nitrogen, indicating a reduced risk of leaching and environmental pollution.
- Increase in nitrate nitrogen and phosphate concentrations, signifying compost stabilization and the formation of compounds readily assimilable by plants.
- pH evolution toward more alkaline values, characteristic of mature compost. To avoid any potential negative effects of alkaline manure on the soil, the applied amount should be calculated based on the soil pH and the recommended dose.
- Acceptable levels of salts and potassium, maintaining fertilization potential without causing osmotic stress to the soil.

Thus, Sample 3, with a fermentation period of over 12 months, exhibits the most favorable characteristics for agricultural use, being a stable, mature organic fertilizer with high agronomic value and minimal environmental risk.

Sample 1, which is not fully fermented, is less suitable for direct application, as it contains unstable nitrogen forms and high moisture content, potentially leading to nutrient losses and unpleasant odors.

Sample 2 represents an intermediate stage, with balanced parameters but it could benefit from an

Table 2. Results obtained for the analyzed manure samples

Analyzed Sample	Fermentation Stage	Fertilizer Quality	Remarks
Sample 1	< 6 months	Low – fresh	- High moisture - High ammoniacal nitrogen - Risk of burning if applied directly
Sample 2	6 - 12 months	Medium – partially matured	- Good balance between nitrogen and potassium forms
Sample 3	> 12 months	High – mature compost	- Ideal for application - Well stabilized - Rich in nitrates and phosphates

additional maturation period to achieve maximum efficiency.

The natural reserves of soil nutrients are limited. Without replenishing the nutrients removed from the soil by crops through the application of organic and mineral fertilizers, soil reserves decline, and with them, crop productivity decreases.

Therefore, maintaining and, in certain situations, enhancing soil fertility is of fundamental importance.

The scientifically grounded and site-specific application of organic and mineral fertilizers is crucial not only for agronomic reasons but also from an ecological and economic perspective. Effective fertilizer application is not possible without thorough knowledge of soil properties, the specific nutritional requirements of crops, and the interactions between fertilizers, soils, and plants [23].

Improper storage of manure in rural areas represents a major source of soil, water, and air pollution. The infiltration of nitrates and phosphates into groundwater, runoff into surface waters, and emissions of ammonia and methane contribute to ecosystem degradation and pose risks to human health. The absence of proper management practices transforms a valuable agricultural resource into an environmental hazard, highlighting the urgent need for education, infrastructure, and regulation in rural communities.

Proper collection of manure is essential for maintaining its quality as a natural fertilizer and for preventing contamination. Separating liquid and solid fractions allows for more efficient nutrient management, while avoiding mixing with non-biodegradable or toxic waste prevents the compromise of compost’s agronomic value and reduces environmental and soil risks [24].

Storage on impermeable platforms equipped with leachate collection systems is a critical measure for protecting soil and groundwater. This approach allows controlled fermentation, reduces odors and nutrient losses, and contributes to producing mature, agronomically valuable manure.

The use of manure as a natural fertilizer represents a sustainable solution for soil fertilization, providing multiple benefits to both agriculture and the environment. It improves soil structure, stimulates biological activity, supplies essential nutrients to plants, and reduces dependency on chemical fertilizers. At the same time, proper utilization of manure helps reduce pollution and promotes ecological, efficient, and responsible farming practices in rural areas.

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