

Food Waste Cost of the Free Nutritious Meals Program from a True Cost Accounting Perspective

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Abstract

This study analyzed food waste cost in Indonesia's Free Nutritious Meals Program or locally Makan Bergizi Gratis (MBG) through a True Cost Accounting (TCA) perspective. An evaluative quantitative case study was conducted at SMK Pelita Madani, Pringsewu, on August 5, 2026. Three Grade XI classes were purposively selected to represent different study programs. Data were collected through direct observation, aggregate food-waste weighing, a self-developed and pilot-tested student questionnaire, and semi-structured interviews. Microsoft Excel was used for descriptive analysis. Sixty-nine meal portions were observed, and 64 valid student responses were analyzed. Of 17,733 grams of solid food served, 1,251 grams remained uneaten, producing a 7.06% food-waste rate. With an assumed raw-material cost of IDR 10,000 per portion, the estimated food-waste cost was IDR 48,677. Vegetables contributed 592 grams (47.3 %) of the total waste. Distribution counts alone did not capture food utilization; waste measurement, acceptance, and cost information provided additional evaluative signals. The study covered one school, three classes, and one observation day. The study proposed a practical TCA-based framework linking physical waste, monetary loss, student acceptance, and multi-capital interpretation.

Keywords: Food Waste Cost, Free Nutritious Meals Program, Multi-Capital, School Meals, True Cost Accounting

1. INTRODUCTION

The Free Nutritious Meals Program, known in Indonesia as Program *Makan Bergizi Gratis* (MBG), is a major school-based nutrition intervention intended to strengthen nutritional access and human capital development in Indonesia. Recent studies on MBG implementation emphasize that program performance should be examined through nutritional, governance, delivery, and outcome dimensions rather than through administrative distribution indicators alone (Babo, Sidi, & Imtiyaz, 2026; Suprpto, Praditya, Dewi, & Adiyoso, 2025). Evidence from school-meal research also shows that meals delivered to students do not automatically indicate that food is consumed or that the allocated resources generate their intended nutritional and social benefits (Byker, Banna, & Serrano, 2017; Ruggiero, Ilic, Bituh, Brecic, & Colic, 2022). Accordingly, evaluating MBG solely based on the number of distributed portions provides an incomplete picture of program performance.

Food waste is an important indicator in school meal evaluation because it reflects both the physical amount of food not consumed and the economic value of resources that do not generate their intended benefit (Berdikulovich, 2026; Usman, Iek, & Hafizriandra, 2025). Studies on school meals show that plate waste is related to menu acceptability, eating time, food quality, portion suitability, meal service policy, and student preferences (Adjapong, Bender, Schaefer, & Roe, 2024; Byker et al., 2017; Cohen, Richardson, Austin, Economos, & Rimm, 2013; Cohen, Jahn, Richardson, Cluggish, Parker, & Rimm, 2016; Ruggiero et al., 2022; Zhao, Panizza, Fox, Boushey, Ahmed, Chen, Serrano, Zee, Fialkowski, & Banna, 2019). Broader food waste literature also confirms that waste at the consumption stage creates economic, nutritional, environmental, and social consequences (Reynolds, Goucher, Quested, Bromley, Gillick, Wells, Evans, Koh, Katzeff, Svenfelt, & Jackson, 2019; Schanes, Dobernig, & Gozet, 2018; Stoeckli, Niklaus, & Dorn, 2018; Thyberg, & Tonjes, 2016; Xue, Liu, Parfitt, Liu, Stenmarck, Ostergren, & Cheng, 2017).

From an accounting perspective, food waste can be interpreted as a signal that part of the program expenditure does not fully translate into student consumption (Aminanto, Rohim, &

[Handayani, 2026](#); [Laili, Narimo, & Fathoni, 2026](#); [von Braun, & Hendriks, 2023](#)). True Cost Accounting (TCA) offers a broader perspective by identifying costs and benefits that are often not visible in conventional financial calculations. TCA has been applied to make food system externalities more transparent, support decision-making, and connect economic, environmental, health, and social dimensions ([Baker, Castilleja, & Jones, 2020](#); [de Adelhart, Yates, Watkins, Bernard, & de Groot, 2021](#); [Food, & Agriculture, 2023b](#); [Food, & Agriculture, 2023a](#); [Hendriks, Acosta, Baumer, Galgani, Godde, Waha, Kanidou, von Braun, Benitez, Blanke, Caron, Fanzo, Greb, Haddad, Herforth, Jorda, Masters, & Watkins, 2021](#); [Michalke, Stein, Fichtner, Gaugler, & Stoll-Kleemann, 2022](#); [Sandhu, Wratten, Porter, & Costanza, 2021](#); [Hendriks et al., 2021](#)). This study aimed to analyze food waste rate and food waste cost in the free nutritious meals program and to interpret the findings through a true cost accounting multi-capital perspective. Specifically, the study examined the amount of food served, the amount of food waste, the estimated food waste cost, the composition of food waste, student acceptance, and how these indicators can be integrated into an evaluation model.

The motivation for this study is grounded in the need to move beyond administrative indicators of food distribution. In a meal program, the number of portions delivered is an important output, but it does not automatically represent the outcome expected from the program. If part of the food is not consumed, the program still incurs raw material costs, while the intended nutritional benefit is only partially realized. This makes food waste a relevant accounting and management issue, especially when a public program is expected to demonstrate efficiency, accountability, and social value. In this context, measuring food waste cost provides a practical way to connect physical waste with the monetary value of resources that are not fully utilized ([Reynolds et al., 2019](#); [Thyberg and Tonjes, 2016](#); [Xue et al., 2017](#)).

This study also addresses a specific empirical and accounting gap. Existing school meal research has generated extensive evidence on plate waste, menu acceptability, food preferences, eating time, and service conditions, whereas TCA research has primarily been applied to food systems, supply chains, farms, and broader agri-food valuation. In the emerging Indonesian MBG context, limited empirical work jointly examines five elements, such as the amount of food served, the quantity and composition of food left uneaten, the monetary value embedded in that physical waste, student acceptance and contextual reasons for non-consumption, and interpretation of those indicators through a multi-capital accounting perspective. This integration is important because a program can achieve full distribution while still experiencing resource loss after meals reach students. By linking physical waste with cost and acceptance information, this study seeks to produce a decision-relevant school-level evaluation framework rather than a national effectiveness estimate. The study was guided by five research questions:

- RQ1. What proportion of the served food remained uneaten in the observed classes?*
- RQ2. How is food waste distributed across the meal components?*
- RQ3. What is the estimated raw material cost associated with the measured food waste?*
- RQ4. What did student responses and contextual evidence indicate about menu acceptance and the reasons for non-consumption?*
- RQ5. How can physical food waste, cost, and student response indicators be integrated within the TCA multi-capital evaluation framework?*

2. LITERATURE REVIEW

Food waste measurement provides the basis for understanding how food resources are used and where inefficiencies occur. In school meal settings, plate waste has been measured through direct weighing, aggregate weighing, visual assessment, or combinations of observation and student-response data. Weight-based measurements provide an objective physical indicator, while aggregate measurements can be practical when individual weighing would interrupt normal meal activities. Prior studies emphasize transparent measurement boundaries, consistent categorization of food components, and careful interpretation when measurements are aggregated by class or serving group ([Boschini, Falasconi, Giordano, & Alboni, 2018](#); [Chapman, Richardson, McLeod, Rimm, & Cohen,](#)

[2019](#); [Kaur, Dhir, Talwar, & Alrasheedy, 2021](#); [Liz, Rodrigues, Cunha, & Rocha, 2020](#); [Zhang, Wang, Duan, & Li, 2016](#)).

Research on school meal waste consistently shows that waste is not only a matter of portion size. Menu quality, taste, sensory characteristics, student preferences, food familiarity, and meal scheduling affect whether food is consumed or discarded. Studies in primary and secondary school contexts indicate that fruits and vegetables often become important components of plate waste, and that student acceptance is essential for achieving nutritional objectives ([Blondin, Djang, Metayer, Anzman-Frasca, & Economos, 2018](#); [Byker, Banna, & Serrano, 2017](#); [Martins, Rodrigues, Cunha, & Rocha, 2021](#); [Ruggiero, Ilic, Bituh, Brecic, & Colic, 2022](#); [Toth, Bittsanszky, & Illes, 2023](#)). Intervention studies also suggest that school food service training, student education, and behavioral strategies can support waste reduction, although results vary by implementation consistency and local school context ([Elnakib, Quick, Mendez, Downs, Wackowski, & Robson, 2021](#); [Serebrennikov, Katare, Kirkham, & Schmitt, 2020](#)).

True cost accounting extends conventional cost analysis by making visible the hidden costs and benefits associated with food systems. The TCA perspective is relevant to school meal programs because food that is purchased, prepared, and distributed but not consumed represents a financial value that does not fully become a nutritional benefit. Existing TCA studies emphasize the importance of defining scope, functional units, valuation boundaries, and responsible communication when economic, environmental, health, and social impacts are used to support decisions ([Baker, Castilleja, & Jones, 2020](#); [de Adelhart, Yates, Watkins, Bernard, & de Groot, 2021](#); [Food, & Agriculture, 2023a](#); [Food, & Agriculture, 2023b](#); [Hendriks, Acosta, Baumers, Galgani, Godde, Waha, Kanidou, von Braun, Benitez, Blanke, Caron, Fanzo, Greb, Haddad, Herforth, Jordaan, Masters, & Watkins, 2021](#); [Michalke, Stein, Fichtner, Gaugler, & Stoll-Kleemann, 2022](#); [Sandhu, Wratten, Porter, & Costanza, 2021](#); [Hendriks et al., 2021](#)).

A cost-accounting perspective strengthens this interpretation because material that is purchased and processed but not converted into the intended service outcome represents inefficient resource use. Material Flow Cost Accounting (MFCA), an environmental management accounting approach, separates the physical and monetary consequences of material losses from the value associated with intended output. [Dierkes and Siepelmeyer \(2019\)](#) showed that MFCA can distinguish efficient from inefficient material demand and make the cost implications of waste visible for management decisions. More recent work further develops MFCA by identifying different inefficiency factors and their monetary effects ([Dierkes & Siepelmeyer, 2025](#)). Although the present study does not implement a full MFCA system, this accounting logic supports the treatment of uneaten meal components as material losses whose economic value should be made visible rather than absorbed invisibly in aggregate program expenditure.

There remains limited empirical work that integrates school meal food waste measurement, food waste cost estimation, student acceptance, and multi-capital interpretation in the context of an emerging public meal program. This study addresses this gap by developing and applying an initial evaluative model for MBG. Because the research objective is descriptive evaluation and cost estimation rather than causal inference, the study does not introduce statistical hypotheses that would imply population-level or causal testing. Instead, research questions were used to guide the analysis, while inferential hypothesis testing was reserved for future multi-school studies with larger probability-based samples.

The literature also indicates that the interpretation of food waste should consider both measurement design and behavioral context. Direct weighing provides more objective information on the physical amount of uneaten food, whereas student response data help explain why the food is left uneaten. Aggregate weighing is particularly useful in school settings where individual weighing may disrupt meal activities or require additional time and personnel. However, aggregate data should be interpreted carefully because they may mask variation among students and menu components. Therefore, combining class-level measurement, component-level weighing, and student questionnaire

data can strengthen the interpretation of food waste patterns ([Boschini et al., 2018](#); [Chapman et al., 2019](#); [Kaur et al., 2021](#); [Liz et al., 2020](#)).

From the TCA perspective, the value of this integration lies in its ability to make hidden program signals more visible. Food waste cost in this study is not intended to represent a complete valuation of environmental, health, and social impacts. Rather, it is used as an initial monetary signal that shows the economic value of food that was provided but not consumed. This position is consistent with the TCA literature, which emphasizes that valuation boundaries, data availability, communication, and responsible interpretation are important when applying TCA to food systems ([Baker et al., 2020](#); [de Adelhart et al., 2021](#); [Hendriks et al., 2021](#); [Michalke et al., 2022](#)).

2.1 Conceptual Framework

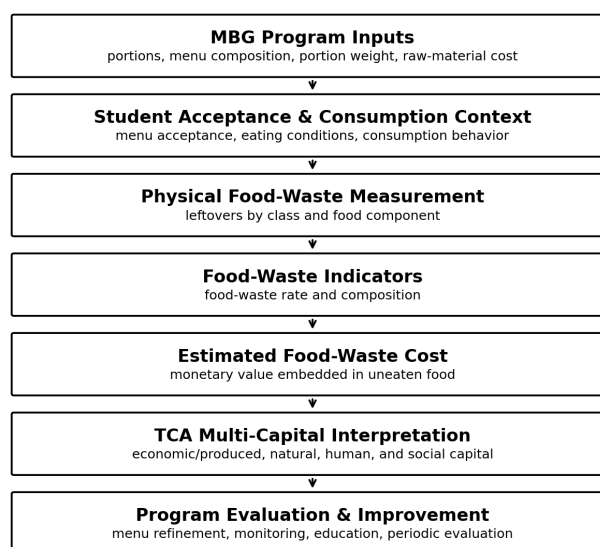


Figure 1. Conceptual framework for evaluating food waste cost in the Free Nutritious Meals Program

The conceptual framework combines school-meal utilization, cost accounting, and TCA. Program inputs consist of portions, menu composition, portion weight, and raw-material expenditure. After distribution, actual utilization is shaped by student acceptance and the meal-consumption context, including taste, familiarity, food condition, eating time, and consumption behavior. Uneaten food is measured physically by class and menu component, and then translated into food-waste rate, waste composition, and estimated food-waste cost. These indicators are interpreted through economic/produced, natural, human, and social capital to support program improvement. The framework therefore positions food waste simultaneously as a physical loss, an accounting signal, and an indicator of whether distributed resources are translated into their intended student benefits. Figure 1 presents the conceptual framework used in this study. It explicitly connects program input, student acceptance and consumption context, physical food waste measurement, food waste indicators, cost estimation, multi-capital interpretation, and program improvement.

The framework clarifies that evaluation does not stop at meal distribution. Inputs first become meals available to students, but actual utilization depends on whether students accept and consume those meals. Physical leftovers are then converted into food waste and cost indicators. These measures are not treated as complete monetization of all environmental or social externalities; rather, they provide an initial accounting signal that is interpreted alongside human and social indicators. This sequence provides the analytical basis for the measurements reported in the methodology and for the multi-capital interpretation in the discussion.

3. RESEARCH METHODOLOGY

3.1 Research Design, Population, and Sampling

This study used an evaluative quantitative case-study design at SMK Pelita Madani, Pringsewu, on August 5, 2026. The school implemented MBG across its classes, while the field evaluation focused on three Grade XI classes, such as XI Software Engineering or locally *Rekayasa Perangkat Lunak/RPL*, XI Hospitality, and XI Pharmacy. The classes were selected purposively to represent different study programs within the vocational school. One class from each selected study program was included to ensure that the evaluation captured variation across student groups while remaining operationally feasible for direct food-waste measurement. The selection was not intended to create a statistically representative sample of all students or all MBG implementation contexts.

Within the three purposively selected classes, a census approach was used for the observation day. All 69 students who were present received meals, and all 69 distributed meal portions were included in the aggregate food-waste measurement. All students present were eligible to participate in the questionnaire. Sixty-five questionnaire responses were received; one response was excluded because the respondent did not provide consent, leaving 64 valid responses for analysis. The valid-response coverage was 92.75% of the 69 students present. Because all eligible students in the selected classes were invited and the analysis was descriptive rather than inferential, no statistical sample size formula was used. The sample size limitation was explicitly acknowledged, and the results were interpreted as a focused case evaluation.

3.2 Data Collection and Research Instruments

Data were collected using four techniques. First, direct observation recorded the number of students present, portions received and distributed, meal-consumption activities, and collection of leftovers. Second, food waste was weighed after the meal and aggregated by class and food component. Third, a student questionnaire captured menu acceptance, portion and eating conditions, consumption behavior, reasons for unfinished meals, and attitudes toward menu improvement. Fourth, semi-structured interviews were conducted with school representatives to provide contextual evidence on meal distribution and student consumption. The interview guide covered the distribution procedure, whether all received portions were distributed, food components commonly left uneaten, perceived reasons for unfinished meals, the relevance of taste, menu familiarity, food condition, and eating time, school handling of leftovers, and feedback received from students. The semi-structured format allowed follow-up questions when clarification was needed.

The questionnaire was self-developed by the research team based on the study objectives and relevant literature on school meal acceptance, eating conditions, consumption behavior, and plate waste (Byker Shanks et al., 2017; Ruggiero et al., 2022; Toth et al., 2023; Zhao et al., 2019). Before the main survey, the instrument was pilot-tested on a separate group of respondents who were not included in the final study sample. The pilot test dataset contained 30 responses, one response from a non-target participant was excluded, leaving 29 responses for instrument testing. Item validity was assessed using the corrected Pearson item-total correlation within each construct, with $df = 27$ and a two-tailed 5% critical value of approximately $r = 0.367$. Four items (P14, P22, P27, and P28) did not meet the validity criterion and were excluded from the final construct scores. Cronbach's alpha coefficients were 0.876 for menu acceptance, 0.681 for portion and eating conditions, 0.732 for consumption behavior, and 0.602 for attitudes toward food waste reduction. The retained items were then used in the main survey.

3.3 Measurement and Accounting-Based Cost Model

The main food waste measurement used a weight-based approach. One solid meal portion weighed 257 grams and consisted of 128 grams of rice or carbohydrate, 66 grams of side dish or protein, 21 grams of vegetables, and 42 grams of fruit. A total of 69 meal portions were analyzed, resulting in 17,733 grams of estimated solid food served. Leftovers were collected after students finished eating and weighed in aggregate by class and food component, such as rice or carbohydrate, side dish or protein, vegetables, and fruit or beverage. Aggregation was chosen to minimize disruption to classroom and meal activities while retaining the class-level and component-level information.

The study used an accounting-based economic model rather than an econometric regression model. Let Served Food (SF) denote the total served food in grams, Food Waste (FW) the total measured food waste in grams, Food Waste Rate (FWR) the food-waste rate, Total Raw Material Cost (TRMC) the total raw-material cost, and Food Waste Cost (FWC) the food-waste cost. The calculations were as follows: $FWR = (FW / SF) \times 100\%$, $TRMC = \text{number of distributed portions} \times \text{IDR } 10,000$, $FWC = FWR \times TRMC$, average food-waste cost per portion = $FWC / \text{number of distributed portions}$. Operational costs were excluded because the directly measured object was physical food waste. The assumed IDR 10,000 raw-material cost per portion was used as an operational research assumption rather than as a claim about the official cost of all MBG meals. FWC is interpreted as the estimated share of raw-material expenditure embodied in uneaten food and is therefore not added again to TRMC. This model supports descriptive cost evaluation but does not estimate causal effects.

Questionnaire and food waste data were processed and analyzed using Microsoft Excel. Questionnaire responses were screened for consent, completeness, eligibility, and consistency. Descriptive statistics included frequencies, percentages, and construct means on a 1–5 scale. The main dataset comprised 64 valid Grade XI student responses, such as 25 males (39.06%) and 39 females (60.94%). Questionnaire results were used to support the interpretation of human- and social-capital dimensions rather than to estimate causal relationships. Observation, weighing, questionnaire, and interview evidence were compared descriptively to identify convergent patterns in food utilization and waste.

Table 1. Research data and measurement indicators

Indicator	Data source	Measurement	Analytical function
Meal distribution	Observation	Number of portions distributed by class	Identifying program input
Served food	Portion weighing and portion count	Portions x weight per portion	Estimating total food available
Food waste	Weighing by class and component	Total leftover food in grams	Measuring uneaten food
Food waste rate	Served food and food waste data	Food waste / served food x 100%	Measuring uneaten food proportion
Conventional raw material cost	Portion count and cost assumption	Portions x IDR 10,000	Estimating program food cost
Food waste cost	Food waste rate and conventional cost	Food waste rate x raw material cost	Estimating economic value of uneaten food
Student acceptance	Student questionnaire	Mean score on a 1-5 scale	Explaining human and social factors

Table 1 summarizes the indicators, data sources, measurement approaches, and analytical functions applied in this study. Food distribution and food waste indicators were obtained through direct observation and weight-based measurement, while economic indicators were calculated using an accounting-based approach. Student acceptance was assessed through a structured questionnaire using a five-point Likert scale. Each indicator was selected to capture different dimensions of the MBG program, including food utilization efficiency, economic implications of waste, and social acceptance among students.

4. RESULTS AND DISCUSSION

Table 2. Food waste rate and food waste cost by class

Class	Portions	Served food (grams)	Food waste (grams)	Food waste rate (%)	Food waste cost (IDR)
XI Software Engineering	21	5,397	347	6.43	13,502
XI Hospitality	24	6,168	369	5.98	14,358
XI Pharmacy	24	6,168	535	8.67	20,817

Class	Portions	Served food (grams)	Food waste (grams)	Food waste rate (%)	Food waste cost (IDR)
Total	69	17,733	1,251	7.06	48,677

Table 2 shows the total number of meal portions analyzed was 69 portions. XI Software Engineering received 21 portions, XI Hospitality received 24 portions, and XI Pharmacy received 24 portions. Based on a solid food portion weight of 257 grams, the total served food was 17,733 grams. Total measured food waste was 1,251 grams, resulting in an overall food waste rate of 7.06%. The questionnaire subsample represented most students present in the observed classes. All 64 valid respondents were Grade XI students 25 (39.06%) were male and 39 (60.94%) were female. All valid respondents confirmed that they received the MBG meal on the study date. Forty-six students (71.88%) reported finishing the meal, whereas 18 students (28.13%) reported that they did not finish it. These characteristics are reported to clarify the composition of the response data and to avoid treating the questionnaire as a population-representative survey.

The food waste rate varied across classes. XI Software Engineering produced 347 grams of food waste from 5,397 grams of served food, resulting in a food waste rate of 6.43%. XI Hospitality produced 369 grams of food waste from 6,168 grams of served food, resulting in a food waste rate of 5.98%. XI Pharmacy produced 535 grams of food waste from 6,168 grams of served food, resulting in the highest food waste rate of 8.67%. With a total raw material cost of IDR 690,000, the total food waste cost was IDR 48,677. This figure is not a cost per portion, it is the total estimated economic value of uneaten food from the 69 analyzed portions. The average food waste cost was approximately IDR 705 per portion.

Table 3. Food waste composition by food component

Food component	Food waste (grams)	Percentage (%)	Interpretation
Rice/carbohydrate	476	38.0	Substantial remaining staple food
Side dish/protein	166	13.3	Lower remaining protein component
Vegetables	592	47.3	Largest food waste component
Fruit/beverage	17	1.4	Smallest remaining component
Total	1,251	100.0	Overall measured food waste

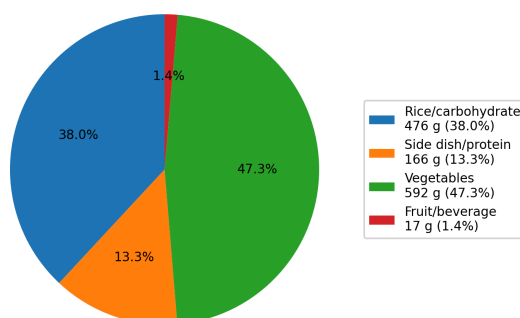


Figure 2. Food waste composition by food component

Table 3 and Figure 2 shows presents the composition of measured food waste based on food components. The total recorded food waste was 1,251 grams, with vegetables representing the largest proportion at 592 grams (47.3%). This indicates that vegetables contributed the highest share of uneaten food among the observed meal components. Rice or carbohydrate waste accounted for 476 grams (38.0%), representing a substantial amount of remaining staple food, while side dish or protein waste reached 166 grams (13.3%), indicating a lower proportion compared with staple and vegetable components. Fruit/beverage waste was the smallest category, with only 17 grams (1.4%) of the total waste. These findings suggest that food waste in the observed MBG implementation was primarily

driven by vegetable and carbohydrate components, highlighting the need for strategies related to menu composition, portion adjustment, and student food preferences to reduce avoidable waste.

The dominance of vegetable waste is substantively important because vegetables are nutritionally valuable but often face acceptance challenges among students. This finding does not imply that vegetable consumption should be reduced. Instead, it suggests the need to improve preparation methods, seasoning, texture, temperature, menu variation and communication with students. School meal literature indicates that fruit and vegetable waste is often influenced by taste, familiarity, exposure, and the eating environment. Therefore, practical responses should focus on increasing acceptance while maintaining the nutritional objectives ([Blondin et al., 2018](#); [Byker Shanks et al., 2017](#); [Elnakib et al., 2021](#); [Ruggiero et al., 2022](#)).

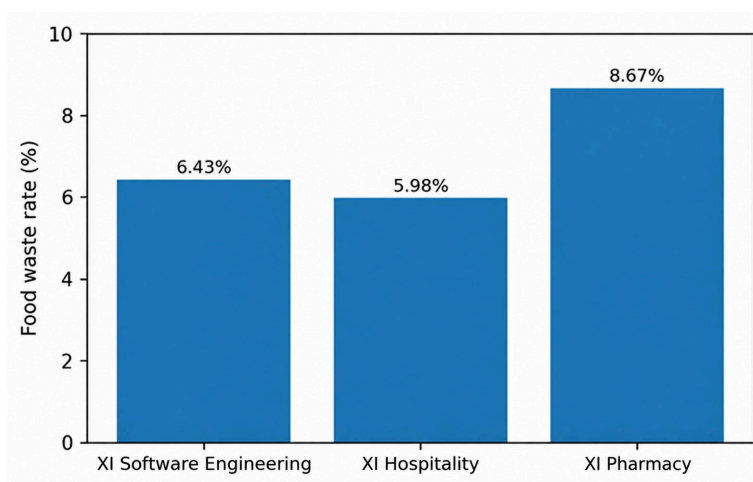


Figure 3. Food waste rate by class

Figure 3 illustrates the food waste rate across three study groups. The highest food waste rate was observed in XI Pharmacy (8.67%), followed by XI Software Engineering (6.43%) and XI Hospitality (5.98%). These results indicate variations in food consumption patterns among classes, with XI Pharmacy showing a greater proportion of uneaten food compared with the other groups. The differences may reflect variations in students' preferences, eating habits, and acceptance of the provided menu. Therefore, class-level evaluation can support more targeted strategies to reduce food waste and improve meal program effectiveness.

Table 4. Student questionnaire results

Construct	Mean score	Interpretation
Menu acceptance	3.67	Fairly good acceptance
Portion and eating condition	3.61	Fairly adequate eating condition
Consumption behavior	3.46	Moderate effort to consume meals
Attitude toward menu improvement	3.73	Positive attitude toward improvement

Table 4 shows the mean score for menu acceptance was 3.67 on a 1–5 scale, indicating moderate to fairly good acceptance. The mean score for portion and eating conditions was 3.61, while consumption behavior scored 3.46. The highest mean score was found in students' attitude toward menu improvement, at 3.73. These results suggest that students generally responded positively to the meal program, although improvements in menu variety and consumption habits may help further reduce food waste. The findings also indicate that student perceptions play an important role in evaluating the effectiveness and sustainability of the program.

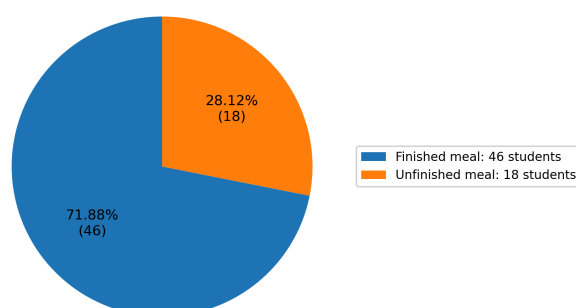


Figure 4. Student consumption status

Figure 4 indicate that most students consumed the meal provided on the observation date. Of the 64 valid student responses, 46 students, or 71.88%, reported that they finished the meal, while 18 students, or 28.13%, reported that they did not finish it. The questionnaire and semi-structured interview evidence helped explain the measured leftovers. Among the 18 students who reported not finishing their meal, 16 identified vegetables as the component most frequently left. Reported reasons for unfinished meals included taste that did not match student preference, low preference for vegetables, lack of familiarity with particular menu items, food that had become cold by the time it was eaten, and dislike of the side dish. These explanations are consistent with school meal research showing that palatability, familiarity, meal timing, food condition, and student preference can influence plate waste ([Byker et al., 2017](#); [Liz Martins et al., 2020](#); [Ruggiero et al., 2022](#); [Toth et al., 2023](#); [Zhao et al., 2019](#)). Therefore, the findings suggest that food waste in the observed classes cannot be explained by portion size alone.

The questionnaire results help explain why the weighing results should not be interpreted only as individual student behaviors. Students may leave food because of personal preference, unfamiliar menu, food condition when received, limited eating time, or the way food is prepared and served. The mean scores also showed that acceptance and consumption behavior were not at the maximum level, even though most students reported finishing their meals. This indicates that a program can have relatively good consumption outcomes while still requiring menu and service improvements. This behavioral information is useful for MBG evaluation because it provides context for interpreting the measured food waste.

4.1 Observation-Derived and Contextual Themes

Three descriptive themes were derived by comparing direct observations, weighing results, questionnaire responses, and semi-structured interview contexts. First, complete distribution did not guarantee complete utilization, all 69 received portions were distributed, yet measurable leftovers remained. Second, waste was component-specific rather than evenly distributed, with vegetables accounting for the largest share of the measured waste. Third, waste varied across student groups and was connected with acceptance and service-context factors, including taste, familiarity, food temperature or condition, and menu variation. These themes were used to interpret the measured patterns and were not presented as statistically tested causal effects.

4.2 Accounting and True Cost Interpretation

From an economic perspective, the estimated food-waste cost of IDR 48,677 represents the share of raw-material expenditure associated with uneaten food in the 69 observed portions. This is not an additional cost layered on top of the IDR 690,000 raw-material expenditure, rather, it is the portion of that expenditure estimated to have been embodied in physical leftovers. The average food-waste cost was approximately IDR 705 per distributed portion. Although this amount is modest in the limited case sample, repeated waste across a larger and recurrent meal program can accumulate materially. Therefore, the calculation functions as a management-accounting signal of resource inefficiency rather than as a complete economic valuation of MBG. This interpretation is consistent

with Material Flow Cost Accounting (MFCA) logic, which makes material losses visible in both physical and monetary terms ([Dierkes & Siepelmeyer, 2025](#)).

The finding that vegetables were the largest food waste component is important because vegetables are often associated with acceptability problems in school meals. Studies show that fruits and vegetables frequently contribute to plate waste and that interventions may reduce waste only when they are matched with menu quality, repeated exposure, food service practices, and student agency ([Blondin, Djang, Metayer, Anzman-Frasca, & Economos, 2018](#); [Byker, Banna, & Serrano, 2017](#); [Elnakib, Quick, Mendez, Downs, Wackowski, & Robson, 2021](#); [Serebrennikov, Katare, Kirkham, & Schmitt, 2020](#)). Therefore, menu improvement in the MBG context should not reduce vegetable provision but should improve preparation, seasoning, serving conditions, and student acceptance. The class-level results also show variation. XI Pharmacy had the highest food waste rate and cost. This indicates that class-level and component-level monitoring can provide more actionable information than school-level aggregate data alone. This is consistent with evidence that school characteristics, meal service conditions, and measurement methods influence the interpretation of plate waste data ([Adjapong, Bender, Schaefer, & Roe, 2024](#); [Boschini, Falasconi, Giordano, & Alboni, 2018](#); [Chapman, Richardson, McLeod, Rimm, & Cohen, 2019](#); [Kaur, Dhir, Talwar, & Alrasheedy, 2021](#); [Liz, Rodrigues, Cunha, & Rocha, 2020](#); [Martins, Rodrigues, Cunha, & Rocha, 2021](#); [Zhang, Wang, Duan, & Li, 2016](#)).

The true cost accounting perspective expands the interpretation of these results. In this study, economic or produced capital is represented by raw material and food waste costs. Natural capital is represented by physical food waste and potential inefficiency of food resources. Human capital is represented by the benefit of meals for students, which depends on their actual consumption. Social capital is represented by menu acceptance, consumption behaviors, and student feedback. This multi-capital interpretation supports the use of TCA as an initial evaluative lens rather than a complete monetary valuation of all MBG impacts ([de Adelhart, Yates, Watkins, Bernard, & de Groot, 2021](#); [Food, & Agriculture, 2023b](#); [Sandhu, Wratten, Porter, & Costanza, 2021](#)).

The proposed evaluation model contributes to the accounting literature by translating the TCA concept into a practical school meal evaluation sequence. The model begins with observable program input, continues with physical measurement of leftover food, converts the result into food waste rate and food waste cost, and then interprets the findings through economic, natural, human, and social capital. Economic or produced capital is represented by raw material value. Natural capital is reflected in the physical loss of food resources. Human capital is related to whether students obtain nutritional benefits from the meals. Social capital is reflected in student acceptance, habits, and feedback. This structure makes the evaluation more comprehensive without requiring complex full-cost valuation in the initial stage.

At the same time, the model should be used with caution. The food waste cost reported in this study is a minimum estimate and does not include broader externalities such as emissions, water use, land use, labor, or long-term health outcomes. Therefore, the TCA perspective was used as an evaluative lens rather than a complete monetization of all impacts. This distinction is important to avoid overclaiming the findings. The strength of the model lies in its simplicity and its potential to be applied by schools or meal providers as a periodic monitoring tool before more advanced valuation methods are developed.

Table 5. True Cost Accounting multi-capital interpretation

Capital component	Research indicator	Interpretation
Economic/produced capital	Raw material cost and food waste cost	Uneaten food represents economic value that does not fully generate intended benefit
Natural capital	Food waste by weight and component	Food waste indicates inefficient use of food resources

Capital component	Research indicator	Interpretation
Human capital	Meal consumption and perceived satiety	Program benefit depends on actual student consumption
Social capital	Menu acceptance and consumption behavior	Student preferences and habits influence whether food is consumed or wasted

Table 5 summarizes the relationship between capital components and food waste indicators. Economic capital reflects the financial value lost through uneaten food, while natural capital highlights inefficiencies in food resource utilization. Human and social capital emphasize the role of student consumption patterns, satisfaction, and preferences in determining food utilization and waste generation.

5. CONCLUSIONS

5.1 Conclusion

This study analyzed the food waste cost of the free nutritious meals program from a true cost accounting perspective. The results showed that in three observed classes at SMK Pelita Madani, 17,733 grams of solid food was served and 1,251 grams remained uneaten, resulting in a food waste rate of 7.06%. Based on a raw material cost assumption of IDR 10,000 per portion, the estimated total food waste cost was IDR 48,677 or approximately IDR 705 per portion. Vegetables were the largest food waste component, accounting for 592 grams or 47.3% of the total food waste. XI Pharmacy had the highest food waste rate and cost. The findings indicate that MBG evaluation should include not only meal distribution but also food utilization, leftover food, student acceptance, and hidden costs. The proposed TCA-based evaluation model integrates food waste measurement, food waste cost estimation, and multi-capital interpretation. In this model, economic or produced capital is reflected in raw material cost and food waste cost, natural capital in food waste and resource inefficiency, human capital in actual meal consumption, and social capital in menu acceptance and consumption behavior.

5.2 Research Limitations

This study has several limitations. It was conducted in one school, covered three purposively selected Grade XI classes, and measured food waste on one observation day. Although the valid questionnaire coverage within the selected classes was high (64 of 69 students present, or 92.75%), the sample is too limited for population-level inference and does not satisfy a design intended for broad hypothesis testing. The raw-material cost of IDR 10,000 per portion was an operational assumption, and operational, labor, energy, water, logistics, and waste-management costs were not included. The questionnaire was self-developed and pilot-tested on a separate 29-response analytic pilot sample, one construct showed lower internal consistency than the others, so the questionnaire results are interpreted descriptively. Aggregate class-level weighing also prevented direct matching of each student's questionnaire response with an individual food-waste weight. Accordingly, the findings should be understood as an initial TCA-based case evaluation rather than a general conclusion about MBG implementation.

5.3 Suggestions and Directions for Future Research

Regular food waste monitoring should be conducted by class and menu component so that distribution success can be evaluated together with actual utilization. Menu improvement should prioritize components with consistently high waste, particularly vegetables, while maintaining the nutritional objectives. Future studies should replicate the framework across multiple schools, districts, and observation days; recruit samples exceeding 120 respondents when inferential testing is intended, use probability-based sampling where population generalization is an objective; compare menus and demographic groups, and test associations between menu acceptance, eating conditions, and individually measured plate waste. Further research should also incorporate labor, logistics, energy, water, and waste management costs, compare TCA estimates with MFCA or other environmental management accounting approaches; and examine environmental and nutritional externalities that are outside the present valuation boundary. Repeated-measures or quasi-experimental designs could be used to test whether menu reformulation, food temperature management, nutrition education, or changes in eating time reduce waste over time.

For implementation, monitoring can begin with a simple recording sheet that captures portions distributed, portion weight, leftover weight by component, raw-material cost, and short acceptance notes. These data can then be summarized in a digital dashboard at the class, school, and menu levels. Such a dashboard would not replace nutritional or food-safety evaluation, but it could provide a practical early-warning mechanism for recurring waste patterns and support evidence-based menu review. Future validation of the self-developed questionnaire should also include larger pilot samples, confirmatory assessment of construct structure, and testing across different school contexts.

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AUTHOR CONTRIBUTIONS

EYP conceived the study, designed the evaluation framework, coordinated field implementation, and prepared the manuscript draft. DZ contributed to data analysis, questionnaire interpretation, and manuscript revision. SD contributed to the study design, data collection, and interpretation of accounting-related findings. IRD contributed to field observation, data documentation, and analysis support. AF contributed to methodological refinement, interpretation of findings, and manuscript review. All authors approved the final version of the manuscript and agree to be accountable for the integrity of the work.

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