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Evaluating Organic Fertilizer Production Potential from MBG Waste in School Environmental Management

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ABSTRACT

The Free Nutritious Meal Program (Program Makan Bergizi Gratis/MBG) is a government effort to improve students' nutrition in schools. While the program helps students eat better, it also generates organic waste every day, including food scraps and kitchen leftovers. If not managed, this waste can harm the environment. This study examines how MBG waste can be converted into compost, an environmentally friendly fertilizer. The research took place from June to October 2025 in three public junior high schools in Surakarta City, Central Java, Indonesia, involving 540 students from grades 7 to 9. The study focused on food leftovers from MBG meals and included waste sampling, sorting, composting, and lab analysis. Results showed that most of the waste came from carbohydrates such as rice and pasta (about 35–50%), followed by vegetables (about 14–25%). On average, each student produced 115.78 grams of food waste per day, which could add up to about 1,169.8 tons of food waste daily from junior high school students across Indonesia. The compost made from MBG leftovers had 1.19% N, 2.42% P_2O_5, and 0.24% K_2O, meeting SNI 7763:2024 standards. It has high organic matter content, neutral pH, and adequate availability of micronutrients. In terms of safety, the microbiological contamination test results indicated excellent quality. Both *Escherichia coli* and *Salmonella* sp. were detected at levels below 3 MPN/g. These findings show that MBG waste can be turned into organic fertilizer, helping schools manage waste and support sustainable agriculture.

Keywords: composting, environmental management, organic waste, school meal program, sustainable agriculture

INTRODUCTION

School meal programs, such as the Free Nutritious Meal Program (Program Makan Bergizi Gratis/MBG), are government efforts to improve students' nutrition. These programs are known to help children eat better, do well in school, and support food security (Nida & Sari 2023). In Indonesia, MBG is part of a national policy to reduce malnutrition and help students stay healthy and focused during the school day (Pemerintah Republik Indonesia 2024).

Although the nutritional benefits of these programs are well known (Chakraborty & Jayaraman 2019), the organic waste they generate, such as leftover rice, meat, vegetables, and fruit, has not been studied as extensively in Indonesia. If this waste is not managed, it leads to the loss of nutrients and resources and can also cause greenhouse gas emissions, bad smells, and hygiene problems in schools (Blondin *et al.* 2023). Research shows that food waste in school canteens affects not only nutrition and costs but also operational and sustainability challenges when it is simply thrown away (Abreu *et al.* 2025; Sundin *et al.* 2024).

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Food waste can be valuable if used for composting. Composting turns waste into a useful soil amendment and aligns with circular economy principles (Almaramah *et al.* 2024). Schools are good places to teach and practice better waste habits, helping students learn about the environment (Wardani *et al.* 2025). Studies show that composting school meal leftovers can reduce waste, recycle nutrients, and improve soil health (Jara-Samaniego *et al.* 2017; Almaramah *et al.* 2024). Composting in schools also helps students learn about sustainability and environmentally responsible consumption (Brighenti *et al.* 2018). Sorting food waste, making compost, and using it in school gardens can give students hands-on experience and encourage better habits (Deksne *et al.* 2025).

There are not many studies that examine how much waste school meal programs generate, how composting could work, and how it can be used in schools, especially in Indonesia. This study sees MBG waste as a resource that can be turned into organic fertilizer and help improve school waste management. Composting food waste needs careful process control and attention to quality (Gu *et al.* 2025). The goal of this research is to determine whether MBG waste can be used to produce compost in schools and to measure the amount of waste produced. Since MBG is a new program in Indonesia, there is little information about the food waste it creates. This study gives new data on

MBG food waste and how it could help improve the program. The findings can help inform recommendations for better, more sustainable food waste management.

METHODS

The research took place in three public junior high schools in Surakarta City, Central Java: SMP Negeri 14, SMP Negeri 24, and SMP Negeri 25. The study ran from June to October 2025 and included 540 students from classes 7A to 9C. These schools were chosen because they take part in the MBG program. The focus was on leftover food from students' MBG meals. Data was collected during two observation periods in 18 classes. The method for choosing schools follows common practices in school food waste research (Shanks *et al.* 2017; Chu *et al.* 2023).

This study used a quantitative approach, including field observations, waste measurements, composting experiments, and compost analysis. After lunch, organic waste from 540 students was collected, hand-sorted, and divided into main categories. Each type of waste was weighed with digital scales accurate to 0.01 kg. The total weight and the share of each category were calculated. The proportions of each waste type were determined, and the data were analyzed using descriptive statistics and multivariate analysis. Principal Component Analysis (PCA) was done using MetaboAnalyst 6.0.

After sorting, the waste was used for composting. The experiment used simple 50-liter bins with an aerobic system. The mix included MBG organic waste, EM4 (Effective Microorganisms) at 10 mL per kilogram of waste, molasses diluted 1:20, and rice husk charcoal, making up about 30% of the total volume. The compost was turned every seven days to provide oxygen and help it break down evenly. The process lasted 30 days. Aerobic composting was chosen because it is simple, needs little equipment, and is easier to manage than other methods (Papargyropoulou *et al.* 2014; Vairagade & Vairagade 2019).

At the end of the composting period, the compost product was analyzed in the laboratory. Compost quality analysis was conducted to evaluate the compost's physical and chemical properties, nutrient content, and environmental and microbiological safety. The basic physical and chemical parameters analyzed included water content, pH, organic carbon (C-organic), and C/N ratio. Water content and pH were determined in accordance with SNI 7763:2024 (Badan Standardisasi Nasional (BSN) 2024), clauses 6.3 and 6.6, respectively. The C-organic content was analyzed by gravimetry, and the C/N ratio was calculated from the organic carbon and total nitrogen contents. Total nitrogen was analyzed according to SNI 7763:2024 clause 6.5.1, while phosphorus (P_2O_5) and potassium (K_2O) contents were analyzed following SNI 7763:2024 clause 6.8. Micronutrient analysis included iron (Fe), manganese (Mn), zinc (Zn), boron (B), cobalt (Co), and molybdenum (Mo) as part of the evaluation of nutrient quality and possible environmental impacts. Fe and Zn content were analyzed based on SNI 7763:2018, Mn using the AOAC 972.02 method, and boron was analyzed spectrophotometrically, while Co and Mo were analyzed following laboratory procedures PO/LAB-PK/06. The results of this analysis were used to assess nutrient availability and ensure that nutrient content remained within safe limits for the environment. Microbiological contamination testing was carried out to ensure environmental and health safety, including analysis for *Escherichia coli* and *Salmonella* sp. The analysis was conducted in accordance with SNI 7763:2018 using the Most Probable Number (MPN) method. All test results were used to assess the compost's suitability for organic fertilizer quality standards, environmental safety, and suitability for sustainable agricultural applications.

RESULTS AND DISCUSSION

Characterization of Waste Types and Quantifications

The results showed that the MBG program generated significant food waste across all grades. This waste consisted of leftover food on students' trays, as shown in Figure 1. All grades and food types produced waste. The main categories were carbohydrates (like rice and pasta), protein (from animal sources), vegetables, side dishes, and fruit. Figure 2 shows this classification.

Observations from both sampling sessions showed that staple foods such as rice and pasta were the main sources of food waste across all classes, accounting for about 35–50% of the total (Figure 3). In the first session, rice leftovers ranged from 26.56 to 73.44 grams per student, with an average of 50.76 grams. In the second session, pasta leftovers ranged from 13.33 to 98.44 grams per student, with an average of 48.10 grams (Table 1). This shows that students often do not finish the staple foods served to them.

Vegetables were the second-largest source of waste, accounting for about 14–25% (Figure 3), followed by fruits, which also had a high level of waste. In the first sampling, vegetable leftovers ranged from 15.63 to 35 grams per student, with an average of 25.60 grams. In the second sampling, carrots and corn leftovers ranged from 17.50 to 25 grams per student, with an average of 22.11 grams. Cabbage, carrots, corn, and stir-fried vegetables were often left uneaten, showing that students do not prefer vegetables. This could be due to taste, texture, or the way the vegetables are served. Leverenz et al. (2019) found that vegetable waste made up 22–26% in a German study. Fruit waste, such as melon, watermelon,

Figure 1 Provision and distribution of MBG food in schools that produces organic waste after consumption.

Figure 2 Type of food waste.

banana, and orange, showed that the fruit was not always eaten completely. This aligns with other research showing that fruits and vegetables are among the most wasted foods (Svartebekk *et al.* 2025). Observations suggest fruit waste may be due to piece size, freshness, or limited time to eat at school.

Protein waste was lower than in other groups. Animal protein waste usually came from inedible parts, such as bones, or from foods with less appealing textures. Side dishes like tempe and meatballs had less waste than carbohydrate and vegetable-based dishes, indicating that students ate more of these protein-rich foods. Tempe, a plant-based protein, had waste levels of about 5–14% (Figure 3). The lower waste from protein and side dishes suggests students liked them or the portions were right. Children often prefer meatballs and meat because they taste savory, are easy to chew, and have a familiar look and smell. The fat and protein in these foods also make them more appealing (Tultabayeva *et al.* 2023). Eating habits at home and initial exposure also make children prefer processed meats over plant-based foods. This supports the idea that familiarity with taste and appearance shapes what children like to eat (Xu & Zeng 2022).

In total, food waste per class ranged from 60.63 to 137.93 grams in the first sampling and from 95.00 to 168.75 grams in the second sampling. On average, each student produced 115.78 grams of food waste per day (Table 1). This pattern aligns with findings from other studies, with carbohydrates and proteins comprising most of the waste (Petchoo *et al.* 2022; Blondin *et al.* 2023). The large amount of rice and chicken waste suggests that changes like adjusting portion sizes, using “offer vs serve” models, or improving menu choices could help reduce waste (Blondin *et al.* 2023). According to the Central Statistics Agency (BPS) (2025), there were 10,103,503 junior high school students in Indonesia in 2024/2025. If each student produces 115.78 grams of waste per day, that amounts to about 1,169.8 tons per day. This estimate assumes that all junior high students in Indonesia

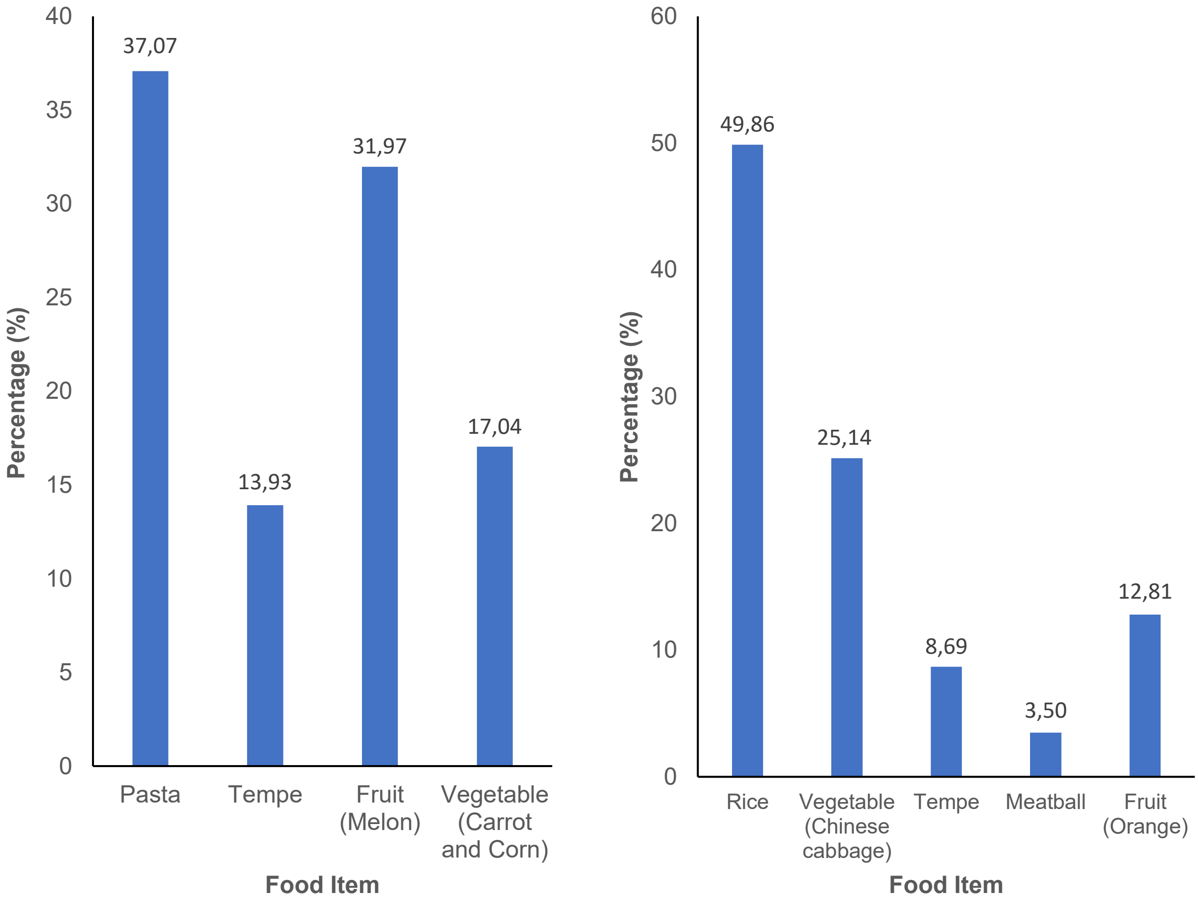


Figure 3 Proportion of food waste (1st sampling (A) and 2nd sampling (B)).

Table 1 The quantity of waste produced by students in grades 7–9 (gr)

Food Item	Grade and class									Average
	7A	7B	7C	8B	8C	8D	9A	9B	9C	
	1st Sampling									
Rice	70.69	73.44	26.56	42.86	58.33	48.28	50	28.33	58.33	50.76
Vegetable (chinese cabbage)	34.48	29.69	15.63	21.43	23.33	25.86	20	25	35	25.6
Tempe	12.07	12.5	9.38	5.36	3.33	10.34	11.67	6.67	8.33	8.85
Meatball	8.62	7.81	1.25	1.43	1.33	6.9	1.33	0	3.33	3.56
Fruit (orange)	12.07	12.5	7.81	17.86	21.67	13.79	6.67	10	15	13.04
Total	137.93	135.94	60.63	88.93	108	105.17	89.67	70	120	101.81
	2nd Sampling									
Pasta	37.93	57.81	98.44	61.61	13.33	62.07	45	18.33	38.33	48.1
Tempe	16.38	20.31	18.75	12.5	20	15.52	17.5	21.67	20	18.07
Fruit (melon)	39.66	50	32.81	30.36	45	42.24	30	33.33	70	41.49
Vegetable (carrot and corn)	20.69	26.56	18.75	19.64	25	24.14	17.5	21.67	25	22.11
Total	114.66	154.69	168.75	124.11	103.33	143.97	110	95	153.33	129.76
Average Per Student										115.784

Note: All data shown are averages calculated on a per-student basis.

receive the MBG program and excludes other education levels.

Identification of Waste-Generating Behaviors throughout Grades

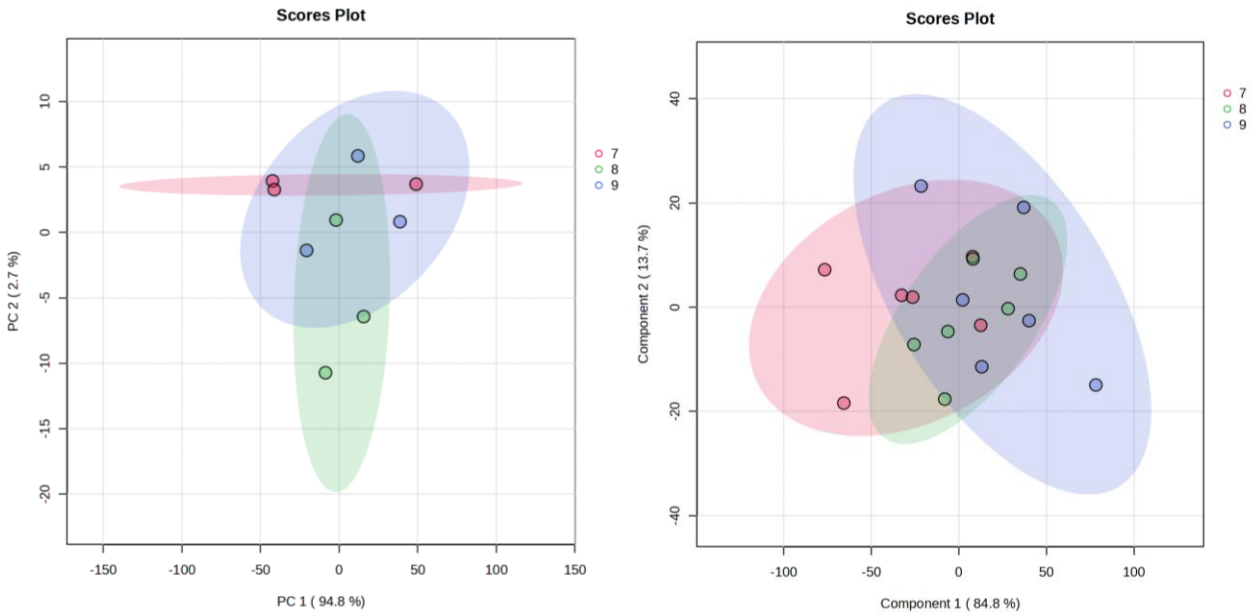
To determine the effect of different grades and portions on total waste generation, a detailed data quantification was performed. The data were analyzed using a multivariate approach (Principal Component Analysis (PCA)) to discover patterns and clusters, enabling an objective explanation of the basis for cluster formation. The quantification of waste indicated a relatively consistent volume across observation days and grades.

Principal Component Analysis (PCA) was conducted separately on two sampling activities to evaluate the consistency of food waste formation patterns among students in grades 7, 8, and 9 (Figure 4). In the first PCA, PC1 explained 94.8% of the data variation and PC2 2.27%, indicating that the data variation was highly dominated by one principal component. Meanwhile, in the second PCA, PC1 explained 84.8% of the total variation, and PC2 13.7%. The dominance of PC1 in both PCAs indicated that the main factors driving food waste were relatively consistent across the two sampling activities.

Similar patterns were visible in both PCAs, with cluster separation along the PC1/Component 1 axis, where grades 7, 8, and 9 show similar distributional tendencies. Grade 7 tended to form a more compact cluster, while grades 8 and 9 exhibited a wider distribution. Overlap between clusters remains in both PCAs, suggesting that some food waste generation behavior was general rather than completely differentiated by grade level.

The differences in patterns between the two PCAs were primarily reflected in the contribution of PC2 (Component 2). The PC2 contribution was relatively small in the first PCA (2.27%), while in the second PCA, its contribution increased significantly (13.7%). This suggested that in the second sampling event, variations in secondary factors, such as menu differences, environmental conditions, or sampling time, played a greater role in differentiating food waste generation behavior throughout grades. However, the similar dominance of PC1 across both PCAs confirmed that the primary structure of the food waste pattern remained stable and consistent across sampling events.

The absence of distinct group differentiation suggested that variation in waste volume among the three grade levels was minimal. The factors influencing waste production were relatively consistent across the three grade levels. This result implies that the daily meal portions, student consumption behavior, and food waste patterns within the Free Nutritious Meal Program (MBG) were comparable among grades 7, 8, and 9. This data indicated that the waste generation rate was uniform across all class levels (Figure 4). This condition is thought to be related to the age range of students in grades 7-9 who are still in the early adolescent phase, so that their preferences for taste and food texture are relatively uniform. Briawan et al. (2023) report that food preferences among Indonesian adolescents are primarily determined by taste, familiarity, and social influence and tend to stay consistent across adolescent age groups. Although food preferences may vary with age, these differences are generally small among adolescents (Cooke & Wardle 2005). Special attention is still needed, given that adolescents are a nutritionally



(A) (B)

Figure 4 Principal component analysis (PCA) from food waste from 7th, 8th, and 9th grade (1st sampling (A) and 2nd sampling (B)).

vulnerable age group and that the quality of their diet plays an important role in determining their nutritional status and long-term health (Wardani *et al.* 2023).

Composting Process and Evaluation of Compost Quality

The composting process in Figure 5 showed the stages of change in organic waste from MBG, from the initial phase to the end of composting. The beginning process was still dominated by fresh pieces. The next step occurs when the raw material enters the active decomposition phase, signaled by the appearance of microbial or fungal colonies. Fungi have an important role in the composting process, especially in the thermophilic phase (Zhu *et al.* 2024). The final phase, which presented a darker, crumbly material, reflected the stabilization of the organic matter. Rice-husk charcoal was used as a bulking agent for aeration and moisture control. This pattern corresponds to the general concept of composting: organic matter undergoes degradation by microorganisms until its structure becomes finer and more homogeneous, ultimately reaching a stable/mature state ready for application to the soil. In the context of the MBG, the high volume and diversity of food waste were common in institutional school meal services. The maturity of compost from MBG waste can be assessed using commonly used stability and maturity indicators, including physical properties. After 30 days, the compost from MBG was characterized by a temperature returning to ambient temperature (Aguilar-Paredes *et al.* 2023) (indicating decreased biodegradation activity) and a change in physical properties to blackish brown, odorless, and crumbly (Figure 5). In this study, the compost yield was approximately 20–30% of the initial food waste weight. This reduction is likely due to the decomposition of organic matter and water loss during the aerobic composting process (Bernal *et al.* 2009).

In addition to these general indicators, the final quality of compost must also be verified against national standards. Based on the laboratory analysis (Table 2), the tested compost exhibited physical, chemical, and microbiological characteristics that meet the criteria for good quality under SNI 7763:2024 for solid organic fertilizers. In terms of basic physical and chemical properties, the compost's moisture content of 21.10% was within the acceptable range, below the maximum limit of 50%. This moisture content allows for optimal aeration and microbial processes when applied to soil. The organic carbon (C-organic) content reached 27.74%, which was well above the SNI minimum standard of 15%. This indicated a high level of organic matter that can improve soil structure, enhance cation exchange capacity (CEC), and support beneficial soil microbial populations. The C/N ratio of 23.39 remains within an acceptable range, although SNI ideally recommends 10–20. This ratio indicates that the decomposition process is still ongoing but has reached a sufficiently stable phase that poses no significant risk of nitrogen immobilization for plants (Srivastava *et al.* 2016). The pH of 7.67 indicates the compost is considered neutral to slightly alkaline, suitable for most crops, particularly horticultural and food plants that thrive in near-neutral conditions for optimal nutrient absorption.

Regarding macronutrients, the results showed that the compost contained nitrogen (N) at 1.19%, phosphorus (P_2O_5) at 2.42%, and potassium oxide (K_2O) at 0.24% (Table 2). According to SNI 7763:2024, the nitrogen content exceeded the minimum requirement of 0.4%, while phosphorus and potassium were also within acceptable ranges. The relatively high nitrogen increases vegetative tissue formation, while phosphorus content contributes to improving root development and flowering. Although the potassium level was moderate, it is still essential for strengthening plant stems and improving crop quality (Ma *et al.* 2022). The combination of N, P, and K indicates that this compost can serve as a balanced natural nutrient source supporting sustainable agricultural systems.

The micronutrient content of the compost also showed promise in supporting plant growth. The total iron (Fe) concentration of 1480 mg/kg, manganese (Mn) at 95.60 mg/kg, and zinc (Zn) at 167 mg/kg (Table 2) reflected the presence of essential micronutrients in sufficient quantities to sustain plant physiological processes (Ho *et al.* 2022). The boron (B) concentration of 0.02% was within a safe range and plays a vital role in cell wall formation and reproductive growth. Meanwhile, cobalt (Co) and molybdenum (Mo) levels were below the detection limit (<0.01 mg/kg and <0.02 mg/kg, respectively). This phenomenon is a common condition in natural organic materials that are not supplemented with inorganic minerals and thus is not a major concern for compost effectiveness from an agronomic perspective.

In terms of safety, the microbiological contamination test results indicated excellent quality. Both *Escherichia coli* and *Salmonella* sp. were detected at levels below 3 MPN/g, far below the maximum permissible limits established by SNI 7763:2024 (Table 2). Eliminating pathogens is an important challenge in the composting process (Rawat & Johri 2013). *Salmonella* and *Escherichia coli* can appear and spread if organic materials are used in a raw state or have not been properly composted, and if the composting process is not managed optimally (Erickson *et al.* 2010). This confirmed that the compost is safe for use, suitable for food and horticultural crops, and environmentally friendly. This implies that it does not contain pathogenic microorganisms that cause health risks to humans or animals.

Overall, the tested compost can be classified as a high-quality solid organic fertilizer based on SNI 7763:2024 parameters. Its high organic matter content, neutral pH, near-ideal C/N ratio, and adequate availability of macro- and micronutrients demonstrate that the compost functions not only as a valuable plant nutrient source but also as an effective soil conditioner that improves soil fertility and biological activity (Sokač *et al.* 2022). Combined with its excellent microbiological safety, this compost is highly recommended for use in environmentally friendly agricultural systems, both conventional and organic. This compost from MBG can be part of current efforts to advance sustainable agriculture and a circular bioeconomy by utilizing organic waste.

The compost analysis confirmed that school-meal program waste is a viable feedstock for producing nutrient-rich organic fertilizer through simple aerobic composting methods. Food waste can be a nutrient-rich material for compost (Wang *et al.* 2015). A composting program can be an option for MBG's food waste management. Apart from technical feasibility, the wider environmental and educational implications are considerable. This waste management option is consistent with SDG 12 and SDG 13 and supports SDG 2 by closing nutrient loops and enhancing fertility in school gardens (Rizzo *et al.* 2025).

However, there are still some practical challenges. Scaling up composting requires sufficient space, regular supervision, training for staff and students, ongoing support after pilot projects, and tracking of long-term results and costs. Emphasize that tracking long-term results helps identify what works and informs continuous improvements. Future research could involve students more in composting as part of environmental education. The compost made could be used in school gardens, helping reduce waste and promote recycling and sustainability. It is also important to study how composting fits into daily school routines and how it can work in different types of schools. The large amount of food waste indicates that MBG programs should focus not only on calories but also on healthier eating habits, such as adjusting portion sizes

Figure 5 Composting process.

Table 2 Results of Compost Analysis

Parameter	Unit	Test Result	Method
Basic Physical & Chemical Properties:			
Moisture Content	%	21.1	SNI 7763:2024 clause 6.3
Organic Carbon (C-Organic)	%	27.74	Gravimetry
C/N Ratio	-	23.39	Calculation
pH	-	7.67	SNI 7763:2024 clause 6.6
Micronutrients:			
Total Fe *	mg/kg	1480	SNI 7763:2018
Manganese (Mn) *	mg/kg	95.6	AOAC 972.02
Zinc (Zn) *	mg/kg	167	SNI 7763:2018
Boron (B)	%	0.02	Spectrophotometry
Cobalt (Co) *	mg/kg	<0.01	PO/LAB-PK/06
Molybdenum (Mo) *	mg/kg	<0.02	PO/LAB-PK/06
Macronutrients:			
Nitrogen	%	1.19	SNI 7763:2024 clause 6.5.1
Phosphorus (P_2O_5)	%	2.42	SNI 7763:2024 clause 6.8
Potassium Oxide (K_2O)	%	0.24	SNI 7763:2024 clause 6.8
Microbiological Contamination:			
Escherichia coli	MPN/g	<3	SNI 7763:2018
Salmonella sp.	MPN/g	<3	SNI 7763:2018

and making meals more appealing. Improvements could include better menus, the right portion sizes, tastier food, a good dining environment, and nutrition education to help students eat more and waste less.

CONCLUSION

The Free Nutritious Meal Program (MBG) in schools generates significant food waste, presenting an opportunity for sustainable management through composting. The waste primarily consists of carbohydrates (about 35–50%) and vegetables (about 14–25%), highlighting the need to address vegetable waste. Each junior high school student produces about 115.78 grams of food waste daily. The compost made from MBG leftovers had 1.19% N, 2.42% P_2O_5, and 0.24% K_2O, meeting SNI 7763:2024 standards. It has high organic matter content, neutral pH, and adequate availability of micronutrients. In terms of safety, the microbiological contamination test results indicated excellent quality. Both *Escherichia coli* and *Salmonella* sp. were detected at levels below 3 MPN/g. This compost from MBG can be part of current efforts to advance school environmental management and sustainable agriculture.

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