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Food Waste in the Implementation of the Free Nutritious Meals (MBG) Program: From Nutrition to Emissions and Management Strategies

Priyaji Agung Pambudi[1]✉, Savina Nurma Fardiani[2]

[1]Environmental Sciency Program, Graduate School, Universitas Gadjah Mada

[2]Independent Research, Yogyakarta

Keywords

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Abstract

The MBG program has reached 58.1 million beneficiaries, however, it also generates environmental impacts in the form of food waste. This study examinated food waste generation and management practices through a conceptual approach, field observations, and interviews with SPPG. The estimated food waste generated by the MBG program reaches 1.1-1.4 million tons per year at both SPPG and schools, with most waste remaining unmanaged and relying solely on landfill disposal. Open dumping landfills pose a significant risk of methane (CH_4) emissions. Existing food waste management practices in the MBG program are estimated to produce annual emissions of approximately 47,600 metric tons of CH_4 and 1,173.2 billion tons of CO_2e, thereby incresing the burden on national emissions reduction targets. Emission prevention and environmental impact mitigation can be achieved through waste management infrastructure at SPPG or colectivelly at district and municipal levels. Ideal management practices include biocomposting (fertilizer production), biodigester (bioenergy production), and maggot cultivation (animal protein production). Through these approaches, the MBG program not only provides nutrition but also transforms waste into fertilizer, bioenergy, and protein, supporting low-carbon developmen initiativest.

INTRODUCTION

The Indonesian Government has designated the Free Nutritious Meals (MBG) Program as one of its national priority programs for the 2024–2029 period (National Nutrition Agency, 2025). The program was introduced to address stunting and improve students' nutrition, thereby enhancing their concentration and academic performance (Qomarrullah et al., 2025). To achieve these objectives, the government distributes millions of meal portions to students every day (Indahri et al., 2024). According to a press release issued by the National Nutrition Agency on January 20, 2026, the MBG Program had reached approximately 59.86 million beneficiaries and was implemented through 21,102 Nutrition Service and Fulfillment Units (Satuan Pelayanan dan Pemenuhan Gizi, SPPG). Although the MBG Program serves an important role in improving children's nutrition, its unintended environmental consequences also warrant attention. One notable concern is the generation of food waste resulting from school meal provision. Feng et al. (2024) reported that school feeding programs have the potential to generate substantial amounts of food waste. Similarly, a study by Adjapong et al. (2024), which evaluated school lunch programs across 134 schools in the United States, found that each student generated an average of 154.22 g of food waste and 104.32 mL of beverage waste.

To date, no official report or peer-reviewed publication has quantified the amount of food waste generated by the MBG Program in Indonesia. Although several recent publications have highlighted the potential for food waste within the program, quantitative evidence remains

✉ priyajiagungpambudi@ugm.ac.id. Yogyakarta

limited. For example, Santoso & Mulyadi (2025) examined food management practices at SPPG in Batam. However, their study focused exclusively on food preparation mechanisms rather than food waste generation. Based on evidence from institutional feeding programs in other countries, as discussed in the previous paragraph, such programs have considerable potential to generate food waste and contribute substantially to the accumulation of organic waste at both schools and food service facilities. Given the large scale of the MBG Program and its millions of beneficiaries, the potential generation of millions of tons of food waste annually deserves serious attention because of its significant environmental implications.

This issue is importance because improper food waste management contributes substantially to greenhouse gas emissions, particularly methane (CH_4). Utami & Malihah (2025) reported that food waste mismanagement is a major source of methane emissions, accounting for approximately 26% of total CH_4 emissions. Furthermore, Workie et al. (2023) reported that the decomposition of food waste in landfills generates significant methane emissions, thereby exacerbating environmental pollution at both local and global scales. Similarly, Edjabou & Scheutz (2023) quantified methane emissions from landfills and reported emission factors ranging from 8.0 ± 0.1 to 42.5 ± 1.5 kg CH_4 h^{-1}, with the actual emission rate largely depending on waste management practices. Based on these findings, if food waste generated by the MBG Program accumulates over a single academic year (approximately 260 school days), the resulting annual greenhouse gas emissions could reach tens of thousands of tons of CO_2-equivalent (Co_2e).

Based on a review of the scientific literature, no comprehensive empirical study has yet evaluated the extent to which food waste generated by the MBG Program can be managed efficiently or assessed the environmental benefits of such management practices. Therefore, it is essential to conduct studies that project food waste generation and evaluate waste management systems within the MBG Program to support evidence-based strategies for reducing its environmental burden.

RESEARCH METHOD

This study employed a qualitative approach using a literature review and in-depth interviews with the heads of two SPPG in East Java Province, Indonesia. The primary data sources comprised peer-reviewed journal articles published in national and international journals covering the MBG Program, food waste, food waste management, school feeding programs, the circular economy, and the environmental impacts of food waste. Participants for the in-depth interviews were selected using an accidental sampling technique, and the interviews were conducted in a semi-structured format.

To provide a more in-depth understanding of the issue and capture recent developments, this study also employed content analysis and tabulation analysis of reports from reputable institutions and articles published in popular media as contextual data sources. These methods were specifically used to obtain preliminary quantitative information on the implementation of the MBG Program, estimated food waste generation, and the evolving policies and practices of food waste management in Indonesia. To further understand field conditions and enrich the analysis, the researchers conducted social observations by observing food preparation processes at SPPG and collected primary qualitative data through in-depth interviews with the heads of the selected SPPG facilities.

During the in-depth interview stage, the researchers interviewed the heads of two SPPG directly involved in implementing the MBG Program in East Java Province. The interviews aimed to gain insights into operational challenges, nutritional considerations, and food waste management practices. Semi-structured interviews were conducted using a set of key guiding questions, while follow-up probing questions were employed to obtain more detailed explanations where necessary. The interview explored whether the SPPG had standard operating procedures (SOPs) for menu preparation, meal distribution, and food waste management; how food ingredients were procured and prepared before cooking; how food preparation waste was managed; how daily menus were determined; how meal portions were established, including the use of standardized portion sizes or gram-based guidelines; the frequency of food leftovers in MBG meal containers; the types of food most frequently left uneaten; the methods used to manage leftover food; whether food waste generation was recorded, including its reporting mechanisms and frequency; and whether the National Nutrition Agency (Badan Gizi Nasional, BGN) and/or SPPG partners provided incentives for kitchens that successfully implemented food waste management practices.

Data were analyzed through a process of identification, classification, and thematic synthesis of findings derived from the literature review, policy documents, field observations, and in-depth interviews. Primary data obtained from the interviews were comparatively analyzed alongside findings from previous studies to identify consistencies, discrepancies, and implementation gaps in food waste management within the MBG Program. The synthesized findings were subsequently used to develop a conceptual framework for food waste management in the MBG Program based on environmental sustainability and circular economy principles.

RESULT AND DISCUSSION

Food Waste Generation in the MBG Program

According to the Global Child Nutrition Foundation (2024, p. 95), which assessed school feeding programs across 169 countries, approximately 407.8 million students benefited from school meal programs worldwide. Among the beneficiaries, 13% were from low-income countries, 24% from lower-middle-income countries, 26% from upper-middle-income countries, and 28% from high-income countries. At the time the report was published, Indonesia had not yet implemented the Free Nutritious Meals (MBG) Program and did not have a large-scale institutional school feeding system. This is explicitly stated in the report as follows:

"In the 2024 Global Survey of School Meal Programs, 17 country governments responded to the survey by reporting that they did not have any large-scale school feeding activities in the country. Among these, 13 countries assigned focal points to complete a short form regarding any past or anticipated future activities related to school feeding. These were Albania, Comoros, Denmark, Equatorial Guinea, Indonesia, Kiribati, Libya, Montenegro, Norway, Pakistan, Palestine, Papua New Guinea, and Samoa."

According to Purba and Faisal (2026), the MBG Program is the second-largest institutional feeding program in the world, serving approximately 61 million beneficiaries, surpassed only by India's school feeding program, which reaches around 181 million beneficiaries. The scale of such programs is inherently associated with greater potential environmental impacts, particularly the generation of food waste. This is especially relevant because meals are prepared and distributed through centralized food service facilities. According to the National Nutrition Agency (Badan Gizi Nasional, 2025), each Nutrition Service and Fulfillment Unit (SPPG) is responsible for preparing and distributing approximately 2,500–3,000 meals per day. Given the large number of beneficiaries and the diversity of individual food preferences, the MBG Program has considerable potential to generate substantial amounts of food waste. Evidence from previous studies supporting this concern is summarized in Table 1.

Table 1
Estimated Food Waste Generation from the MBG Program

Estimated Quantity of Food Waste	Data Sources
50-100 grams/student/day	Director of Waste Management, Ministry of Environment
1.1-1.4 million tons/ year nationwide	National Development Planning Agency

Source: Javier (2025), Utami & Malihah (2025), and National Food Agency (2025)

Table 1 indicates that the MBG Program has the potential to generate substantial quantities of food waste at both regional and national scales. According to the Director of Waste Management at the Ministry of Environment, as quoted by Javier (2025) in Tempo.com, food waste generated by the MBG Program is estimated to range from 50 to 100 g per student per day. Similarly, an assessment conducted by the National Development Planning Agency (Bappenas), as cited by the National Food Agency (2025) and Utami and Malihah (2025), estimated that the MBG Program could generate approximately 1.1–1.4 million tons of food waste annually nationwide, equivalent to 72.82–92.68 g per student per day based on 58.1 million beneficiaries. These estimates suggest that while the MBG Program provides substantial nutritional benefits to the population, it may also impose considerable environmental pressures if food waste is not managed effectively and systematically.

The substantial amount of food waste potentially generated by the MBG Program highlights a significant challenge to both food system sustainability and environmental management. As noted by Krause et al. (2023), food waste is a major contributor to greenhouse gas emissions because its decomposition in landfills produces methane (Ch_4). Furthermore, Alexander et al. (2017) argued that high levels of food waste also reflect the inefficient use of valuable resources, including water, energy, and food inputs consumed throughout the production and distribution processes before reaching beneficiaries. In the context of the MBG Program, food waste generation may be influenced by several factors, including mismatches between menu offerings and students' food preferences (Joyce et al., 2020), excessively large portion sizes (Lonska et al., 2025), and limited education on sustainable food consumption (Henriques et al., 2025).

A closer examination suggests that appropriate meal portion sizes are strongly influenced by age, habitual dietary intake, and individual energy requirements as reflected by body mass index (BMI). This finding is supported by Shidik et al. (2025), who reported that the nutritional requirements of school-aged children should ideally be determined based on their energy needs, which are closely associated with BMI and physical activity levels. Therefore, meal portioning should ideally be tailored to each child's BMI and physical activity level rather than standardized across all students, even within the same age group. Such an individualized approach is more likely to accommodate variations in children's nutritional requirements, which are often better understood by their parents or caregivers.

Given the considerable variation in children's BMI and physical activity levels, the standardized meal portions provided under the MBG Program—determined primarily by the allocated budget of IDR 8,000–10,000 per meal, as specified by the National Nutrition Agency (2026)—are unlikely to adequately meet individual nutritional requirements. Aji (2025) argued that a budget ceiling of IDR 10,000 per serving is insufficient to fulfill the nutritional needs of children on an individual basis and suggested that portion sizes should, at a minimum, be differentiated according to age groups. Under such budget constraints, meal portions are unlikely to correspond to children's actual nutritional requirements, particularly because the program adopts standardized portion sizes. Previous studies have consistently identified meal standardization as a major driver of food waste in school feeding programs. Adjapong et al. (2024) reported that standardized menus contribute substantially to food waste because children's food preferences vary considerably, in addition to differences in the amount of food they are able or willing to consume. Similarly, Truong et al. (2025) found that standardized portion sizes fail to account for variations in individual energy requirements, resulting in many children being unable to consume an entire MBG meal. This finding is consistent with the study by Fauziyah et al. (2026), which documented that differences in students' food preferences at SDN Makam Haji 04 Sukoharjo resulted in substantial plate waste. Likewise, Habib et al. (2025), in their evaluation of the MBG Program at a school in Bandar Lampung, emphasized the need to optimize menu planning because students' acceptance of certain menu items remained relatively low.

The in-depth interviews revealed that meal portioning and menu selection are the two primary factors contributing to food waste in the MBG Program. Food waste is generated not only from plate waste at the consumption stage but also from meals that remain undistributed because of logistical and distribution constraints. In some cases, meals have even been returned by schools after being deemed unfit for consumption due to spoilage. Such incidents have been documented in several regions of Indonesia. Junaedi and Ihsanuddin (2026) reported that, on 31 January 2026, an elementary school in Polewali Mandar, West Sulawesi, rejected MBG meals because they had spoiled and were considered unsafe for consumption. A similar case was reported by Rosalina (2026) in Jombang, where a school returned MBG meals to the SPPG after determining that the side dish had spoiled, thereby preventing potential adverse health consequences. These cases demonstrate that food waste in the MBG Program is multidimensional and can occur throughout the food supply chain, from menu planning and meal preparation to distribution and final consumption. This finding is consistent with the perspective expressed by one of the SPPG heads interviewed in this study: *"We do not differentiate the menus served; the only distinction lies in portion size and caloric content according to students' age groups. Children attending Posyandu, preschool (PAUD), kindergarten (TK), and Grades 1–3 of elementary school receive the smaller meal package (IDR 8,000), whereas students in Grades 4–6 of elementary school, junior high school, and senior high school receive the larger meal package (IDR 10,000). We follow the guidelines established by the National Nutrition Agency (BGN). If the Agency issues specific directives in the future regarding adjustments to meal portions for different beneficiary age groups, we will implement them accordingly."*

These findings suggest that, from a sustainability perspective, the substantial potential for food waste generation within the MBG Program requires an approach that goes beyond conventional waste management practices. Without an integrated strategy for food waste prevention and management, the program's success in improving nutritional outcomes may be offset by increased environmental pressures, particularly those related to organic waste management and greenhouse gas emissions.

Food Waste Management Practices in the MBG Program

Based on field observations and the literature review, food waste management practices within the MBG Program vary considerably across regions. To date, food waste generated by the program is generally not managed by SPPG kitchens. Instead, most food waste is collected and transported to landfills for final disposal. This prevailing practice reflects a conventional end-of-pipe approach that focuses primarily on waste disposal rather

Table 2
Observation and In-Depth Interview Findings on Food Waste Management in the MBG Program

Location	Waste Management Practices	SPPG Justification
East Java 1	Food waste was collected in waste bins and removed by municipal sanitation workers. Occasionally, some vegetable waste was taken by SPPG staff for use as livestock feed.	Food waste was collected in waste bins and removed by municipal sanitation workers. Occasionally, some vegetable waste was taken by SPPG staff for use as livestock feed.
East Java 2	Unused vegetable residues were taken home by some SPPG staff to be used as livestock feed, while the remaining food waste was collected and removed by municipal sanitation workers.	Unused vegetable residues were taken home by some SPPG staff to be used as livestock feed, while the remaining food waste was collected and removed by municipal sanitation workers.

Source: Processed Primary Data, 2026

than on waste prevention, reduction, or resource recovery. Similar conditions were observed at the study sites, as reflected in the interview excerpts presented in Table 2.

As shown in Table 2, neither of the two study sites had implemented dedicated or systematic food waste management practices for the MBG Program. Existing practices remained largely business as usual, with food waste handled through routine disposal methods rather than through structured waste reduction or recovery initiatives. According to the interview participants, this situation was primarily attributable to the absence of official guidelines issued by the National Nutrition Agency (BGN) regarding food waste management at SPPG facilities. This finding was further emphasized by one of the SPPG heads interviewed in this study: "*From my perspective as the person responsible for managing the SPPG, food waste management is not a mandatory responsibility as long as the National Nutrition Agency (BGN) has not issued any regulations requiring kitchens to manage food waste. Our primary obligations are to provide nutritious meals, ensure food safety, and distribute the meals to schools. Food waste generated after distribution is, in principle, the responsibility of the beneficiaries rather than the kitchen. If responsibility for post-consumption food waste were assigned back to the SPPG, it would not be appropriate, as effective food waste management requires additional funding, personnel, and time.*"

The statement made by the SPPG head reflects a practical and operationally grounded perspective, highlighting the need for clear policies and standard operating procedures (SOPs) governing food waste management within the MBG Program. If the government intends to integrate food waste management into SPPG operations, dedicated personnel with appropriate technical expertise will be required to manage food waste effectively and professionally. Although field observations at the study sites did not identify any structured food waste management practices, the researchers identified several examples of good practices implemented in other regions of Indonesia. The findings from the content analysis of these documented practices are summarized in Table 3.

As shown in Table 3, food waste management initiatives within the MBG Program have begun to emerge in several regions of Indonesia, although examples of good practice remain limited. Afrianti et al. (2025) and Rahmiani et al. (2025) reported the implementation of biopore technology in schools as an effective strategy for mitigating food waste generation. This approach not only reduces the volume of organic food waste

Table 3
Good Practices of Food Waste Management in the MBG Program

Practice	Implementation Outcomes
Biopore Technology in Schools	The implementation of biopore systems significantly reduced the volume of organic waste generated by the MBG Program. The resulting compost was utilized to fertilize school gardens and public green spaces.
Environmentally Responsible Human Resource (HR) Management	Recruiting environmentally conscious personnel, providing environmental awareness training, and implementing environmental reward systems fostered more efficient w ork practices, reduced waste generation, and supported the provision of nutritionally balanced meals.
Biopore Technology in Schools	Students' knowledge increased significantly, as indicated by the Wilcoxon test (p = 0.011). Students were able to independently apply biopore techniques, and compost was successfully harvested after one month.
Food ingredient managemen in SPPG.	Practices included separating chillers for vegetables and meat, maximizing the utilization of all edible parts of food ingredients, adjusting meal production to the number of beneficiaries, and converting organic waste into compost and livestock feed. These practices were found to be effective in reducing food waste generation.

Source: Afrianti et al. (2025), Aspani & Faeni (2025), Rahmiani et al. (2025), and Santoso & Mulyadi (2025)

but also serves as an educational tool to enhance students' environmental awareness. These initiatives are consistent with the source-based waste management approach described by Sugiartha et al. (2023), which emphasizes that organic waste is most effectively managed at its point of generation. In addition, Santoso and Mulyadi (2025) demonstrated that improved food ingredient management at SPPG kitchens can reduce food waste through production planning measures, including adjusting meal preparation to the number of beneficiaries and maximizing the utilization of food ingredients. Together, these findings indicate that effective food waste management in the MBG Program requires coordinated efforts across the entire food supply chain, involving both upstream stakeholders (SPPG kitchens) and downstream stakeholders (meal beneficiaries).

The four examples of good practice presented in Table 3 demonstrate that food waste generated by the MBG Program can be effectively managed through a range of practical and sustainable approaches. This conclusion is supported by Aspani and Faeni (2025), who found that environmental awareness training, incentive mechanisms, and a supportive organizational culture play critical roles in ensuring the consistent implementation of environmentally responsible practices. This perspective is consistent with institutional theory, as described by Ngo (2023), which posits that organizational practices are more likely to achieve long-term sustainability when they are supported by well-established norms, formal regulations, and clear institutional structures.

Greenhouse Gas (GHG) Emission Potential from Food Waste Generated by the MBG Program

As discussed in the previous section, the objectives of the MBG Program should be accompanied by a strong commitment to environmental management to mitigate the potential greenhouse gas (GHG) emissions associated with food waste. Such a commitment is essential because, from a socio technical systems perspective, Subekti et al. (2022) argued that large-scale social programs may generate significant

Table 4
Matrix of GHG Emission Impacts from Food Waste Generated by the MBG Program

Emission Source	Emission Release Mechanism	Estimated Emissions
CH_4.	Anaerobic decomposition of organic food waste	8.0–42.5 kg CH h ⁻, depending on the waste treatment technology employed.
CH_4 and CO_2	Leakage from landfill waste management systems and landfill gas control systems	2,352.9 tons of CH and 65,888.2 tons of CO e from a single municipal -scale landfill.
CH_4 and CO_2	Fugitive methane emissions from landfilled food waste	For every 1,000 tons (907 metric tons) of food waste disposed of in a landfill, an estimated 34 metric tons of fugitive me thane (838 MMT CO e) are released.

Source: Edjabou & Scheutz (2023), Setiawan et al. (2025), and Krause et al. (2023)

environmental pressures unless they are accompanied by appropriate impact mitigation mechanisms. In the context of the MBG Program, food waste that is managed primarily through landfill disposal may directly contribute to increased methane (CH_4) emissions. This is supported by the findings of Mar et al. (2022), who reported that methane can persist in the atmosphere for an extended period and contributes substantially to climate change, accounting for up to 40% of its impact, with a greater warming effect than carbon dioxide (CO_2). Table 4 presents a matrix summarizing the potential greenhouse gas emission impacts associated with food waste generated by the MBG Program.

As shown in Table 4, food waste has considerable potential to release greenhouse gases (GHGs), particularly methane (CH_4) and carbon dioxide (CO_2), into the atmosphere. The continued accumulation of these gases increases their atmospheric concentrations, thereby intensifying climate change. According to the Intergovernmental Panel on Climate Change (IPCC) (2021), atmospheric CO_2 concentrations reached 410 ppm in 2019, while CH_4 concentrations increased to 1,866 ppb. Compared with pre-industrial levels approximately 800,000 years ago, atmospheric CO_2 concentrations had increased by 47%, whereas CH_4 concentrations had risen by 156%. Furthermore, the IPCC (2023) reported that greenhouse gas emissions continue to increase at an alarming rate, accelerating global warming and resulting in an increase of approximately 1.23°C in the global mean surface temperature over the period 1750–2021. Without substantial emission reductions, global warming is projected to reach 1.5°C by around 2030.

Given the substantial contribution of greenhouse gas (GHG) emissions to climate change and rising global mean surface temperatures, effective mitigation measures are essential to prevent further environmental deterioration. In the context of the MBG Program, the National Development Planning Agency estimated annual food waste generation at 1.1–1.4 million tons, as reported by the National Food Agency (2025) and Utami & Malihah (2025) (Table 1). Applying the emission factors reported by Krause et al. (2023), this amount of food waste could generate an estimated 37,400–47,600 metric tons of CH_4 and 921.8–1,173.2 billion tons of CO_2e. These estimates suggest that, if left unmanaged, food waste generated from the MBG Program could impose a substantial burden on Indonesia's efforts to reduce greenhouse gas emissions in line with the Second Nationally Determined Contribution (SNDC) 2030 and its commitments under the Paris Agreement.

Table 5
Alternative Food Waste Management Practices for MBG

Management Practice	Operating Principle	Operational Workflow	Infrastructure and Human Resource Requirements	Outputs	Added Value and Potential Applications in the MBG Program	Advantages
Bio-composting	Aerobic treatment of organic waste to produce solid compost.	(1) Separate organic waste; (2) Shred the waste; (3) Mix carbon-rich and nitrogen-rich materials; (4) Turn or stir the compost regularly; (5) Monitor temperature and moisture; (6) Harvest compost every 3–4 weeks.	(1) Aerobic composter or biopore composting system; (2) Waste shredder; (3) Mixing tools; (4) Weighing scale; (5) Technical SOPs; (6) Trained personnel.	(1) High-quality organic compost; (2) Reduced organic waste volume; (3) Lower potential CH emissions.	(1) Compost for school gardens and urban farming; (2) Fertilizer for farms supplying ingredients to the MBG Program; (3) Environmental education for students; (4) Reduced fertilizer procurement costs.	(1) Simple technology; (2) Low operating costs; (3) Easy to implement in schools and SPPG facilities.
Biodigester	Anaerobic treatment of organic waste to produce biogas and digestate.	(1) Separate organic waste from plastics and metals; (2) Mix with water; (3) Feed the biodigester reactor; (4) Monitor pH and temperature; (5) Capture and utilize biogas; (6) Manage digestate residues.	(1) Sealed biodigester reactor; (2) Inlet and outlet tanks; (3) Gas storage unit; (4) Biogas stove; (5) Gas safety system; (6) Trained technicians/operators.	(1) Renewable biogas; (2) Liquid or solid digestate for fertilizer; (3) Reduced potential CH emissions.	(1) Biogas for cooking at SPPG kitchens; (2) Digestate as organic fertilizer; (3) Reduced LPG and energy costs; (4) Support for low-carbon development.	(1) Produces renewable energy; (2) Reduces energy costs; (3) Environmentally friendly.
Black Soldier Fly (BSF) maggot cultivation	Utilization of BSF larvae to convert organic waste into high-protein biomass.	(1) Separate organic waste; (2) Shred organic waste, particularly vegetable and fruit residues; (3) Feed waste to BSF larvae; (4) Maintain the rearing medium; (5) Harvest larvae every 10–14 days; (6) Process frass residues.	(1) BSF rearing facility; (2) Rearing racks; (3) Egg incubation containers; (4) Harvesting equipment; (5) Trained person n			

Source: Processed Primary Data, 2026

Therefore, comprehensive assessment, monitoring, and mitigation of methane (CH_4) emissions from the MBG Program are necessary to align its implementation with Indonesia's national climate targets.

Alternative Food Waste Management Practices for the MBG Program

Given the considerable environmental impacts associated with food waste generated by the MBG Program, effective management strategies are urgently needed. Ideally, food waste generated by the program should be managed in accordance with the principles of sustainable waste management and the circular economy. Table 5 presents a range of alternative practices that could be adopted to improve food waste management within the MBG Program.

Fundamentally, food waste generated by the MBG Program possesses significant intrinsic biochemical value that can be recovered through appropriate resource recovery strategies. As shown in Table 5, two promising approaches are bio-composting and anaerobic digestion using biodigesters. Bio-composting may be implemented through biopore systems, aerobic composting facilities, or Black Soldier Fly (BSF) maggot cultivation, producing valuable outputs such as organic compost and high-protein biomass. In particular, BSF larvae can be utilized as a sustainable source of high-protein animal feed for aquaculture and livestock, thereby supporting circular resource utilization. The implementation of these practices would enable food waste generated by the MBG Program to be transformed into valuable resources for other production systems. Organic compost can be used to fertilize vegetable and fruit farms supplying ingredients to SPPG facilities, school gardens, and urban farming initiatives. Likewise, BSF larvae can be utilized as fish feed in school aquaculture projects or by partner suppliers, while biogas produced through anaerobic digestion can serve as a renewable cooking fuel for SPPG kitchens. Collectively, these resource recovery strategies support the transition toward a circular economy by converting food waste into valuable resources, reducing greenhouse gas emissions, and improving the sustainability of food production and waste management systems.

CONCLUSION

The MBG Program, as a nationwide social intervention with the primary objective of improving nutritional outcomes, also has the potential to generate significant environmental impacts through food waste generation. The program is estimated to produce 1.1–1.4 million tons of food waste annually, with a projected GHG emission potential of 37,400–47,600 metric tons of CH_4 and 921.8–1,173.2 billion tons of CO_2e per year. Such emission levels present an emerging challenge to Indonesia's efforts to achieve its Second Nationally Determined Contribution (SNDC) 2030 targets. Accordingly, food waste management within the MBG Program should be recognized as an environmental governance and climate policy issue requiring structured, systematic, and large-scale implementation. Cross-sectoral policies should be complemented by food waste management education at the operational level, particularly in SPPG and schools, as well as by investment in the necessary waste management facilities and infrastructure. Among the available management options, the most promising approaches include bio-composting for organic fertilizer production, anaerobic digestion through biodigesters for renewable energy generation, and BSF maggot cultivation for producing high-protein animal feed. By adopting circular resource recovery strategies, the MBG Program could transform food waste from an environmental burden into a valuable resource, thereby promoting sustainable nutrition and supporting low-emission development.

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