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Evaluating local organic waste potential for composting: Physico-chemical insights from Uzbekistan's cattle manure and wheat straw

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ABSTRACT

The intensification of agricultural and livestock production has led to a substantial increase in the generation of organic waste worldwide. In Uzbekistan, large volumes of local organic waste, such as livestock manure and crop residues are generated annually, but most of this organic waste remains underutilized. Therefore, identifying effective composting strategies using local organic waste is essential for sustainable agriculture. This study investigated the physicochemical characteristics of two common local organic waste materials (cattle manure and wheat straw) in evaluating their suitability as raw materials for composting. The research methodology involved a laboratory-based physicochemical characterization of both materials. Samples were analyzed for bulk density, moisture content, pH, organic matter, total nitrogen (N), phosphorus (P), potassium (K), and the carbon-to-nitrogen (C/N) ratio using standard analytical procedures. The data obtained were evaluated for the composting potential of cattle manure and wheat straw, and the outcomes were compared with previous research to validate their suitability as substrates. Results showed that cattle manure exhibited a relatively high nitrogen content (2.3%) and moderate levels of phosphorus (0.22%) and potassium (0.52%), indicating its role as a significant nutrient source. Wheat straw in contrast was characterized by a high carbon concentration and low nitrogen content, resulting in an initial C/N ratio of 122. The combination of these local wastes forms a balanced composting mixture with an optimal C/N ratio and improved aeration, enhancing microbial activity under aerobic static pile conditions. In conclusion, the complementary properties of cattle manure and wheat straw make them highly suitable for co-composting. This research offers a scientific basis for optimizing compost formulations using locally available agricultural waste, contributing to sustainable waste management in Central Asia.

Keywords: cattle manure, wheat straw, physico-chemical composition, C/N ratio, composting, sustainable agriculture.

INTRODUCTION

The intensification of agricultural and livestock production has led to a substantial increase in the generation of organic waste worldwide. Global straw production is estimated at approximately 846 million tons, while livestock generate around 3.7 billion metric tons of manure annually, including 127 million metric tons of nitrogen (FAO, 2022; Garrido et al., 2023). Livestock manure contributed more than 1.4 billion tons of CO_2-equivalent greenhouse gas emissions in 2018 (FAO, 2020). In addition, the accumulation of livestock manure leads to the emission of malodorous gases, which can pose significant health risks to both humans and animals (Greff et al., 2022). The open burning of crop residues, particularly wheat straw, is a major contributor to atmospheric pollution, greenhouse gas emissions, and soil nutrient depletion. The burning of one ton of wheat straw results in the release of approximately 1.460 kg of carbon dioxide (CO_2), 60 kg of carbon monoxide

(CO), 3 kg of particulate matter (PM), 2 kg of sulfur dioxide (SO_2), and 199 kg of dust (Chanana et al., 2023; Rosmiza et al., 2014). These unsustainable methods contribute an estimated 12–14% to the global warming potential each year (Montero et al., 2018). In addition to atmospheric impacts, straw burning results in substantial nutrient losses from soils – up to 100% of organic carbon, 93% of nitrogen, 25% of phosphorus, 20% of potassium, and 5–60% of sulfur is volatilized during combustion (Dobermann and Fairhurst, 2002). These irreversible losses degrade soil fertility, reduce agroecosystem resilience, and undermine the long-term sustainability of agricultural production. Straw can be efficiently processed and decontaminated through aerobic composting, an economical and environmentally sustainable technology (Awasthi, 2015; Fang et al., 2021; Petric et al., 2009). In contrast, composting has gained recognition as a sustainable and biologically mediated strategy for the valorization of organic waste. Composting is considered one of the most viable treatment options for biodegradable waste, as it is a natural process that requires comparatively low capital investment (Bhave and Joshi, 2017). This process entails the controlled aerobic decomposition of biodegradable organic matter into stable, humified end-products characterized by improved nutrient availability and beneficial soil-conditioning attributes (Bernal, 2009). The composting of local organic waste minimizes the environmental burden associated with agricultural waste disposal, promotes nutrient recycling and reduces dependence on synthetic fertilizers. In semi-arid regions, such as the Samarkand region of Uzbekistan, the used of compost has been shown to enhance soil structure, increase water-holding capacity, and aid in the rehabilitation of degraded soils (Kholikulov and Pardaev, 2014). However, the efficiency and quality of composting processes are strongly influenced by the physical and chemical characteristics of the feedstock materials. Among these, the carbon-to-nitrogen (C/N) ratio and moisture content are critical parameters that govern microbial activity and compost maturity (Bernal, 2009; Tiquia and Tam, 2000). Optimal composting typically requires a C/N ratio in the range of 25:1 to 30:1 as well as moisture content between 50% and 65% (Azim, 2018; Li et al., 2020; Uvarov, 2025).

Cattle manure is widely regarded as a valuable source of organic matter and essential nutrients. Fresh cattle manure contains high levels of nitrogen, especially in the form of ammonium (NH_4^+), as well as phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) (Gao, 2019). Cattle manure is generally rich in nitrogen and microbial biomass, but is characterized by high moisture content and low porosity, the conditions that may inhibit oxygen diffusion and promote localized anaerobic zones. Cattle manure can be effectively converted into high-quality organic fertilizer through aerobic composting, a method widely adopted for sustainable manure management in many countries (Ravindran et al., 2019). Conversely, wheat straw is a lignocellulosic, carbon-rich material with high structural integrity but limited nitrogen content. Thus, combining these substrates offers a synergistic balance, facilitating improved aeration, microbial colonization, and overall composting performance. In Uzbekistan, few studies have systematically analyzed the chemical characteristics of local organic wastes. However, authors reported that manure simples had an average total nitrogen content of 1.8%, organic matter 68%, and a C/N ratio of around 18–22. Wheat straw, on the other hand, showed an average C/N ratio of 80-100, making it an ideal component to dilute the nitrogen load in composting systems (Kholikulov, Sh.T; Pardaev, 2015).

Despite the agronomic potential of local organic waste, there is a notable paucity of scientific literature characterizing their initial chemical properties in the context of Uzbekistan. Furthermore, limited studies have assessed their compatibility and performance as co-substrates in composting systems adapted to local agricultural practices and climatic conditions. Therefore, this study aimed to (i) evaluate the initial physicochemical properties of local organic waste (cattle manure and wheat straw) collected from the Pastdargom district of the Samarkand region, (ii) compare the nutrient balance and decomposition potential of these substrates with the findings from previous studies on compostable agricultural wastes. Specific parameters analyzed include bulk density, moisture content, ash content, organic matter, and macro-nutrient concentrations (N, P, K), with particular attention to their C/N ratios.

MATERIALS AND METHODS

Study area

The study was conducted in the Pastdargom district (39.660431° N, 66.662297° E), Samarkand region, Uzbekistan. during the summer and autumn of 2024. The district located in the central part of Uzbekistan, within the Zarafshan River basin, and represents one of the key agricultural zones of the region, as shown in Figure 1. The area is characterized by an arid continental climate, with hot, dry summers and mild, relatively wet winters. The average annual temperature ranges from +13 to +14 °C, while summer temperatures often exceed +35 °C. During the study period, temperatures were particularly high, with reports indicating that they reached and exceeded 40 °C in midsummer. The average annual precipitation is about 300–350 mm, most of which falls between November and April (Kholbaev et al., 2023). No precipitation was observed in the area during the study period. Agriculture is a major economic activity, cereal crops occupy approximately 32% of arable land, with winter wheat as the principal crop, sown in October–November and harvested in June–July, producing significant wheat straw residues (FAO, 2022). Wheat harvesting in early to mid-summer yields large quantities of dry straw, favorable for composting. These residues, combined with cattle manure, served as the primary raw materials for this study. Pastdargom district supports mixed livestock systems, predominantly cattle, managed by private farms and household plots. Livestock are stall-fed with conserved fodder, including hay, straw, and crop by-products, generating substantial manure often concentrated seasonally after harvest and feeding cycles. Livestock farming accounts for 46–47% of national agricultural output, with approximately 90% from household production. Sustainable management practices and improved feeding strategies further amplify organic waste generation, emphasizing the need for efficient collection and utilization.

Sampling procedure and sample preparation

Wheat straw was collected from a selected location in this district, from a field where winter wheat had recently been harvested. Fields were chosen based on their accessibility, common cultivation practices, and use of widely grown local wheat varieties, thereby ensuring that the collected straw was representative of residues typically available to farmers in the area. Approximately 20–25 kg of composite samples of each material were collected from each selected site. All prepared samples were transported to the experimental site in sealed polyethylene bags to prevent contamination, cross-contamination, and moisture exchange with the environment. Fresh, undecomposed cattle manure was collected from representative small-scale farms and household plots across the study area to ensure that the samples accurately reflected the typical livestock management and manure handling practices in the region. All the samples air-dried in the shade for 2–3 days to reduce excess moisture. To ensure representativeness, composite samples (n=3 for each material) were prepared by combining subsamples from 4–5 randomly distributed locations within the farm or field. The samples were mixed to maintain their physical and chemical integrity and then averaged for analysis. The combined collection of cattle manure and wheat straw ensured that the raw materials used in the study were representative of local livestock and crop management systems, providing a reliable basis for subsequent composting experiments.

Physico-chemical analysis

The physico-chemical properties of cattle manure and wheat straw were analyzed following standard procedures with minor adaptations to

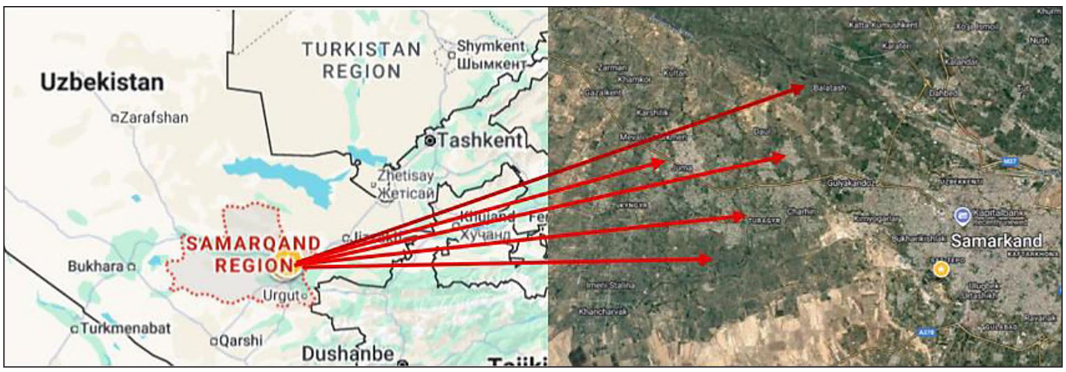

Figure 1. Study area and sample taken area

local laboratory conditions, as shown in Figure 2. Moisture content was determined gravimetrically by drying subsamples at 105 °C for 24 h in a forced-air oven. Ash content was measured in a muffle furnace at 550 °C for 4 h according to the standard method, and organic matter (OM) was calculated as the difference between 100% and ash percentage (Faithfull, 2002). Bulk density was determined using the core method, as described by Ahn et al. (Ahn et al., 2008) in which a known volume of the sample was collected using a cylindrical core sampler, oven-dried to constant weight, and bulk density calculated as dry mass per unit volume (g cm^{-3}). The pH and electrical conductivity (EC) of a 1:10 (w/v) aqueous extract were measured using a calibrated digital pH meter (Mettler Toledo) and conductivity meter (Biobase 950), respectively, following standard soil and compost analysis protocols (Holatko et al., 2022). Prior to analysis, all samples were oven-dried at 65 °C until constant weight, ground to pass through a 2 mm sieve, and homogenized. Total nitrogen (TN) was quantified using the Kjeldahl digestion method (Bremner, 1996), total P was determined calorimetrically using a spectrophotometer (Biobase), and total K was analyzed with a flame photometer (Faithfull, 2002). Carbon content (C) was estimated indirectly from the OM, assuming that organic matter contains 58% carbon (Faithfull, 2002). The C/N ratio was subsequently calculated as the ratio of total C to total N. All measurements were carried out in triplicate to ensure reproducibility and data reliability.

Data analysis

Descriptive statistics were used to summarize the physico-chemical characteristics of raw materials. The relationships between parameters were assessed using Pearson correlation. Statistical analyses were performed using OriginPro 2024, and results were expressed as mean ± standard deviation (n=3). Heatmaps were used for visualization of correlations among key physicochemical properties.

RESULTS AND DISCUSSION

Physico-chemical characteristics of local organic waste

Determining the physicochemical properties of organic waste is essential for their effective management and utilization. Parameters such as moisture content, pH, organic matter, nutrient composition, and C/N ratio are key indicators that utilize organic wastes. Accurate characterization of these properties enables researchers to optimize waste management strategies, improve nutrient recycling, and enhance the quality of the final compost. For instance, appropriate balancing of carbon and nitrogen, adjustment of moisture, as well as selection of suitable raw materials are all guided by physicochemical data (FAO, 2020; Rao and Parsai, 2023).

Several studies have emphasized that understanding the physicochemical attributes of organic residues not only supports efficient

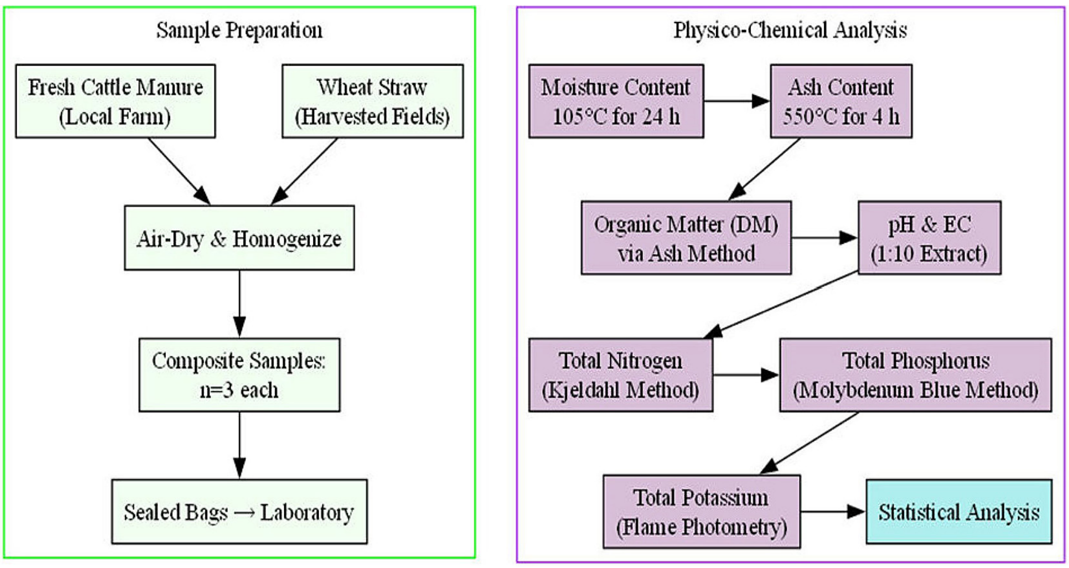

Figure 2. Flowcharts of physico-chemical analysis

decomposition but also informs sustainable agricultural practices. Characterization of waste facilitates prediction of composting dynamics, prevents potential environmental risks, and maximizes the agronomic value of compost products (Ma et al., 2021; Miao et al., 2018). The initial physicochemical properties of cattle manure and wheat straw are presented in Figure 3.

Moisture content and organic matter also differed significantly between the two substrates Cattle manure had a high moisture content (78.8%), while wheat straw contained only 10.72%. This difference reflects their intrinsic nature: manure is a fresh, wet material rich in water, while straw is a dried lignocellulosic residue. Moisture is critical for microbial activity, and both extremes – excess water in manure and dryness in straw – can hinder composting (Tiquia and Tam, 2000). Their complementary moisture levels make co-composting advantageous, as manure prevents desiccation and straw improves aeration, thereby avoiding anaerobic conditions. Organic matter content was substantial in both substrates, though higher in wheat straw (92.63%) compared to manure (74.46%). The high organic matter of straw reflects its cellulose, hemicellulose, and lignin fractions, which decompose slowly (Wei et al., 2019). The organic matter of manure includes partially digested feed residues and microbial biomass, making it more labile and easily degradable (Awasthi, 2015). This combination – labile carbon from manure and recalcitrant carbon from straw – supports a balanced decomposition process and sustained microbial activity throughout composting.

The bulk density of cattle manure was 859.52 ± 5.22 kg/m³, which was significantly higher than that of wheat straw (151.25 ± 2.5 kg/m³). This difference is expected, as manure is a dense, moisture-retentive material, whereas straw is light and porous. Bulk density is closely linked with porosity and aeration, both of which are critical for oxygen diffusion during composting (Ahn et al., 2008). The low bulk density of straw enhances aeration but limits microbial activity if used alone, while the higher density of manure promotes microbial contact but can lead to anaerobic conditions if not balanced. Therefore, combining these two materials creates an optimal structure for composting by balancing aeration and moisture retention (Bernal, 2009). The pH of cattle manure was neutral to slightly alkaline (7.65 ± 0.98), while wheat straw exhibited a more acidic pH (5.36 ± 1.22). The relatively high pH of manure is typical, resulting from the presence of ammonium and bicarbonates generated during animal digestion (Ravindran et al., 2019). By contrast, the acidic pH of straw reflects residual organic acids and lignocellulosic compounds in plant residues (Cao et al., 2023). Since pH influences microbial succession during composting, the contrasting pH values of these substrates suggest that mixing them would provide a moderated environment suitable for microbial growth (Fang et al., 2024). The EC values showed an inverse trend to pH: wheat straw had significantly higher EC (4.96 ± 0.12 dS/m) compared to cattle manure (1.94 ± 0.03 dS/m). The elevated EC in straw likely results from soluble salts absorbed from soil and fertilizers during crop growth (Goyal et al., 2005). Manure generally exhibits moderate EC due to the presence of dissolved minerals but remains within a range favorable for composting

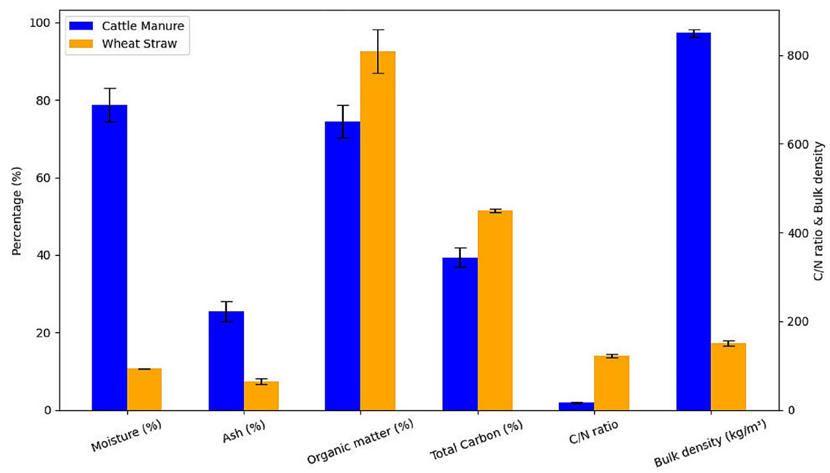

Figure 3. Physico-chemical properties of cattle manure and wheat straw

(Ren et al., 2023). High EC may inhibit seed germination if compost is applied directly, but during the composting process, salt redistribution and leaching usually reduce this effect. While manure contained higher nitrogen, wheat straw had very low nitrogen content, leading to a very high C/N ratio. A high C/N ratio in straw alone would result in slow decomposition due to nitrogen limitation for microbes (Xu et al., 2020). Manure, as a nitrogen-rich input, balances this deficiency. The integration of both substrates lowers the overall C/N ratio into the optimal range (25–30), which is essential for efficient composting (He et al., 2024).

In summary, the contrasting properties of manure (dense, moist, nitrogen-rich) and straw (light, porous, carbon-rich) justify their combined use in composting. Their complementary characteristics balance structural properties, nutrient ratios, and microbial needs, creating an environment favorable for efficient organic matter decomposition and stable compost formation. However, the low nitrogen content of wheat straw and high C/N ratio require it to be complemented with nitrogen-rich inputs like manure for effective composting. The bulk density of the cattle manure was 859.52 ± 5.22 kg/m³, significantly higher than that of wheat straw (151.25 ± 2.5 kg/m³), indicating that straw is lighter and more porous. This substantial difference in bulk density – directly linked to porosity and aeration – highlights the need for co-composting these materials to achieve a balanced physical structure. The contrasting properties of manure (dense, moisture-retentive) and straw (light, porous, carbon-rich) justify their combined use in composting, as this integration balances nutrient ratios, moisture retention, and aeration while supporting microbial activity. Ultimately, these materials complement each other: wheat straw provides structure and carbon, while manure supplies moisture and nitrogen, creating an ideal environment for efficient composting.

Nutrient composition of raw materials (cattle manure and wheat straw)

The nutrient content of cattle manure and wheat straw is shown in Figure 4. The total N, P, and K contents were significantly higher in cattle manure than in wheat straw. The average nitrogen content in cattle manure was around 2.3%, compared to only 0.42% in straw. Interestingly, the phosphorus (0.26%) and potassium (0.98%) contents were higher in wheat straw than in cattle manure (0.22% and 0.52%, respectively). The total N, phosphorus (P_2O_5), and potassium (K_2O) contents of raw materials are critical for evaluating composting potential. The relatively high nitrogen content of cattle manure (2.3%) as well as moderate P and K levels in both substrates suggest that their combination offers a balanced nutrient supply for composting. The obtained results are in agreement with previous studies, cattle manure typically contains 1.5–2.8% total nitrogen (Bernal, 2009), with some studies reporting values up to 3.2% (Awasthi et al., 2021). Similarly, the P and K contents of around 0.9% and 1.5% have been observed in fresh cattle manure (Qian et al., 2014). The low nutrient concentrations in wheat straw are consistent with its fibrous, lignocellulosic composition (Yang et al., 2024). N content (0.42%) is lower than that of manure, but it provides structural carbon and improves aeration, which is crucial in passive composting systems. The K_2O content (0.98%) supports previous findings that agricultural residues, though low in nitrogen, significantly contribute to potassium enrichment (Escobar et al., 2024). Interestingly, wheat straw showed slightly higher phosphorus content (0.26%) than cattle manure (0.22%), likely due to P being concentrated in phytate form within cereal residues (Yang et al., 2025). A blend of both materials can optimize nutrient availability and compost maturity (Zhou et al., 2022). The overall nutrient profile of these substrates meets the minimum requirements set by FAO for compost production from livestock and crop residues (FAO, 2020). The combination supports their use as an alternative to mineral fertilizers, particularly in integrated nutrient management systems in semi-arid regions, such as Uzbekistan. Balancing high-moisture, nutrient-rich manure with dry, carbon-rich straw ensures optimal C/N ratios (~25–30), which supports microbial activity and composting efficiency. Manure contributes moisture and nitrogen, while straw enhances porosity and prevents compaction. Both pH and EC values were within acceptable ranges for composting. The slightly alkaline pH of manure and acidic nature of straw complemented each other, stabilizing the compost environment. However, due to the relatively high EC of wheat straw, salt accumulation should be monitored to avoid phytotoxicity during application

The contrasting physicochemical properties of these materials make them highly compatible for co-composting, supporting both nutrient

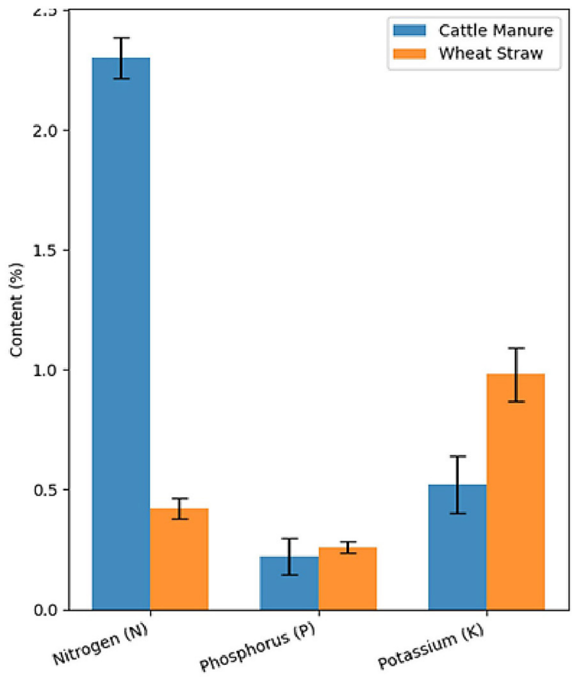

Figure 4. The nutrient content of cattle manure and wheat straw

enrichment and aeration. The measured nutrient values, particularly the NPK contents, align with the findings from previous international studies, affirming their suitability for composting. For instance, similar N and P levels have been reported in the studies from India, Iran, and China, indicating that Uzbek agricultural waste resources can be effectively transformed into quality compost comparable to global standards. These findings are consistent with those reported by some research results to demonstrate the importance of balanced C/N ratios and physical properties in achieving high-quality compost (Awasthi, 2015; Bernal, 2009; Qian et al., 2014; Tiquia, 2000). Overall, the findings provide a scientific foundation for promoting the use of locally available organic waste in sustainable farming practices. The compost produced from these materials could serve as an affordable, environmentally friendly alternative to synthetic fertilizers, particularly for smallholder farmers seeking to improve soil health and crop productivity.

Pearson correlation coefficients were calculated to assess the relationships among the physico-chemical parameters of cattle manure and wheat straw. The results revealed both strong and weak linear associations between different variables, offering insight into their potential interactions and influence on composting efficiency as shown in Figure 5.

A strong negative correlation was observed between moisture content and bulk density (r = –0.997), indicating that as moisture increases; the bulk density tends to decrease. This is expected, as higher moisture generally results in looser structure and lower compaction, particularly in organic materials like manure. Similarly, a strong positive correlation between organic matter content and pH (r = 0.85) suggests that the substrates with higher volatile solids tend to have a more neutral to slightly alkaline pH, which is favorable

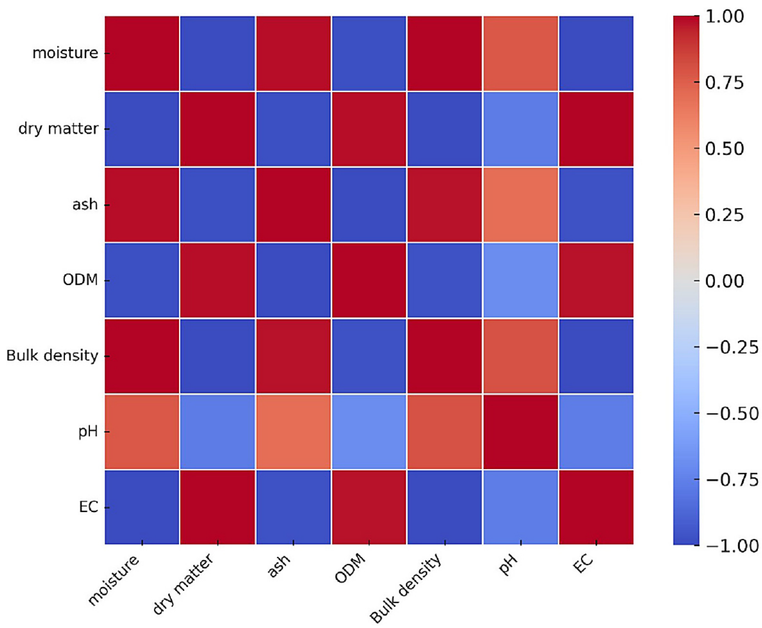

Figure 5. Heatmap Pearson correlation coefficients

for microbial activity during composting (Bernal, 2009). In contrast, EC exhibited a strong negative correlation with pH (r = –0.95), indicating that materials with higher salt concentrations may tend to have more acidic conditions, particularly in the wheat straw, which showed significantly higher EC levels (4.96 dS/m) compared to cattle manure (1.94 dS/m). The positive correlation between EC and bulk density (r = 0.93) implies that denser materials may contain more concentrated soluble ions, affecting microbial degradation and nutrient availability during composting. These correlations highlight key physicochemical dependencies that should be considered when mixing feedstocks. For example, the high EC and low moisture of wheat straw can be effectively balanced by the low EC and high moisture of cattle manure, promoting a more stable composting environment. The correlation analysis confirms that key composting parameters, such as bulk density, moisture, and organic matter are interlinked. High organic matter content tends to reduce both bulk density and moisture, which may impact on aeration and microbial dynamics. These interrelationships should be considered when designing composting formulations for optimal physical balance and microbial activity.

CONCLUSIONS

The findings of this study confirm that local organic waste (cattle manure and wheat straw) are complementary organic substrates suitable for composting under the semi-arid climatic conditions of Uzbekistan. Cattle manure exhibited a relatively high nitrogen content (2.3%) and moderate levels of phosphorus (0.22%) and potassium (0.52%), indicating its role as a significant nutrient source. Wheat straw in contrast was characterized by a high carbon concentration and low nitrogen content, resulting in an initial C/N ratio of 122. When co-composted in appropriate proportions, these materials can be adjusted to an optimal initial C/N ratio of approximately 25–30, which is conducive to enhanced microbial activity, efficient organic matter degradation, and compost stabilization. The synergistic physicochemical characteristics of these feedstocks not only promote nutrient enrichment but also improve aeration, thereby enhancing the overall quality of the compost. The results indicate that these agricultural residues can serve as promising raw materials for compost production. Their complementary nutrient composition and structural synergy underline their potential as reliable raw materials for composting in the regions with comparable agroecological conditions.

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