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Analysis of the nutrient profile in organic manure from Romanian animal farms

Analiza profilului nutrienților din gunoiul de grajd procesat din fermele de animale din România

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ABSTRACT

The livestock industry has a harmful effect on the environment and contributes to climate change by producing significant amounts of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ammonia (NH_3). In line with this, the production and composting of manure is an important issue in livestock farming. During composting, the manure undergoes physical and nutritional profile changes, which can affect the environment. In this context, in the present study, we have investigated the dynamics of the chemical parameters such as pH, humidity (U%), organic matter (MO%), ammonium nitrogen $N\text{-}NH_4^+$ (g/kg), nitrogen in the form of nitrite $N\text{-}NO_2^-$ (g/kg), nitrate nitrogen $N\text{–}NO_3^-$ (g/kg) and phosphorus phosphate $P\text{-}PO_4^{3-}$ (g/kg) of organic manure from cattle and swine farms during composting. The results revealed a pH variation between 6.9 and 8.23 during composting, which is normal for compost, as mentioned in the literature. A high water content of over 90% was preserved in organic manure and compost because the samples were very liquid. Nutrient values showed increased ammonium and total inorganic nitrogen in cattle farms and one pig farm during composting. This study highlights a rise in nutrient values, especially of ammonium and total inorganic nitrogen in both cattle and pig farms, an aspect that reinforces the need to evaluate intervention strategies and develop a set of recommendations leading to the reduction of exposure risks and a subsequent reduction in human health impacts.

Keywords: cattle, farming, organic manure, compost, land fertilization, greenhouse gases

REZUMAT

Industria zootehnică are un efect dăunător asupra mediului și contribuie la schimbările climatice, producând cantități semnificative de gaze cu efect de seră, cum ar fi dioxid de carbon (CO_2), protoxid de azot (N_2O), metan (CH_4) și amoniac (NH_3). În conformitate cu aceasta, producția și compostarea gunoiului de grajd este o problemă importantă în creșterea animalelor. În timpul compostării, gunoiul de grajd suferă modificări ale profilului fizic și nutrițional, care pot afecta mediul. În acest context, în studiul de față am investigat dinamica parametrilor chimici precum pH-ul, umiditatea (U%), materia organică (MO%), azotul de amoniu N-NH_4^+ (g/kg), azotul sub formă de nitrit N-NO_2^- (g/kg), azot azotat N–NO_3^- (g/kg) și fosfat fosforic P-PO_4^{3-} (g/kg) ai gunoiului de grajd organic de la fermele de bovine și porcine în timpul compostării. Rezultatele au evidențiat o variație de pH între 6,9-8,23 în timpul compostării, ceea ce este normal pentru compost, așa cum se menționează în literatură. S-a păstrat un conținut ridicat de apă de peste 90% atât în gunoiul de grajd organic, cât și în compost, deoarece probele au fost foarte lichide. Valorile nutriționale au arătat o creștere a amoniului și a azotului anorganic total în fermele de bovine și la o fermă de porci în timpul compostării. Acest studiu evidențiază o creștere a valorilor nutrienților, în special a amoniului și azotului anorganic total, atât în fermele de bovine, cât și de porcine, aspect care întărește necesitatea evaluării strategiilor de intervenție și elaborarea unui set de recomandări care să conducă la reducerea riscurilor de expunere și a impactului asupra sănătăţii umane.

Cuvinte cheie: bovine, agricultură, gunoi de grajd organic, compost, fertilizarea terenului, gaze cu efect de seră

INTRODUCTION

The livestock industry has a harmful effect on the environment and contributes to climate change (Grossi et al., 2018). Livestock farming produces significant amounts of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ammonia (NH_3). Furthermore, with animal husbandry, there is a risk of surpassing the carbon dioxide limit in the future, as animals naturally emit CO_2 (Halmaciu et al., 2022). In addition to this, the production of manure is another issue in livestock farming. Over 30 million tons of manure are generated annually worldwide, and this trend is increasing (Li et al., 2021).

The rearing of animals results in large amounts of residual organic matter of liquid, solid, and semiliquid consistency. Manure from livestock farming can be recovered following modern treatments and reused for biogas production. One of the organic manure management options is aerobic composting, which is considered an optimal method due to its economic and environmental advantages. Manure composting was initially used for smell management and prevention of crop contamination with pathogens. However, this treatment option has proven to be a practical strategy for reducing soil contaminants (pesticides, aromatic hydrocarbons, petroleum) or hormones (Gou et al., 2018). Aerobic composting occurs in three stages: the mesophilic stage (25-40 °C), the thermophilic stage (50-60 °C), which favors the destruction of pathogens and contaminants, and the maturation - fermentation stage.

Through condensation and polymerization reactions, the decomposed organic material is converted into humus, and the formed stable product is called compost (Li et al., 2023). Manure, used as a soil amendment, introduces nutrients into the soil, helping to improve its structure, thus increasing the water and nutrient retention capacity and the amount of organic matter in the soil.

The available studies conclude that raw manure should not be applied to the field two months before the harvest of vegetables, while composted manure can be applied anytime. Eating vegetables harvested during this period potentially threatens human health (Gou et al., 2018; Ekman et al., 2021). Several food safety programs generally mandate a time interval between applying untreated manures to soil and harvest. The Australian Guidelines for Fresh Produce Safety recommend a withholding period of 90 days for high-risk products and 45 days for all other products. The National Organic Program from the USA mandates withholding periods of 120 and 90 days for high- and low-risk products, respectively (Ramos et al., 2019), whereas Integrated Farm Assurance (2019) recommends a minimum 60-day withholding period for all products regardless of risk. In Australia, it has been suggested that the new Harmonised Australian Retailer Produce Scheme (HARPS) program adopt a 365-day withholding period, at least for high-risk products (Ekman et al., 2021). In contrast, the UK Red Tractor Assurance Standard and California Leafy Greens Marketing Association suggest 12 months between application and planting for leafy greens (Fresh Produce Standards, 2017). Adopting such a lengthy withholding period would help avoid applying untreated or semi-treated manures for many horticultural producers.

The principal organic manure types applied to land are cattle, pigs, and poultry. Manure characteristics are related to livestock diet and performance, housing and storage systems, and subsequent processing before land application (Montgomery et al., 2022). For cattle and pigs, organic manure consists of mixed urine, feces, and water with relatively little bedding material and with a dry matter content typically in the range of 1-10%, or farm yard manure consisting of urine and feces mixed with large amounts of bedding material having higher dry matter content (Wang et al., 2020). Nitrogen species are present in the manure in organic and inorganic forms (ammonium, nitrate, uric acid, and urea). Excessive chemical nitrogen (N) and phosphorous (P) inputs inevitably cause soil degradation and environmental imbalances (Zhao et al., 2022). Synthetic nitrogen species used as fertilizers can disrupt symbiotic partnerships between plants and soil microbiota, subsequently affecting the micronutrient and phytochemical content. Both organic farming and synthetic nitrogen fertilizers can adversely impact soil life, mineral uptake, and phytochemical production (Johansson et al., 2014). However, mixing these two types of farming could positively impact soil life and crop nutritional profile.

Defining the time that optimum nutrient concentrations and desirable physical properties can be attained with different manure application rates is crucial for planning to avoid excessive build-up (Schlegel et al., 2017). In livestock manure management, improved practices are required during the storage and/or processing of manures to potentially result in more and/or higher availability of N species at land application. Long-term research on animal manure application studies can provide insight into the rate of change of soil chemical properties, including nutrient build-up, to determine beneficial rates and intervals of application.

In this context, the main purpose of this article was to evaluate the nutrient potential of the organic manure from cattle and swine farms and to assess its risk to the environment in different stages of treatment by composting before application on agricultural land.

MATERIALS AND METHODS

Selection of farms participating in the study

In this study, five livestock farms were included, which met the selection norms regarding the total volume, the capacity of the tanks in which the manure is stored, and the method used for treating the manure was composting. Three integrated pig farms were selected, with a total of 23,000 heads, and two cattle farms, subjected to milk production, which presented 527 and 322 heads, respectively, the breeding being carried out in the mixed version - chain breeding and free growth. For the selection of pig farms, the epidemiological status of African Swine Fever was taken into account because, in our country, there have been numerous outbreaks of swine fever in more than 25 counties. Therefore, radical measures have been imposed, including farm biosecurity conditions, multiple beheadings, and movement restrictions. As a result, pig farms in the centre of the country, where no outbreak of ASF was recorded, were studied.

In the two cattle farms (CF1, CF2) processing and storage of manure is done in surface ponds. The slurry and manure, together with the residual water obtained from the sanitation of the living spaces, are stored for 4-7 months with mixing once or three times a week. After a variable storage period, the compost is spread on adjacent plots and incorporated into the soil. The sanitization of the stables housing the animals is carried out with biocides, at regular time intervals.

The 3 pig farms (PF3, PF4, PF5) add up to over 23,000 heads with the purpose of reproduction and growth. Similar to cattle farms, manure is stored in special basins where it is subjected to biosterilization with biocides and then it is used as fertilizer for the lands adjacent to the farms.

Sampling of manure/compost - volume, transport and storage

Five sampling campaigns were carried out in two consecutive years, 2019 and 2020. In total, 17 liquid and solid samples (500 g each) were taken from basins in various stages of composting or from manure storage platforms (Table 1).

Table 1. Coding of the samples collected from the 5 livestock farms selected for the study

Farm	Sample code
CF1	C01, C02, C05, C14
CF2	C07, C16
PF3	P10, P11, P15
PF4 Liquid phase	P08, P09, P12, P13
PF5 Solid phase	P03, P04, P17, P18,

Legend: CF1, cattle farm 1; PF3, pig farm 3; C, cattle; P, pig

All samples were transported according to protection rules and refrigeration conditions, to minimize the risk of contamination with other microorganisms of exogenous origin and to be received and analyzed in the laboratory. The samples taken were kept on ice, in refrigerated boxes, transported to the laboratory, stored at 5+/-3 °C and analyzed within 24 hours of sampling.

Preliminary chemical load analysis of compost samples

The quantitative determination of several physico-chemical parameters from the manure/compost samples was carried out by electrometric and spectrophotometric methods. The following parameters were measured: pH, humidity (U%), organic matter (MO%), ammonia nitrogen N-NH_4^+ (g/kg), nitrogen in the form of nitrite N-NO_2 (g/kg), nitrate nitrogen N-NO_3 (g/kg), phosphorus in the form of phosphate P-PO_4^{3-} (g/kg).

Determination of the pH values

To detect the pH values of the compost, the previously described potentiometric method was used (Korostynska et al., 2007). Hydrogen ions' activity can be experimentally determined by using a glass electrode. This glass electrode has a thin glass membrane bulb which contains an electrolyte and a silver chloride electrode. When there is a difference between the solution inside the electrode and the solution it is immersed in a potential difference occurs between the two sides of the glass membrane (internal and external). The difference is measured compared to a reference electrode potential that isn't pH dependent (usually a calomel electrode is used). The two electrodes (glass and reference are combined in a single electrode attached to the pH meter, which is, in fact, a millivoltmeter.

pH determination for liquid samples: after being washed with distilled water and dried, the electrode is directly immersed in the liquid sample which must be continuously stirred. The electrode bulb must be completely immersed in liquid.

pH determination for solid samples: a suspension is prepared using 10 ± 0,1g solid sample and 25 ml of distilled water. The mixture is thoroughly stirred preferably using a magnetic stirrer. Maintain the magnetic shaking of the suspension throughout the determination. The pH value is recorded after stabilization/approximately 30 seconds.

Determination of humidity

The water content of solid samples (soil/sediment) can be measured and expressed in different ways, depending on the purpose of the determination. Water content can normally be expressed as either gravimetric water content or volumetric water content.

Gravimetric water content is the mass of water contained in a unit mass of dry sample (soil/sediment) in the oven (FAO, 2023). The volume content of water in the sample is calculated using the relationship:

$$U\% = [(G_1 - G_2) / (G_1 - T)] \times 100,$$

where:

- T = volume content of water/sediment in the soil
- G_1 = mass of the wet sample (before drying)
- G_2 = mass of the dry sample (after drying)
- The density of water is considered ρ = 1 g/cm³.

The volumetric water content of the sample is the volume of water in the sample relative to the volume of the solid part: H_2O cm³ /solid cm³, which is a dimensionless fraction. The volume content of water in the sample is calculated using the relationship:

$$T = (G_1 - G_2) / (\pi r^2 h),$$

where:

- T = volume content of water/sediment in the soil (adimensional fraction) θ
- G_1 = cylinder mass with pre-drying test (g)
- G_2 = cylinder mass with test after drying (g)
- r = cylinder radius (diameter/2), in cm
- h = height of the solid column in the cylinder in cm
- The density of water is considered ρ = 1 g/cm³.

Determination of the organic content of compost samples

The experimental determination of organic content is based on the property of organic matter to decompose at high temperatures. It consists of calcining the sample at 550 °C in the oven (Navarro et al., 1993). For this, the sample ≈ 1.0000 g is weighed in a porcelain crucible, previously brought to a constant mass and placed in an oven, programmed at 550 °C, for 4 h. Then, the crucible is removed from the oven and placed in the desiccator for cooling. After it has reached room temperature, it is weighed again.

The percentage of organic matter in the soil is calculated using the relationship:

$$OM\% = [(G_1 - G_2) / (G_1 - T)] \times 100,$$

where:

- T = mass of empty crucible (g)
- G_1 = mass of the crucible after adding the soil/sediment sample (g) before calcination
- G_2 = mass of sample crucible/soil sediment (g) after calcination.

Determination of inorganic nitrogen species in compost samples

For the determination of inorganic nitrogen species from solid samples, the spectrophotometric method is used. Nitrogen chemical species are associated with solid particles in different quantities, depending on the nature of the chemical compound, the amount of organic matter in solid samples and particle sizes. The analysis of the chemical composition of solid samples implies, first of all, the desorption of compounds on the particle surface. The extraction of the compounds to be analyzed is first done. Extraction is carried out with electrolyte solutions containing chemical species that can exchange ions with the ions adsorbed on soil particles that are needed for determination. The exchange may take place if the strength of the interactions between ions introduced with the extraction solution and soil/sediment particles is higher than that of the extracted species. Analyses of inorganic and organic forms of nitrogen are carried out on the obtained extractant solution. These are the bioavailable forms of nitrogen, as the solution used in extraction is similar to the solution in the soil, which is taken over by primary producers.

Determination of ammonium nitrogen (N-NH_4^+)

The salicylate and nitroprusside method is proposed for the determination of ammonium nitrogen (Berthelot, 1859; Utomo et al., 2023). Sodium dichloroisocyanate is used as a chlorinating agent, which generates hypochlorite ions in situ by alkaline hydrolysis. At pH = 12.6, the subsequent reaction of the formed chloramine with sodium salicylate takes place in the presence of sodium nitroprusside used as a catalyst. Sodium citrate, if present in the reaction medium (buffer solution), masks the interference of any cations present in the sample (especially Ca^{2+} and Mg^{2+}).

Determination of nitrogen nitrate (N-NO_3^-)

Among the many spectrophotometric methods that have been developed for the determination of nitrate nitrogen (N-NO_3^-), the most used was the phenoldisulfonic acid procedure (Bremner, 1965), which is also applicable to the analysis of this compound in soil samples. A variant of this method using salicylic acid as a chromogenic agent was used for the analysis of samples of interest (Schneider and Dickinson, 1974).

The method involves nitration of salicylic acid under acidic conditions (concentrated sulfuric acid), the resulting compound being yellow in a basic medium and then assayed based on its absorbance at 410 nm.

Determination of nitrite nitrogen (N-NO_2^-)

Spectrophotometric determination of nitrate ion is based on its property to react with an aromatic amine (sulfanilamide), in an acidic medium, with the formation of a diazonium salt (Griess, 1879).

Determination of phosphorus in the form of phosphate P-PO_4^{3-}(g/kg)

One of the most used spectrophotometric methods for phosphate determination is based on forming phosphomolybdate with added ammonium molybdate, followed by reduction with hydrazine in an acidic medium. Orthophosphate and molybdate ions condense in an acidic solution to give molybdophosphoric (phosphomolybdic) acid, which upon selective reduction (perhaps with hydrazinium sulphate) produces a blue colour, due to molybdenum blue of uncertain composition. The intensity of the blue color is proportional to the amount of phosphate (Lin et al., 2021).

RESULTS

The samples collected from the CF1 and CF2 and PF3, PF4, and PF5 farms were chemically analyzed after being homogenized. The measured parameters were: pH, humidity (U%), organic matter (MO%), ammonium nitrogen N-NH_4^+ (g/kg), nitrogen nitrogen N-NO_2 (g/kg), nitrogen nitrate N-NO_3^- (g /kg) and phosphorus phosphate P-PO_4^{3-} (g/kg). The results are presented in Table 1.

A first analysis of the values shows a range of pH variation values between 6.9 and 8.23, which is normal for compost, as also mentioned in the literature. The samples were very liquid and had a high water content, over 90%, with only a few exceptions. The organic matter content was determined by calcination at 550 °C of the solid fraction obtained after water evaporation. The value in the table expresses the percentage of organic matter in the dry solid fraction. Considering the very high water content of the samples, the organic matter content of the samples is very low (Table 2).

Nutrient values show a net increase in ammonium and, consequently, in total inorganic nitrogen, from the first sampling date to the last, in all farms, as can be easily seen in Figure 1. The increase is very abrupt for pig farms, approximately 10 times higher than in the case of cattle farms. The same trend was obtained for P-PO_4^{3-}, in cattle farms and PF3. For the PF4 and PF5, a decrease in P-PO_4^{3-} was obtained for the last sampling. The decomposition of organic matter in cattle farms occurs from the 3rd month of composting, and in pig farms after the 5th month of composting (Figure 1).

Table 2. Chemical parameters determined from the samples taken from cattle and pig farms

Farm	Cattle farm 1 – CF1				Cattle farm 2 – CF2		Pig farm 1 –PF3			Pig farm 2 –PF4				Pig farm 3 –PF5			
Phenotype	C01-basin evacuation	C02	C05	C14	C07	C16	P10-basin evacuation	P11	P15	P08	P09	P12	P13	P03-basin evacuation	P04	P06	P17
pH	7.68	7.57	6.91	7.98	7.98	7.95	8.05	8	6.9	6.9	7.95	6.91	7.83	7.76	8.23	7.83	8.05
U%	94.67	91.1	86.08	80.94	94.75	96.63	99.25	99.06	99.19	70.19	90.71	76.39	98.93	91.89	96.26	97.24	99.28
OM%	81.13	75.52	85.82	86.27	74.81	64.38	39.13	85.25	45.45	86.57	63.43	86.05	48.6	75.33	82.56	72.68	55.96
N-NH_4^+	0.117	0.086	0.131	1.185	0.186	1.110	0.151	0.164	9.519	0.112	0.131	0.825	10.556	0.046	0.041	0.113	11.866

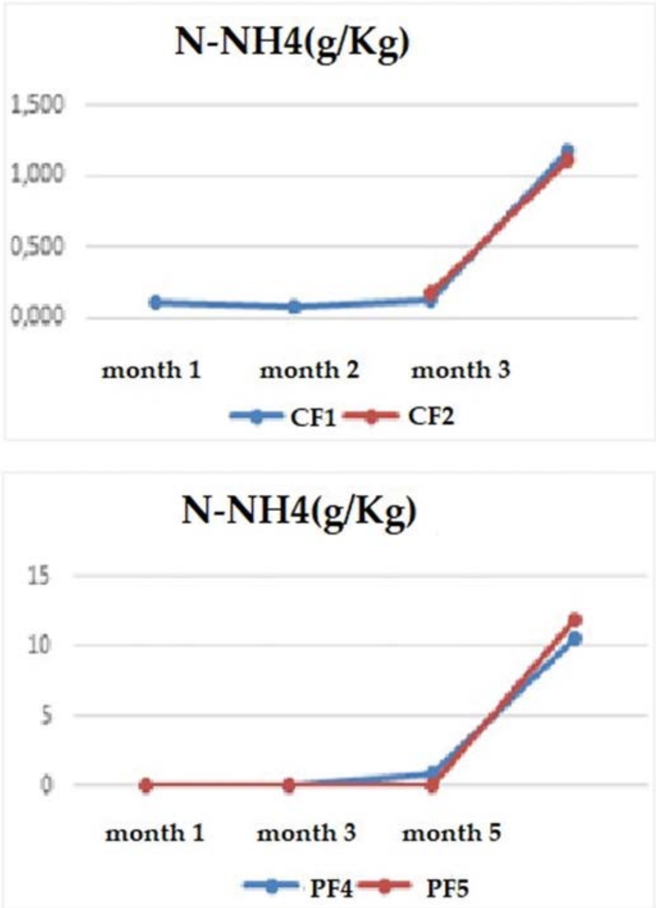

Figure 1. Dynamics of N-NH_4^+ concentrations (g/kg) in cattle and pig farms with sampling data

DISCUSSION

During composting, the manure undergoes physical and nutritional profile changes, which can affect the microbial populations in the manure. Composting has been shown to reduce the abundance of human pathogens and antibiotic-resistant microorganisms (Gaballah et al., 2021; Pu et al., 2019; Wang et al., 2019). However, agricultural soils are frequently treated with animal manure compost and can represent a significant ecological reservoir for antibiotic-resistant microbes.

In this study, five livestock farms which have met the selection norms regarding the total volume, the capacity of the tanks in which the manure is stored and the methods of treating the manure by composting were included. The three selected pig farms harboured a total of 23,000 heads, and two cattle farms were subjected to milk production, which presented herds of 527 and 322 heads, respectively, the breeding is carried out in the mixed version - chain breeding and free growth. In total, 17 liquid and solid samples were taken from basins in various stages of composting or from manure storage platforms.

Several chemical parameters were analyzed to evaluate the nutrient potential of the organic manure from cattle and swine farms: pH, humidity (U%), organic matter (MO%), ammonium nitrogen N-NH_4^+ (g/kg), nitrogen in the form of nitrite N-NO_2 (g/kg), nitrate nitrogen N-NO_3^- (g/kg) and phosphorus phosphate P-PO_4^{3-} (g/kg) (Table 1).

A first analysis of the values shows a range of pH variation values between 6.9 and 8.23, as also mentioned in the literature (Schlegel et al., 2017). In contrast, Wang and collaborators found that long-term applications of chemical nitrogen, phosphorus, and potassium fertilizer lowered soil pH by an annual average of 0.07, stabilizing between 4-5. However, organic fertilizer increased soil pH by about 0.04, suggesting that mixing organic fertilizer with chemical fertilizer should prevent soil acidification (Wang et al., 2023). In addition, Citak and Sonmez (2011) found that organic manure applications could be used to neutralize soil acidity and increase soil pH. In a meta-analysis including 348 observations collected from 74 studies in Chinese vegetable fields, Wang and collaborators aimed to quantify the impact of chemical fertilizers replacement with organic manure on soil pH and vegetable yields. They observed that manure substitution can significantly improve soil pH and vegetable yield. Manure substitution increased the soil pH by 2.6%, 5.6%, and 9.0% and the vegetable yield by 11.0%, 12.6%, and 3.2%, respectively. In addition, when the initial soil pH was ≤ 6, the soil pH increased with manure substitution. Conversely, manure substitution decreased the soil pH when the initial soil pH was > 8. (Wang et al., 2019). Chen and collaborators conducted a 3-year field experiment in which they applied manure compost for 12 consecutive harvest seasons and observed the alleviation of soil acidity, with a pH increase of 0.49–0.75 units (Chen et al., 2022).

In terms of humidity, the samples analyzed in this study had a high water content, over 90%. However, other studies focused on deciphering the nutrient potential of organic manure from pig and cow farms observed a moisture content between 40-60% (Giosanu et al., 2022). Another study investigating the stoichiometry of manure and moisture regimes on soil properties revealed that organic fertilizers increased soil moisture retention (Bhanwaria et al., 2022). Moisture content significantly impacts the degradation and transformation of organic matter (Kovshov and Skamyin, 2017). Moisture content can change the physical and biological characteristics of composted materials, including the metabolic process of microorganisms, the dissolving and transporting of nutrients, and microbial migration (Kim et al., 2016). In addition, moisture affects oxygen transfers and microorganism metabolism, thereby affecting the organic material transformation (Li et al., 2021). A too-low initial moisture will cause water shortage at the early stage of composting (Luangwilai et al., 2018), while excessively high moisture could cause the discharge of free water as leachate, which contains a larger amount of nitrogen and phosphorus, leading to nutrients loss (Wei et al., 2014).

Nutrient values show a net increase in ammonium and, consequently, in total inorganic nitrogen, from the first sampling date to the last, in all farms, as can be easily seen in Figure 1. The increase is very sharp for the farms of pigs, about 10 times higher than cattle farms. The same trend was obtained for P-PO_4^{3-}, in cattle farms and a pig farm. Similarly, Gerald and Charles revealed that several selected composted farm wastes contained more and retained more N and P than other farm wastes. Significant volumes of N and P were retained in composted materials compared to those managed by surface decomposition (Gerald and Charles, 2022). Different N-NH_4^+ and N-NO_{3-} concentrations were observed by Santos and collaborators in pig slurry compost. Losses of N during their experiment could have occurred by leaching or denitrification (Santos et al., 2018). A study conducted from 1999 to 2008 evaluated the rate of change in soil nutrient concentration and soil chemical properties due to cattle manure and swine effluent application. The study included ten treatments (three levels of cattle manure and swine effluent [P, N, and 2N], three levels of N fertilizer, and a control). Soil NO_{3-}, N, P, K, micronutrients, and pH were measured annually. Swine P treatment resulted in significantly greater NO_{3-}N concentration in most years than all other treatments, followed by the Cattle 2N and Swine 2N treatments. The cattle treatments, in the order Cattle 2N > Cattle N > Cattle P, contributed significantly to the total N, soil P, and total C levels over the years compared with all other treatments. Soil pH did not change over time for most treatments except for the Swine P and Swine 2N treatments (Schlegel et al., 2017).

For the other two pig farms, a decrease in P-PO_4^{3-} was obtained for the last sampling. The observation of fewer nutrients after composting/surface decomposition compared to the baseline nutrients can be explained on two accounts: the loss of carbon in a gaseous form during the decomposition process and the loss of carbon through microorganisms that feed on organic matter and convert it into their body cells/tissues (Gerald and Charles, 2022). The loss of carbon in a gaseous form or combined with oxygen is a greenhouse gas lost to the atmosphere, which is a serious problem to the environment (Obi et al., 2016). Other studies revealed that the fertilization of acid soils with compost can increase total P, available P, inorganic P fractions, and organic P (Mensah and Frimpong, 2018; Horta, 2019). This was possible because compost increased soil pH and exchangeable bases while reducing exchangeable acidity. In addition, incorporating compost in highly weathered soils can enhance the dissolution and immobilization of phosphate rock. Furthermore, adding compost to soils can prevent soil P sorption because P sorption sites and the bonding energy for phosphate sorption to the soil solid phase decrease, increasing soil P availability (Horta, 2019). In a long-term manure experiment, the group led by Mao et al. (2023) used a modified P fractionation scheme to analyze P fractions at two soil layers for three treatments (cattle manure, cattle manure, and chemical fertilizer application, and control without fertilizer application). This 14-year long-term manure experiment allowed them to conclude that manure application can increase the concentration of

P fractions at the 0–40 cm soil, except for moderately labile-P (NaOH-Pi). In addition, cattle manure and chemical fertilizer application can help reduce residual P and may represent an optimized long-term yield approach.

The excessive use of chemical fertilizers has led to increased food production but has also caused significant environmental and health problems. Therefore, governments and other organizations need to provide empirical data to small-scale farmers on the nutritional value of farm waste and how to manage it effectively. Similarly, better handling and storage of manure can result in efficient cycling of carbon and nutrients. This paper contributes to the existing knowledge by measuring and recording the baseline nutrient content of farm waste before disposal, assessing the variation of farm waste managed through composting and surface disposal, and identifying the primary source of major nutrients among selected farm wastes.

CONCLUSIONS

Inspection of the measured physico-chemical parameter values indicates a pH variation between 6.9-8.23 and a high water content of over 90%. Despite the positive impact of manure substitution on soil pH and vegetable yield improvement, the interactions among different factors during these farming processes remain complicated and require further validation based on local conditions.

Nutrient values show a clear increase in ammonium and total inorganic nitrogen in cattle farms and one pig farm from the first sampling date to the last. A clear increase in the concentration of inorganic forms of nutrients is observed during composting, especially in the case of compost from pig farms, the increase in values being approximately 10 times higher than in the case of cattle farms.

Using inorganic fertilizer to increase yield is effective as a short-term solution but demands consistent use on a long-term basis. The high cost of inorganic fertilizers makes them less accessible to small-scale farmers, and it is also undesirable due to their hazardous environmental effects. In the future, soil amendment with organic manure for improving nutrient profile will be unavoidable for enhancing long-term agriculture.

This study shows a clear increase in ammonium and total inorganic nitrogen in cattle and pig farms, stressing the need for strategies to reduce exposure risks and protect human health. Recommendations should focus on improved manure management and nutrient recovery to ensure safer, sustainable farming.

Future research on soil amendment with organic manure should focus on optimizing nutrient efficiency through precision application techniques and exploring how manure impacts different soil types while mitigating environmental risks like pathogen transmission and ammonia emissions. Studies on nutrient recovery technologies, such as anaerobic digestion and manure treatment systems, are essential for enhancing sustainability. Investigating the effects on soil microbial communities and organic carbon sequestration will help gauge long-term soil health. Comparative analyses of manure types and synergies with other amendments, along with economic assessments and policy development, will guide best practices. Lastly, public education on manure use and consumer perceptions of organic farming should be prioritized to ensure widespread adoption.

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