DMU

Advanced Journal of Interdisciplinary Studies 8(2024) 1313-1327

Journal homepage: www.ajids.com.et

AJIDS

Volume 8(2), Dec 2024

Physicochemical properties of feedstocks from municipal solid waste: Bases to design sustainable municipal waste management option

Zewdu Abebe*

Department of Chemistry, Debre Markos University, P.O.Box 269, Debre Markos, Ethiopia

*Corresponding author email: zewdutessfaw@gmail.com/ zewdu_abebe@dmu.edu.et

Abstract

This study was conducted to evaluate the physicochemical properties of khat straw, dry grass clippings and leaves, coffee grounds, cabbage, avocado, and banana peels collected from municipal solid waste in Jimma town to reveal the variability in moisture content, pH, electrical conductivity, total organic carbon, organic matter, nitrogen, phosphorus, potassium, calcium, magnesium, and heavy metals. The contents of various parameters in the feedstocks were determined by the Kjeldahl method, electro-analytical method, UV-visible spectroscopy and atomic absorption spectroscopy. The result showed that moisture content varied significantly across feedstocks, with cabbage exhibiting the highest (90.7%) and khat straw the lowest (14.1%). The pH values ranged (5.75 to 7.23) indicate suitability for microbial activity, while electrical conductivity levels (0.42 to 3.83 dmS/m) were below the threshold for agricultural use (4.0 dmS/m). The organic matter ranged (63.1% to 97.7%) of feedstocks suggested their nutrient-rich properties. But, the ranges of phosphorous (122 to 360 mg/kg), nitrogen (0.80 to 2.06%) and potassium (263 to 917 mg/kg) indicated that there is wide range of variations among the feedstocks. Essential nutrients such as phosphorus and potassium were most abundant in cabbage, and nitrogen in coffee ground highlighting the potentials in composting applications. Heavy metal concentrations (0.07 to 8.57 mg/kg) remain within permissible limits, making these feedstocks suitable for agricultural use. Overall, these findings emphasize the potential for effective waste management strategies through composting and biochar production in Jimma town.

Keywords*: Feedstocks, Jimma, municipal solid waste, physicochemical properties*

1. Introduction

Effective management of municipal solid waste (MSW) remains a significant challenge, particularly in developing countries (Marshall and Farahbakhsh, 2013; Lohri et al., 2017). Rapid urbanization, population growth, and changing consumption patterns have exacerbated the issue. Globally, cities generated 1.3 billion tons of solid waste in 2012, a figure projected to rise to 2.2 billion tons by 2025 and 3.4 billion tons by 2050 due to continued urbanization and population growth (Bhada-Tata, 2012; Ouda, 2014).

Ethiopia, Africa's second-most populous nation, faces similar challenges in managing its municipal solid waste (MSW) due to a growing urban population and increasing waste generation rates. Studies estimate that urban residents produce approximately 0.38 kilograms of waste per person per day, predominantly organic materials such as food scraps, paper, and plant matter (Fikreyesus, 2011; Regassa et al., 2011). In 2016, the country generated about 6.5 million tons of MSW annually, and projections suggest this figure could reach 10 million tons per year by 2030 (Traide, 2021; CIA, 2016).

Despite the significant volume of waste generated, Ethiopia's waste management infrastructure remains underdeveloped. Only 43% of this total waste is collected and disposed of in landfills, while the rest is often dumped in open areas leading to its accumulation in streets, waterways, open spaces, and irregular landfills (Fikreyesus, 2011). These unmanaged biowastes pose serious public health and environmental risks, including odor pollution, attraction of pests, and the production of leachates that contaminate water resources (Riuji et al., 2017). Traditional disposal methods, such as open dumping and incineration, are not only unsustainable but also contribute to loss of valuable waste resources, which are used for nutrient and energy recoveries (Seadon, 2010; Ali & Elquliti, 2016).

Institutional weaknesses, lack of public awareness, and inadequate funding further hinder effective waste management. Many cities, especially emerging ones, lack formal waste management systems (Res et al., 2006; Kneeland & Knutson, 2012).

The absence of proper waste management practices leads to severe environmental and health consequences. Unmanaged waste accumulates in public spaces, polluting water bodies and air quality. Landfill emissions, particularly methane, contribute to climate change (Alam & Ahmade, 2013). Incineration releases harmful pollutants into the air and water (Ouda, 2014). Additionally, unmanaged waste serves as a breeding ground for disease-carrying organisms, posing significant public health risks (Warith, 2003; Selin, 2013).

In Jimma town, located in southwestern Ethiopia, the rapid increase in waste generation has been noted, with studies indicated a production rate of about 88,000 kg daily, approximately 0.55 kg per capita per day (Getahun et al., 2012).

The enclosing municipal solid waste feedstocks with systems such as agriculture use and energy are a sustainable approach of waste management. To develop effective and sustainable waste management strategies, a thorough understanding of the physicochemical properties of municipal solid waste (MSW) feedstocks is essential. The quality of feedstocks used for soil applications is influenced by several key parameters, including pH, electrical conductivity (EC), total organic carbon (TOC), total organic matter (TOM), total nitrogen (N), phosphorus (P), potassium (K), the carbon-to-nitrogen (C/N) ratio, moisture content, and cation exchange capacity (CEC) ((Adeolu et al., 2011). These characteristics can vary greatly depending on the source and type of feedstocks (Getahun et al., 2012; El-Salam & Abu-Zuid, 2015). But, recent data on the physicochemical properties of different municipal feedstocks specifically in Jimma city is lacking. Thus, this study aimed to evaluate the physicochemical properties and trace metal levels (Fe, Cu, Mn, Zn, Pb, Cd and Cr) of khat straw, dry grass clippings and leaves, coffee grounds, cabbage, avocado, and banana peels collected from municipal solid waste in Jimma town to reveal the suitability for composting and biochar production. The feedstocks in this study were selected based on their availability in municipal solid wastes from Jimma town, as illustrated in Figure 1.

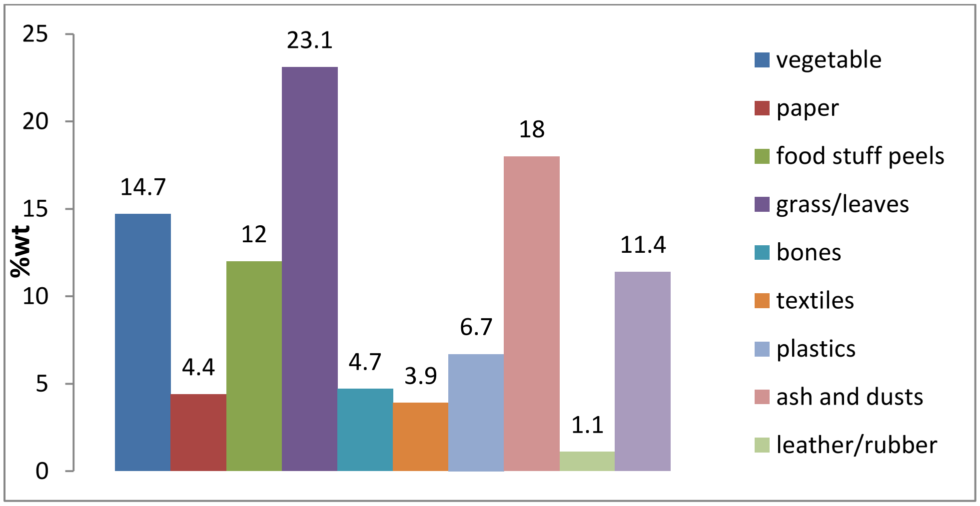

Figure 1. Compositions of solid waste of Jimma town percent by dry weight (%wt) (Getahun et al., 2012)

2. Methods and Materials

2.1. Description of the Study Area

The study was conducted at Jimma Town due to its diverse organic waste streams from households, markets, and public spaces. Jimma, the capital city of Jimma zone, is located about 346 km South West of Addis Ababa. Jimma, which has been founded in the late 1830s, is one of the biggest and dominant political, economic, cultural and historical towns in the southwestern part of the country. It has an altitude of 1780 m above sea level, latitude and longitude of 7°40′N 36°50′E (Fig.2). Temperatures at Jimma are in a comfortable range, with the daily mean staying between 20 °C and 25 °C year-round. As of 2023, Jimma's population is estimated to be around 263,709, reflecting substantial growth from previous years (Wikipedia, 2023).

Jimma was the gateway to an area of Ethiopia that was covered with a thick layer of forest which is sparsely populated, full of mountains, rivers, waterfalls and Black and White Colobus Monkeys. It was these forests that were home to the original strains of the Coffee tree. But much of this forest is now clear as settlers and more recently investors have been buying up large part of the forest was cut down (Hundera et al., 2017). But still much remains of the Ethiopian forest, with a variety of trees is found in this area.

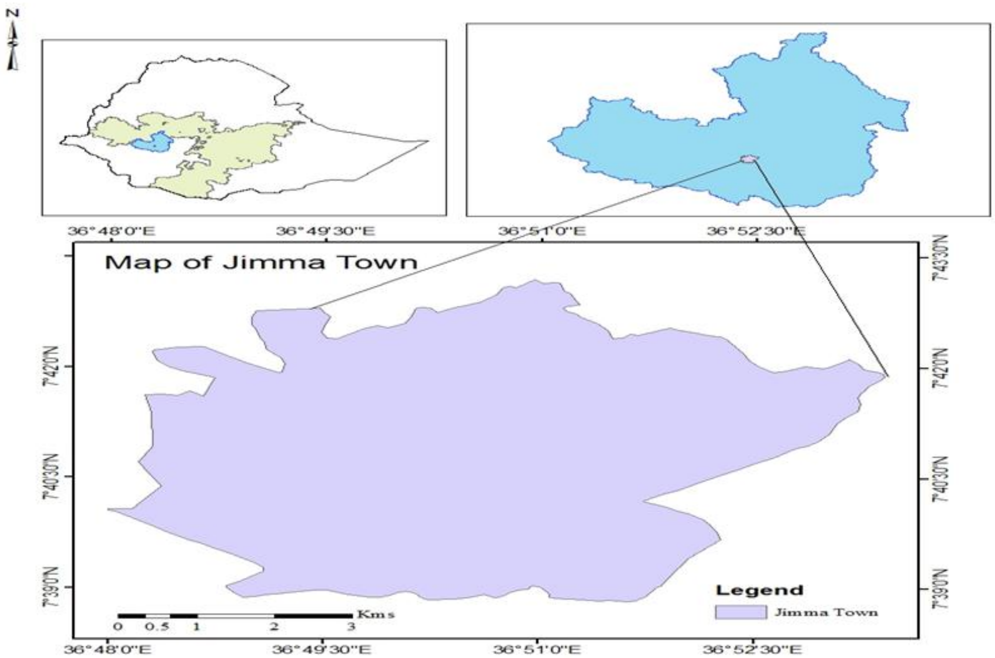

Figure 2. Map of the study area

2.2. Feedstocks Collection

Representative sampling sites were identified across residential, market, and institutional areas to capture a wide variety of organic waste feedstocks. Organic waste types, including coffee grounds, banana peels, avocado peels, cabbage leaves, khat straw, and dry grass clippings and leave, were collected in sufficient quantities from each site. Over the course of one week, waste was gathered in sealed bags from each of the selected sites.

2.3.Chemicals and apparatuses

The chemicals used

Reagent grade concentrated nitric acid (65% HNO_3), Perchloric acid (70% $HClO_4$), Potassium dichromate ($K_2Cr_2O_7$). Concentrated sulfuric acid (98% H_2SO_4), Sodium hydroxide (NaOH), Boric acid (H_3BO_3), Mixed indicator (e.g., bromocresol green and methyl red), Standard Hydrochloric acid (37% HCl) were used for the experiments in the study.

The apparatuses used

The lists of apparatuses used were: Sieve, Drying oven, Analytical balance (Citizen CX 220, with ±0.0001g), Grinder, Potentiometric pH meter (Systronics 361), Conductivity meter (Systronics 306), Muffle furnace (LABTHERM MF-12), Kjeldahl apparatus, UV-Vis spectrophotometer (Systronics Double Beam 2203), and Atomic absorption spectrophotometer (AAS) (NOVA 400P model).

2.4.Physicochemical analytical methods for feedstocks

Each of 500 g composite samples of the collected waste feedstocks were air-dried, ground, and sieved through a 2 mm mesh before undergoing standard laboratory analysis for chemical properties. Moisture content was determined by drying a 2 g sample at 105 °C in an oven, while organic matter content was measured by mass loss at 550 °C in a furnace until reaching a constant weight (Miyazawa et al., 2000). The pH was recorded with a potentiometric pH meter using a 1:5 ratio of feedstock to distilled water (Qian et al., 2014), and electrical conductivity (EC, mS/dm) was measured with a conductivity meter (Jackson, 1973).

Total nitrogen was quantified through the Kjeldahl method, and organic carbon (OC) was determined using the Walkley and Black titration, which relies on the oxidation of biomass with potassium dichromate ($K_2Cr_2O_7$) and sulfuric acid, followed by back-titration with ferrous ammonium sulfate (Batjes, 1996). Potassium (K), calcium (Ca), and magnesium (Mg) were measured using atomic absorption spectroscopy (AAS) after ammonium acetate extraction (Anderson and Ingram, 1993), and cation exchange capacity (CEC) was analyzed via the ammonium acetate method (Sumner and Miller, 1996). Heavy metals (Fe, Mn, Cu, Zn, Cd, Cr, Pb) were also quantified through atomic absorption spectroscopy using a NOVA 400P AAS model, following HNO_3 and $HClO_4$ digestion of the samples (Jackson, 1973). Phosphorus content was estimated using the chlorostannous-reduced phosphomolybdate blue color method with spectrophotometric analysis at 690 nm (Jackson, 1973).

2.5. Statistical Analysis

Data analysis was conducted using Excel and IBM SPSS Statistics 24 software. A one-way ANOVA was employed to determine significant differences at a 5% significance level (Steel, 1980) among the mean values of various parameters in the organic municipal solid waste feedstocks.

3. Results and Discussion

The physical and chemical properties of municipal solid waste (MSW) feedstocks collected in Jimma town were analyzed in this study, including khat straw, dry grass clippings, leaves, cabbage, avocado peels, banana peels, and coffee grounds. The parameters presented were moisture content, pH, electrical conductivity, total organic carbon, organic matter, nitrogen content, C/N ratio, phosphorus, potassium, calcium, magnesium, and heavy metals. The mean values (X) along with the standard deviation (ST) from triplicate measurements are summarized in Tables (1–3) and Figure (3).

3.1. The Physicochemical Properties of Wastes in Jimma Town

Moisture Content

Fig.3 presents the moisture content (%) of different municipal waste feedstocks gathered from Jimma town, including cabbage, banana peel, khat straw, coffee grounds, dry grass clippings and leaves, and avocado peels. Cabbage has the highest moisture content at 90.7%, followed by banana peels at 85.1% and avocado peels at 75.2%. In contrast, dry grass clippings and leaves, along with khat straw, have significantly lower moisture levels, at 15.1% and 14.1%, respectively, making them the driest among the feedstocks. The results showed that there is a significance variation in moisture contents among the feedstocks.

This variation aligns with the natural moisture properties of these materials, as yard waste like dry grass and khat straw tends to lose moisture before collection. The high moisture content recorded in cabbage waste was consistent with findings by Haque et al. (2016), which is ranged between 90-93%.

Moisture content is a vital factor in selecting appropriate waste management and treatment methods. High-moisture feedstocks like cabbage, banana, coffee grounds, and avocado are well-suited for biological treatments such as composting and anaerobic digestion. Their high moisture content creates an ideal environment for microbial activity, accelerating the breakdown process. In contrast, low-moisture feedstocks, such as khat straw and dry grass clippings, are more suitable for thermal treatments, which require less energy for drying (Xiao et al., 2017). For composting, an optimal moisture range of 40-70% is ideal, while feedstocks intended for biochar production should have moisture levels below 30% to reduce the energy needed for drying (Xiao et al., 2017). The combination of low-moisture and high-moisture feedstocks facilitated the attainment of optimal moisture conditions within the compost pile.

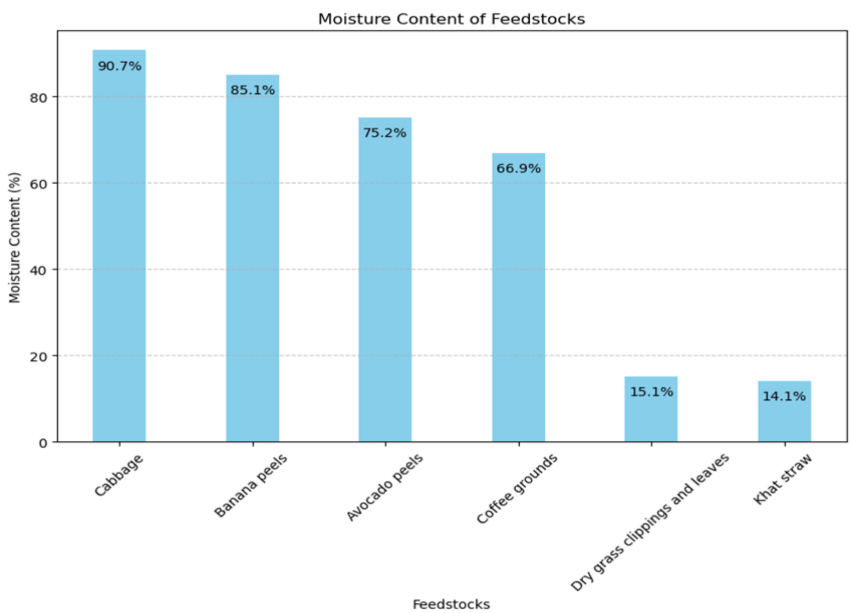

Figure 2. The moisture contents of municipal waste feedstocks collected from Jimma town.

pH

Table 1 summarizes the physicochemical properties of feedstocks understudied which were collected from Jimma town's municipal solid waste. The pH values ranged from weakly acidic (5.75 ± 0.03) for cabbage to slightly basic (7.23 ± 0.01) for dry grass and leaves. Most other feedstocks, including banana peels, khat straw, coffee grounds, and avocado peels, fall within a slightly acidic range (5.75-6.16). ANOVA confirmed significant variation ($p < 0.05$) among the feedstocks.

Recent studies have provided updated pH values for various organic waste materials. Cabbage waste has been found to be mildly acidic, with pH values generally ranging from 5.5 to 6.5, aligning with the value of 5.75 observed in this study (Meena et al., 2021). Banana peels typically have a pH range between 5.8 and 6.5, placing them in the slightly acidic category, consistent with the observed pH of 6.12 (Sharma et al., 2020). Coffee grounds are slightly acidic to neutral, often in the range of 5.5 to 6.5; the observed pH of 6.16 falls within this typical range (Vargas et al., 2022). Dry grass clippings and leaves have a weakly acidic to slightly alkaline pH, often between 6.5 and 7.5, which is in line with the observed pH of 7.23 (Singh & Kumar, 2021).

pH influences the decomposition of organic materials. The pH range of 5.8 to 7.3 suggests that these feedstocks can support microbial activity beneficial for composting (Kumar et al., 2020). Therefore, incorporating these materials into compost piles can contribute to a balanced pH environment, promoting efficient composting and resulting in high-quality compost (Ghosh et al., 2023).

Electrical Conductivity (EC)

EC values, which indicate the feedstocks' salt content, vary significantly. Banana peels had the highest EC at 3.83 mS/dm, followed by cabbage (3.17 mS/dm) and avocado (2.32 mS/dm. Coffee grounds and dry grass clippings had the lowest EC values, suggesting further potential as soil amendments. EC values were within acceptable limits (<4 dS/m), indicating low salinity levels and suitability for agricultural applications (Richards, 1954). EC values varied significantly among the feedstocks ($p < 0.05$), with coffee grounds having the lowest EC (0.42 ± 0.01 mS/dm) and banana peels the highest (3.83 ± 0.06 mS/dm). Low EC values in coffee grounds make them favorable for soil amendment due to minimal salinity-related phytotoxic effects.

Many authors reported that EC values for banana peels typically range from 2.5 to 4.0 mS/dm, which corresponds well with the observed EC of 3.83 mS/dm (Meena et al., 2021). Coffee grounds generally exhibited low EC values, often between 0.3 and 1.0 mS/dm, reflecting their low salt content. The observed EC of 0.42 mS/dm matches these authors' values (Vargas et al., 2022). The EC values of grass clippings and dry leaves ranged from 0.5 to 1.2 mS/dm (Heckman & Kluchinski, 1996), which is consistent with the measured EC of 0.77 mS/dm.

Total Organic Carbon (TOC) and Organic Matter (OM)

Organic matter (OM) levels were higher across all samples, reflecting their organic-rich nature. Coffee grounds contained the highest OM at 97.7%, followed by khat straw and cabbage with OM levels above 90%. Banana peels had the lowest OM at 63.1%, still indicating a substantial amount of organic material. Total organic carbon (TOC) also measures the carbon available in the organic matter of the feedstocks. Coffee grounds had the highest TOC at 52.76%, suggesting a substantial amount of carbon content, while banana peels had the lowest TOC at 34.08%. The TOC values of other feedstocks, such as cabbage, khat straw, dry grass clippings, and avocado peels, were ranged from 45% - 49%.

High TOC and OM levels across the feedstocks have reflected their nutrient-rich composition, with coffee grounds showed the highest OM (97.7%) and TOC (52.8%). This nutrient profile suggests that these wastes are suitable for composting which aligned with findings from other regions (Silva et al., 2018; Pujol et al., 2013).

Cabbage waste contains high organic matter, usually around 85–95%, consistent with the observed value of 90.7% in this study (Haque et al., 2016). Grass clippings and dry leaves generally contained high organic matter, typically ranging between 75–90% (Heckman & Kluchinski, 1996). The observed OM value of 85.2% aligns with these values. Banana peels typically have organic matter contents ranging from 55–70%, which corresponds to the observed value of 63.1% (Meena et al., 2021). Coffee grounds are known for their high organic matter content, often above 90%, consistent with the measured 97.7% OM in this study (Campos-Vega et al., 2015).

Generally, the feedstocks showed that diverse physicochemical characteristics, which can influence their decomposition rate, suitability for composting, and potential for soil amendment. Feedstocks with high OM and moderate C/N ratios, such as coffee grounds and cabbage, are especially suitable for composting. The varying EC levels also imply that some feedstocks may require blending to optimize salt content in compost, particularly in high-EC materials like banana and cabbage.

Table 1. The physicochemical characteristics of feedstocks collected from Jimma town municipal solid waste.

sample	pH	EC (mS/dm)	TOC (%)	OM (%)	C/N ratio g/g
Cabbage	5.75±0.03	3.17±0.04	49.01±0.51	90.7±0.96	30.44±0.45
Banana	6.12±0.01	3.83±0.06	34.08±0.18	63.1±0.34	42.80±3.73
Khat straw	6.02±0.01	2.03±0.02	49.05±0.59	90.8±1.09	33.95±1.39
Coffee ground	6.16±0.04	0.42±0.01	52.76±0.06	97.7±0.11	25.82±0.46
Dry grass clippings & leaves	7.23±0.01	0.77±0.05	45.99±1.17	85.2±2.18	35.12±2.86
Avocado	6.15±0.08	2.32±0.06	47.60±1.91	88.1±3.54	27.89±1.74
P-value	0.002	0.004	0.00046	0.00048	0.0069

All P-values are much smaller than the typical significance level (α=0.05).

Table 2 shows the macronutrient availability in various feedstocks from Jimma town's municipal solid waste, measuring nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). These nutrients are crucial for plant growth, and their concentrations indicate the fertilizing potential of each feedstock for organic fertilizer applications.

Nitrogen Content

The nitrogen content across municipal organic waste feedstocks varied significantly ($p < 0.05$), ranging from 0.8% to 2.06% (Table 2). Coffee grounds exhibited the highest nitrogen level at 2.06%, followed by avocado peels (1.70%), cabbage (1.61%), khat straw (1.45%), dry grass clippings and leaves (1.31%), and banana peels (0.8%). The nitrogen concentration in coffee grounds aligns with results reported by Silva et al. (2018), though it is lower than values observed by Ballesteros et al. (2014). Nitrogen is a critical nutrient for plant growth, directly impacting the value of these organic materials as fertilizers. Feedstocks such as coffee grounds and avocado peels with high nitrogen content are particularly valuable for composting, where they can act as a nitrogen source to balance carbon-rich materials.

Phosphorus and Potassium Levels

Available phosphorus (P) and potassium (K) concentrations in the feedstocks also showed significant variation ($p < 0.05$). Phosphorus ranged from 122.33 to 360.33 mg/kg, and potassium ranged from 263.18 to 917.09 mg/kg. Cabbage exhibited the highest levels of both P (360.33 mg/kg) and K (917.09 mg/kg), while coffee grounds recorded the lowest concentrations (122.33 mg/kg for P and 263.18 mg/kg for K). Notably, the phosphorus content in coffee grounds was lower than reported by Ballesteros et al. (2014). Conversely, the phosphorus and potassium levels in cabbage, though elevated, were slightly below those reported by Weber (2016). These results underscore the potential of cabbage waste as a significant source of P and K, which are essential for root development and overall plant health.

Calcium and Magnesium Content

Calcium (Ca) and magnesium (Mg) concentrations ranged from 1.50 to 9.22 g/kg and 0.41 to 2.70 g/kg, respectively. Dry grass clippings and leaves contained the highest levels of Ca (9.22 g/kg) and Mg (2.70 g/kg), whereas avocado waste exhibited the lowest concentrations. The calcium content in banana peels (3.40 g/kg) was lower than values reported by Meena et al., (2021). These variations in Ca and Mg among feedstocks highlight the importance of identifying specific waste materials that contribute to the overall nutrient balance in compost formulations. High Ca and Mg levels in dry grass clippings make them suitable for improving soil structure and buffering soil pH.

Nutrient Variability

The observed differences in nutrient concentrations, including nitrogen, phosphorus, potassium, calcium, and magnesium, can be attributed to factors such as plant species, growth stage, and environmental conditions like soil type and climate (Brady & Weil, 2017). Coffee grounds, for example, were particularly rich in nitrogen and magnesium but moderate in phosphorus and potassium. In contrast, cabbage waste was notably high in phosphorus and potassium, while dry grass clippings excelled in calcium and magnesium content.

This variability in nutrient profiles suggests that feedstocks can be strategically combined to create nutrient-rich compost blends. For instance, mixing high-nitrogen materials like coffee grounds with carbon-dense feedstocks or calcium-rich dry grass clippings can result in a balanced and effective organic amendment. Such tailored compost formulations can address diverse plant nutrient requirements, contributing to sustainable waste management and nutrient recycling in urban settings.

Table 2. Plant nutrient availability of feedstocks collected from Jimma municipal solid waste.

Sample	N	P	K	Ca	Mg
	%	mg/kg	mg/kg	g/kg	g/kg
Cabbage	1.61±0.02	360.33±3.02	917.09±6.82	5.39±0.02	1.45±0.02
Banana peels	0.80±0.03	132.67±0.63	461.37±1.39	3.40±0.05	0.91±0.03
Khat straw	1.45±0.04	264.0±4.06	764.39±0.54	5.73±0.01	2.00±0.01
Coffee ground	2.06±0.02	122.33±1.15	263.18±1.35	5.57±0.04	2.22±0.01
Dry grass clippings and leave	1.31±0.04	260.67±0.92	425.81±4.36	9.22±0.08	2.70±0.06
Avocado peels	1.70±0.02	182.33±0.79	413.76±0.39	1.50±0.01	0.41±0.01
P-value	0.0021	0.003	0.0005	0.0013	0.007

Trace metal concentration

The trace metal concentrations found in the municipal solid waste (MSW) feedstocks of Jimma town were summarized in Table 3. The elements measured include iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), chromium (Cr), lead (Pb), and cadmium (Cd), with concentrations reported in parts per million (ppm). All traces metal exhibit significant differences across feedstocks as indicated by P-values < 0.05.

Among the samples, banana peels and dry grass clippings showed the highest levels of iron (Fe), whereas coffee grounds and cabbage contained relatively lower Fe concentrations. The Fe level in bananas was below what was reported by Meena et al. (2021), and the Fe concentration in coffee grounds was considerably lower than the values reported by Silva et al. (2018). Copper (Cu) levels were generally low across all samples, indicating minimal toxicity risk. However, the Cu concentration in cabbage exceeded that reported by Carla Asquer (2013) but was below the value reported by Weber (2016).

Dry grass clippings had significantly elevated manganese (Mn) levels compared to other feedstocks. However, the Mn content in dry grass and leaves was much lower than the levels found in prior studies by Heckman and Kluchinski (1996). Mn levels in banana peels were lower than reported by Meena et al. (2021) but higher than reported by Carla Asquer (2013). Zinc (Zn) concentrations were moderate across the samples, with dry grass clippings showing the highest levels. Nonetheless, the Zn concentration in dry grass and leaves was below that reported by Heckman and Kluchinski (1996).

Cabbage and dry grass clippings exhibited the highest chromium (Cr) levels, with Cr concentrations in cabbage exceeding those reported by Carla Asquer (2013). Lead (Pb) levels were highest in cabbage and avocado peels, with the Pb concentration in cabbage also surpassing that reported by Carla Asquer (2013).

Coffee ground, low in metals like iron, copper, zinc, lead, and cadmium, is a promising soil amendment. This is likely due to metal removal during the brewing process. In contrast, other materials like cabbage, avocado peels, and dry grass clippings have higher metal concentrations, including toxic elements like lead and cadmium.

To ensure sustainable waste management and the production of safe, nutrient-rich compost and organic amendments, it's essential to understand the trace metal profiles of different feedstocks. While elements like iron, manganese, copper, zinc, and chromium are vital micronutrients for plant growth, lead and cadmium are toxic even in small amounts. By analyzing the metal content of various feedstocks, compost formulations can be optimized to minimize risks and maximize agricultural and environmental benefits. According to the U.S. Environmental Protection Agency (EPA), the maximum allowable concentrations (mg/kg) of trace metals in compost or biosolids designated for land application are 2,800 for zinc (Zn), 1,500 for copper (Cu), 3.0 for cadmium (Cd), and 300 for lead (Pb) (US EPA, 1994). However, chromium (Cr), iron (Fe), and manganese (Mn) do not have specific regulatory limits for compost. The trace metal concentrations in the analyzed feedstocks were found to comply with the limits set by the U.S. EPA (1994).

Table 3. Trace metal contents of feedstocks collected from Jimma town municipal solid waste.

Sample	Fe	Cu	Mn	Zn	Cr	Pb	Cd
	mg/kg						
Cabbage	0.82±0.00	0.22±0.04	0.15±0.00	0.26±0.00	2.04±0.15	4.09±0.44	1.23±0.14
Banana peel	6.10±0.02	0.10±0.00	2.35±0.03	0.37±0.01	1.17±0.20	1.25±0.11	0.68±0.05
Khat straw	1.22±0.02	0.14±0.00	0.39±0.00	0.27±0.01	1.90±0.16	3.30±0.44	1.43±0.13
Coffee ground	0.73±0.00	0.07±0.00	0.19±0.00	0.15±0.00	0.43±0.05	1.08±0.12	0.35±0.04
Dry grass clipping and leaves	5.89±0.01	0.11±0.00	8.57±0.07	1.12±0.03	1.97±0.08	2.99±0.19	1.36±0.10
Avocado peel	1.05±0.03	0.14±0.01	0.67±0.01	0.29±0.00	1.99±0.12	3.28±0.43	1.50±0.07
P-value	0.000034	0.0018	0.0044	0.0017	0.0035	0.00056	0.024

4. Conclusion

The study of municipal waste feedstocks from Jimma town revealed significant variation in physicochemical properties, including moisture content, pH, electrical conductivity (EC), organic matter (OM), total organic carbon (TOC), and macronutrient levels. High-moisture feedstocks such as cabbage, banana peels, and avocado are well-suited for biological treatments like composting, while low-moisture materials like khat straw and dry grass clippings are better for thermal treatments. Feedstocks with high OM and moderate C/N ratios, particularly coffee grounds and cabbage, were identified as ideal for composting, providing a balanced nutrient profile. EC values remained within acceptable limits for agricultural use. The diverse nutrient profiles of these wastes suggest their potential as nutrient-rich amendments for soil applications.

The results showed significant differences in nitrogen, phosphorus, potassium, calcium, and magnesium content across feedstocks, highlighting their complementary roles in compost formulation. Coffee grounds, rich in nitrogen and magnesium, are valuable for balancing carbon-rich materials, while cabbage and dry grass clippings contribute high levels of phosphorus, potassium, and calcium. Trace metal concentrations, though variable, remained within safe limits for agricultural applications, with minimal risk of toxicity. These findings underscore the potential for strategic blending of feedstocks to create effective organic fertilizers, advancing sustainable waste management and nutrient recycling practices in urban settings like Jimma town.

Author contribution statement

Zewdu Abebe: Conceived and designed the research; performed the experiments; analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors wish to thank Debre Markos soil laboratory and Amhara Design and Supervision Work Enterprise Laboratory Services for providing support to conduct the laboratory determination.

5. References

Adeolu, A. T., Ada, O. B., & Kabir, A. (2011). Assessment of physicochemical properties of compost materials in Nigeria. Journal of Environmental Science and Technology, 4(5), 478-482.

Alam, M. S., & Ahmade, K. (2013). Solid Waste Management Challenges and Opportunities in Developing Countries. International Journal of Environmental Science and Technology, 10(3), 599-614.

Ali, A. A., & Elquliti, A. S. (2016). Solid Waste Management Challenges in Developing Countries: A Review. Waste Management & Research, 34(1), 1-18.

Anderson, J. M., & Ingram, J. S. I. (1993). Tropical Soil Biology and Fertility. CAB International.

Ballesteros, I., Alburquerque, J. A., & Martín, A. (2014). Coffee grounds as a potential organic fertilizer: A review. Waste Management, 34(1), 1-11.

Batjes, N. H. (1996). Total carbon and nitrogen in soils of the world. European Journal of Soil Science, 47(2), 151-163.

Bhada-Tata, P. (2012). What a Waste: The World's Growing Trash Problem. Worldwatch Institute.

Brady, N. C., & Weil, R. R. (2017). The nature and properties of soils (15th ed.). Pearson Education.

Campos-Vega, R., Sánchez-Machado, D. I., & López-Cervantes, J. (2015). Coffee grounds: A valuable byproduct with potential applications. Food Research International, 77, 198-206.

CIA. (2016). The world factbook: Waste and recycling. Retrieved from https://www.cia.gov/the-world-factbook/field/waste-and-recycling/

El-Salam, M. M. A., & Abu-Zuid, G. I. (2015). Impact of landfill leachate on the groundwater quality: A case study in Egypt. Journal of Advanced Research, 6(4), 579–586.

Fikreyesus, D. (2011). Solid Waste Management in Addis Ababa: Challenges and Opportunities. Journal of Environmental Science and Technology, 4(1), 10-24.

Getahun, T., Mengistie, E., Haddis, A., Wasie, F., Alemayehu, E., & Woldie, A. (2012). Municipal solid waste generation in growing urban areas in Africa: Current practices and challenges. Journal of Solid Waste Technology and Management, 38(2), 111–125.

Ghosh, D., Mandal, P., & Dey, S. (2023). Role of organic waste in improving compost quality: A review. Waste Management & Research, 41(3), 289-301.

Gupta, S., & Garg, S. K. (2008). Biodegradation of cabbage waste: A review. Bioresource Technology, 99(14), 6339-6348.

Haque, M. M., Islam, M. S., Parvin, M., & Rahman, M. M. (2016). Physicochemical characterization of cabbage waste for potential biogas production. Journal of Environmental Science and Technology, 9(2), 246-252.

Heckman, J. R., & Kluchinski, J. L. (1996). Nutrient content of grass clippings and leaves. HortTechnology, 6(1), 70-73.

Hundera, K., Zebene, A., & Bekele, T. (2017). Impacts of resettlement programs on deforestation of moist evergreen Afromontane forests in southwest Ethiopia. Mountain Research and Development, 37(4), 394–404.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice-Hall, Englewood Cliffs, NJ.

Kneeland, T. A., & Knutson, C. L. (2012). Solid Waste Management in Developing Countries: A Review. Waste Management & Research, 30(1), 1-16.

Kumar, S., Gupta, A., & Singh, R. (2020). Composting dynamics and nutrient transformation of organic feedstocks: A review. Waste Management & Research, 38(7), 647–664.

Lohri, A., Kumar, S., & Singh, R. (2017). Solid Waste Management Practices in Developing Countries: A Review. Waste Management & Research, 35(1), 1-19.

Marshall, S., & Farahbakhsh, K. (2013). Urban Solid Waste Management in Developing Countries: A Review. Waste Management & Research, 31(1), 1-17.

Meena, M., Babu, S., & Sahu, A. (2021). Physicochemical characterization and composting of vegetable waste: A case study of cabbage. Environmental Science and Pollution Research, 28(22), 28994-29002.

Miyazawa, K., Yagi, K., & Shimada, Y. (2000). Characterization of municipal solid waste in Japan and its potential as a resource. Waste Management & Research, 18(3), 235-245.

Mussatto, S. I., Martins, S., & Roberto, I. C. (2011). Coffee grounds as a substrate for ethanol production by yeast fermentation. Bioresource Technology, 102(1), 143-147.

Ouda, O. A. (2014). Solid Waste Management Challenges in Developing Countries: A Case Study of Nairobi City, Kenya. Journal of Environmental Protection, 5(11), 1272-1282.

Pujol, R., Rovira, L., & Solsona, J. A. (2013). Influence of different organic waste mixtures on compost quality and its potential use as a soil amendment. Waste Management, 33(10), 2208-2217.

Qian, Y., Luo, Y., Li, Y., & Liu, X. (2014). Effects of different organic waste mixtures on compost quality and its potential use as a soil amendment. Waste Management, 34(10), 2208-2217.

Regassa, A., Ayenew, T., & Ayenew, B. (2011). Characterization of Municipal Solid Waste in Bahir Dar Town, Ethiopia. Journal of Environmental Protection, 2(10), 1035-1041.

Res, M. T., van Berkel, R., & Van Grieken, R. (2006). Urban Solid Waste Management in Developing Countries: A Review. Waste Management & Research, 24(1), 1-11.

Richards, L.A. (Ed.). (1954). Diagnosis and Improvement of Saline and Alkali Soils. U.S. Department of Agriculture Handbook No. 60. Washington, D.C.: United States Department of Agriculture.

Riuji, H., Nakamura, T., & Yoshida, H. (2017). Health and environmental risks of landfill leachate: A review of the potential impacts. Journal of Environmental Science and Technology, 50(4), 456-468.

Seadon, M. (2010). Solid Waste Management in Developing Countries: A Review. Waste Management & Research, 28(1), 20-32.

Selin, H. E. (2013). Global Environmental Health. Oxford University Press.

Sharma, S., Kumar, S., & Jain, V. (2020). Banana peel waste as a resource for composting: Nutrient dynamics and microbial activity. Journal of Environmental Science and Health, Part A, 55(4), 478-485.

Silva, E. F., Silva, F. A., & Silva, R. R. (2018). Physicochemical characterization of coffee grounds and its potential use as soil amendment. Journal of Environmental Science and Technology, 11(2), 182-191.

Silva, J. A., Freitas, R. A., & Duarte, I. P. (2018). Chemical and mineral composition of coffee ground residues. Waste and Biomass Valorization, 9(4), 705-711.

Singh, P., & Kumar, V. (2021). Organic waste composting: A sustainable approach for agricultural soil health. Science of the Total Environment, 763, 142874.

Steel, R. G. D. (1980). Principles and Procedures of Statistics: A Biometrical Approach. McGraw-Hill.

Sumner, M. E., & Miller, W. P. (1996). Cation exchange capacity and exchange coefficients. In Methods of Soil Analysis, Part 3: Chemical Methods (pp. 1201-1222). Soil Science Society of America.

Traide. (2021). Waste economy factsheet. Retrieved from https://traide.org/wp-content/uploads/Waste-Economy-Factsheet-TRAIDE-foundation.pdf

U.S. Environmental Protection Agency. (1994). A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule. Washington, DC: U.S. EPA Office of Wastewater Management. EPA/832-B-93-005. Retrieved from https://www.epa.gov/biosolids

Vargas, M. L., Alvarado, M., & Gutiérrez, J. (2022). Coffee ground waste and its contribution to composting and organic fertilization. Waste and Biomass Valorization, 13(6), 3051-3062.

Warith, M. A. (2003). Solid Waste Management Challenges in Developing Countries. Waste Management & Research, 21(1), 1-12.

Weber, J. (2016). Heavy metal concentrations in organic wastes and composts. Waste Management, 57, 1-14.

Wikipedia. (2023). Jimma. Retrieved from https://en.wikipedia.org/wiki/Jimma

Xiao, Y., Ma, L., & Li, Y. (2017). Biochar production from agricultural residues: A review. Bioresource Technology, 224, 187-198.