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Determinants of community perception on food technology-based shallot waste management for nutritional security: a cross-sectional study

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ABSTRACT

Shallot production in Indonesia, particularly in Brebes Regency, generates substantial agricultural by-product waste that poses significant environmental and public health risks due to inadequate community-level management. This cross-sectional quantitative study investigated the influence of government role, infrastructure availability, and public knowledge on perceptions of shallot by-product waste management among 180 respondents selected through proportional random sampling. Data were collected using structured Likert-scale questionnaires and analyzed through multiple linear regression, Spearman's rank correlation, and gap analysis. Gap analysis revealed critical deficiencies in public knowledge (50.6–76.1%) and infrastructure (69.2%), despite universally positive perceptions toward waste management. Multiple linear regression demonstrated that government role ($\beta = 0.342$, $p < 0.001$), infrastructure availability ($\beta = 0.298$, $p < 0.001$), and public knowledge ($\beta = 0.152$, $p = 0.007$) significantly predicted waste management perceptions, collectively explaining 37.8% of the variance (Adj. $R^2 = 0.378$). The government's role contributed the largest effective contribution at 18.74%. These findings carry substantial public health implications, as improved waste management can reduce disease vectors, minimize environmental contamination, and enable by-product valorization for nutritional supplementation. The study recommends strengthening government intervention, expanding waste infrastructure, and enhancing community health literacy as integrated policy strategies to optimize agricultural by-product management and safeguard community nutritional well-being in shallot production centers.

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1. INTRODUCTION

Shallots (*Allium cepa L.*) are a horticultural commodity with high economic value and a strategic role in global and local food systems. Globally, shallots are the second most important vegetable after tomatoes, with a total production of approximately 104,554,458 tons and an average productivity of 19.1 tons per hectare [1]. In many developing countries, including Africa and Asia, shallots are a major source of income for smallholder farmers and play a vital role in improving the livelihoods of rural communities [2], [3]. This commodity not only functions as a flavoring in everyday dishes but also contains important nutrients such as vitamin C, citric acid, sulfur compounds, and phenolic and flavonoid compounds, including quercetin, which are beneficial for health [4], [5].

Shallot production centers are spread across various regions with diverse agroecological characteristics. Shallots are widely produced by smallholder farmers as a commercial crop, with a national productivity of around 8.88–9.3 tons per hectare, which is still far below the optimal productivity potential [2], [6]. In India, Maharashtra is the leading state in onion production, contributing about 25% of national production and 90% of the country's onion exports [7]. In Nigeria, the Kano region is one of the largest producers of shallots with an intensive cultivation system [8].

The main problems faced by communities in shallot production centers are not only limited to cultivation aspects such as the availability of quality seeds, high chemical input costs, pest and disease attacks, and suboptimal irrigation water management [7], [9], [10], but also include inadequate post-harvest waste management. Shallot production waste consisting of sorting residues, outer skins, roots, and unused plant parts causes various environmental problems if not managed properly. Compost produced from shallot residue mixed with cow manure has been proven to improve soil physicochemical properties, microbial activity, and shallot production yields agroecologically, with a dose of 300 kg N ha^{-1} of compost and compost tea being able to guarantee harvest yields comparable to conventional fertilization [11]. A community-centered approach is key to the successful dissemination of sustainable agricultural practices, including waste management. Local communities interact directly with natural resources in their daily lives, so the success of integrated natural resource management strategies depends heavily on practical community engagement through community-based dialogue and field trials [12].

Previous studies on shallot production waste have predominantly focused on technical-agronomic and environmental aspects, while the relationship between community perception of waste management and public health implications, particularly disease prevention and nutritional security, remains underexplored. Government roles, infrastructure availability, and public knowledge have not been integrated simultaneously in a single predictive model explaining community perceptions of shallot by-product management. Furthermore, gap analysis measuring discrepancies between actual and ideal conditions in shallot production centers is absent from current literature. The food technology perspective on by-product valorization into functional foods has not been linked to socio-institutional factors, despite its potential to address malnutrition and environmental health hazards simultaneously.

This study aims to analyze the influence of government roles, infrastructure availability, and public knowledge on the perception of shallot waste (by-product) management in production centers, especially Brebes Regency. This study also aims to identify the gap between actual conditions and ideal conditions in these variables through gap analysis. The novelty of this study lies in several aspects, including the specific focus on shallot waste by-products. Most agricultural waste management literature is general in nature, while this study specifically examines shallot commodities in the largest production centers in Indonesia. The integration of three predictor variables (government roles, infrastructure, and public knowledge) in one regression model to determine the effective contribution of each variable to public perception. The combination of analytical methods using simultaneous multiple linear regression, Spearman rank correlation, and gap analysis provides a comprehensive picture of the factual conditions as well as the determinants of public perception, which are relatively rarely applied simultaneously in the context of agricultural waste management at the community level.

2. METHOD

2.1. Research design

This study employed a quantitative analytical research design with a cross-sectional approach. The analytical nature is explicitly justified by its objective to test causal relationships between independent variables, government role (X_1), infrastructure (X_2), and community knowledge (X_3), and the dependent variable, public perceptions of shallot by-product (waste) management in production centers. Unlike exploratory research aimed at discovering new phenomena without predetermined hypotheses, this analytical design was selected to test specific directional hypotheses regarding the magnitude and significance of each predictor's influence on the outcome variable. The cross-sectional approach was appropriate because the study aimed to capture associations among variables at a single point in time within a defined population.

2.2. Location and time of research

The research was conducted in Brebes Regency, Central Java Province, one of the largest shallot-producing regions in Indonesia. Site selection was based on purposive criteria: its status as a major production center, the presence of substantial shallot by-product waste, and the local community's direct experience with waste management challenges. The study was conducted over a six-month period encompassing instrument development, field data collection, and data analysis.

2.3. Population and sample

The target population comprised all individuals residing in shallot production center areas of Brebes Regency with direct or indirect relationships to shallot production and waste management activities. The sample size of 180 respondents was determined using the formula, recommending 15–20 observations per predictor variable for multiple regression analysis. With nine predictors (three independent and six sociodemographic control variables), the minimum requirement was $9 \times 20 = 180$ respondents, also exceeding the threshold recommended, namely $N \geq 50 + 8\ m = 122$.

Respondents were selected using proportional random sampling. The production center area was stratified by sub-district, and respondents were randomly selected proportional to each sub-district's population size. Inclusion criteria were: i) minimum age of 19 years, ii) residence in the production center area for at least one year, and iii) voluntary willingness to participate. Exclusion criteria included individuals unable to communicate effectively, those refusing to complete the questionnaire entirely, or those residing in the area for less than one year.

2.4. Research instruments

The instrument was a structured questionnaire comprising five sections: sociodemographic characteristics, government role (12 items), infrastructure (10 items), community knowledge (12 items), and perceptions of waste management (10 items). All attitudinal items were measured using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Content validity was established through expert review by three academics. Construct validity was assessed through a pilot study of 30 respondents using Pearson product-moment correlation, with items retained if the r-calculated exceeded the r-table ($\alpha = 0.05$, df = 28; r-table = 0.361). Reliability was tested using Cronbach's Alpha with an acceptance threshold of ≥ 0.78, exceeding the commonly recommended minimum of 0.70. All retained items satisfied both thresholds.

2.5. Data collection technique

Data were collected through structured face-to-face interviews administered by trained enumerators. This method was chosen because the majority of respondents had low educational attainment (57.2% completed only elementary school), necessitating assistance to ensure proper comprehension. Enumerators underwent standardized training covering interview procedures, research ethics, and probing techniques. Written informed consent was obtained from all respondents prior to participation.

2.6. Data analysis techniques

Data analysis proceeded sequentially. First, descriptive analysis characterized respondent profiles through frequency distributions, percentages, means, and standard deviations. Second, gap analysis identified discrepancies between actual and ideal conditions (100%) across indicators. Third, classical assumption tests were conducted, including multicollinearity (VIF < 10), autocorrelation (Durbin-Watson), normality (Kolmogorov-Smirnov), and heteroscedasticity (Glejser test). Fourth, hierarchical multiple linear regression was performed: sociodemographic control variables were entered in the first block, followed by the three independent variables in the second block, to isolate unique predictor contributions while controlling for potential confounding variables. Fifth, Spearman's rank correlation measured bivariate associations, including ordinal sociodemographic variables. Sixth, effective contribution (SE) and relative contribution (SR) analyses determined each predictor's proportional contribution to explained variance. All analyses were conducted at $\alpha = 0.05$ using SPSS version 26.0.

3. RESULTS

Based on Table 1, the sociodemographic characteristics of the 180 respondents show that the proportion of female respondents (51.7%) is slightly higher than that of male respondents (48.3%). The average age of respondents was 42.59 years (SD = 14.692), with an age range of 19 to 87 years. The majority of respondents had an elementary school education (57.2%), followed by junior high school (20.0%) and high school (16.1%), while those with diplomas and bachelor's degrees or above were only a small proportion (1.7% and 5.0%). Most respondents were employed (85.6%), with the type of employment dominated by the "Other" category (63.0%) and farm laborers (37.0%). In terms of income, more than half of respondents (53.3%) had an income ≥ IDR 2,000,000, while 46.7% earned less. Overall, the respondent profile reflects the community in the large production center area, which is dominated by the productive age group with relatively low levels of education and income.

The gap analysis reveals substantial disparities between actual and ideal conditions across knowledge, experience, and infrastructure dimensions of shallot by-product management, as presented in Table 2. Knowledge indicators exhibit the highest gaps, particularly in product utilization awareness (76.1%), recycling program familiarity (75.0%), and program participation (73.9%). The experience dimension shows that management difficulties remain prevalent (78.9% gap), while infrastructure availability demonstrates considerable deficiency

(69.2% gap). Notably, public perception is the sole indicator of achieving ideal conditions (0.0% gap), suggesting that despite significant limitations in knowledge, experience, and facilities, communities maintain favorable attitudes toward waste management. This positive perception constitutes valuable social capital that can serve as a strategic leverage point for future capacity-building interventions and infrastructure development programs.

Based on Table 3, the results of multiple linear regression analysis show that the three independent variables simultaneously have a significant effect on the perception of shallot by-product (waste) management, as evidenced by the F-statistic value of 37.18 ($p < 0.001$). Partially, the role of government ($\beta = 0.342$, $p < 0.001$), infrastructure ($\beta = 0.298$, $p < 0.001$), and public knowledge ($\beta = 0.152$, $p = 0.007$) each have a positive and significant effect on the dependent variable. The coefficient of determination (Adj. R^2) of 0.378 indicates that the three independent variables are able to explain 37.8% of the variation in perception of shallot waste management, while the remaining 62.2% is explained by other factors outside the model. Based on the standardized coefficient value (β), the role of government is the most dominant predictor, followed by infrastructure and public knowledge. The regression model also meets the classical assumptions, indicated by the VIF value of all variables below 10 (free from multicollinearity) and the Durbin-Watson value of 1.856, which is close to 2 (no autocorrelation).

Table 1. Sociodemographic characteristics of respondents

No	Characteristics	Category	Frequency (n)	Percentage (%)	Descriptive statistics
1	Gender	Man	87	48.3	
		Woman	93	51.7	
2	Age (years)				Min = 19; Max = 87; Mean = 42.59; SD = 14.692
3	Education	Elementary school	103	57.2	
		Junior high school	36	20.0	
		Senior high school	29	16.1	
		Diploma	3	1.7	
		Bachelor, Magister, and Doctor	9	5.0	
4	Employment status	Work	154	85.6	
		Doesn't work	26	14.4	
5	Type of work	Farm workers	57	37.0	
		Other	97	63.0	
6	Income	< Rp. 2,000,000	84	46.7	
		≥ Rp. 2,000,000	96	53.3	

Table 2. Gap analysis comparing knowledge, experience, and public perception indicators

No	Dimensions	Indicator	Actual condition (%)	Ideal condition (%)	Gap (%)	Intervention priorities
1	Knowledge	Knowledge of onion by-products	49.4	100	50.6	High
2	Knowledge	Environmental impact awareness	31.7	100	68.3	Very high
3	Knowledge	Ever heard of recycling programs?	25.0	100	75.0	Very high
4	Knowledge	Understanding the benefits of recycling	28.3	100	71.7	Very high
5	Knowledge	Knowledge of the use of valuable products	23.9	100	76.1	Very high
6	Knowledge	Participation in management programs	26.1	100	73.9	Very high
7	Experience	Service involvement program	50.0	100	50.0	High
8	Experience	No management difficulties	21.1	100	78.9	Very high
9	Infrastructure	Average availability of facilities	30.8	100	69.2	Very high
10	Perception	Positive perception (Good + Very good)	100	100	0.0	Achieved

Table 3. Multiple linear regression results

Variables	B	Std. Error	β	t	p-value	VIF
(Constant)	35.450	5,230		6.78	< 0.001	
Role of government (X_1)	0.425	0.078	0.342	5.45	< 0.001	1.52
Infrastructure (X_2)	0.512	0.095	0.298	5.39	< 0.001	1.58
Knowledge (X_3)	1.234	0.456	0.152	2.71	0.007	1.23
Model statistics						
R/R^2/Adj. R^2		0.623/0.388/0.378				
F-statistic (df = 3; 176)		37.18			< 0.001	
Standard error of estimate		11.72				
Durbin-watson		1.856				
N		180				

Notes: Dependent variable = Variable Y, B = Unstandardized regression coefficient,
β = Standardized regression coefficient, and VIF = Variance inflation factor.

Based on Table 4, the results of the Spearman rank correlation analysis show that the three main variables, public knowledge (rs = 0.356; p < 0.01), infrastructure (rs = 0.489, p < 0.01), and government role (rs = 0.534, p < 0.01), have a significant positive relationship with perceptions of shallot by-product (waste) management. The role of the government shows the highest correlation with perceptions, followed by infrastructure and public knowledge. In addition, there is a fairly strong intercorrelation between infrastructure and government roles (rs = 0.567, p < 0.01), indicating that the availability of waste management infrastructure is closely related to government intervention. Sociodemographic variables such as education also correlate significantly with perceptions (rs = 0.203, p < 0.01), while age does not show a significant relationship (rs = 0.124, p > 0.05). These findings confirm that institutional and infrastructure factors play a more dominant role than individual characteristics in shaping public perceptions of shallot waste management in production center areas.

Based on Table 5, it can be explained that the three predictor variables together provide a total effective contribution (SE) of 39.11% to the variation in perception of shallot by-product (waste) management, which is also the R^2 value. The government role variable (X_1) provides the largest effective contribution, namely 18.74% (SR = 48.30%), followed by infrastructure (X_2) at 14.96% (SR = 38.56%), and public knowledge (X_3) at 5.41% (SR = 13.94%). This finding indicates that the role of the government is the most dominant factor that determines public perceptions of shallot waste management in production center areas, while public knowledge provides the smallest contribution. The remaining 60.89% is influenced by other factors outside this research model that were not examined.

Table 4. Spearman rank correlation matrix between main variables

Variables	Age	Education	Income	Knowledge	Infrastructure	Role of government	Perception
Age	1.000	-0.312**	-0.185*	-0.198**	-0.142	0.087	0.124
Education		1.000	0.345**	0.267**	0.189*	0.156*	0.203**
Income			1.000	0.178*	0.215**	0.134	0.187*
Knowledge				1.000	0.423**	0.312**	0.356**
Infrastructure					1.000	0.567**	0.489**
Role of government						1.000	0.534**
Perception							1.000

Notes: *p < 0.05; **p < 0.01.

Table 5. Effective and relative contribution of each predictor

Variables	β (Standardized)	r (with Y)	SE (β × r × 100%)	SR (SE/R^2×100%)
Role of government (X_1)	0.342	0.548	18.74%	48.30%
Infrastructure (X_2)	0.298	0.502	14.96%	38.56%
Knowledge (X_3)	0.152	0.356	5.41%	13.94%
Total			39.11% ≈ R^2	100%

4. DISCUSSION

The present study investigated the determinants of public perception regarding shallot by-product (waste) management in production center areas, focusing on three principal predictors: the role of government, infrastructure availability, and public knowledge. The findings reveal a complex interplay among these variables, with the government role emerging as the most dominant predictor, followed by infrastructure and public knowledge. These results are consistent with the broader waste management literature, which consistently identifies institutional and infrastructure factors as critical determinants of community engagement and perception in waste management systems [13]-[15].

The multiple linear regression analysis (Table 3) demonstrates that the role of government is the most influential predictor of public perception of shallot waste management, with the highest standardized coefficient (β = 0.342, p < 0.001) and the largest effective contribution of 18.74% (Table 5). The Spearman rank correlation analysis further corroborates this finding, showing that the government role has the strongest correlation with perception (rs = 0.534, p < 0.01) among all main variables (Table 4). This dominance of the government role is consistent with findings from Inaku *et al.* [13], who reported that the role of government and community leaders had a significant relationship with public perceptions of plastic waste management on Kelapa Island, Indonesia (p-value = 0.002). Similarly, Rousta *et al.* [15] found in their meta-analysis of household waste sorting participation in developing countries that governmental incentives significantly influence participation, and that trust and satisfaction with the waste management system and laws introduced by the government have a significant effect on waste sorting participation. This underscores the notion that in developing country contexts, where institutional frameworks are often nascent, the government's visible commitment through regulation, program implementation, and community engagement serves as a critical signal that shapes how communities perceive and respond to waste management initiatives [16]-[20].

The strong intercorrelation between infrastructure and government roles ($rs = 0.567$, $p < 0.01$) observed in Table 4 further suggests that the availability of waste management infrastructure is closely tied to government intervention. This finding aligns with the argument advanced by Herdiansyah *et al.* [14], who noted that communities cannot carry out waste management activities independently and require support from relevant agencies, which play a role in providing infrastructure, education, and law enforcement. In Nigeria, Abila *et al.* [21] similarly documented that limited solid waste infrastructure is one of the major contributing factors to poor waste management systems, and that waste management operates across all governmental levels. Government action is not merely a standalone predictor but also an enabler of infrastructure provision, creating a synergistic effect on public perception [22]-[24].

Infrastructure availability emerged as the second most important predictor of public perception ($\beta = 0.298$, $p < 0.001$), with an effective contribution of 14.96% and a relative contribution of 38.56% (Table 5). The Spearman correlation between infrastructure and perception was also substantial ($rs = 0.489$, $p < 0.01$). However, the gap analysis (Table 2) reveals that the average availability of facilities stands at only 30.8%, representing a gap of 69.2% from the ideal condition classified as a "very high" intervention priority. This stark deficit in infrastructure underscores a fundamental challenge in large production center areas: despite the community's positive perception of waste management, the physical means to operationalize effective management remain severely lacking.

This finding resonates with the broader literature on waste management in developing countries. Perceived behavior control, which is influenced by the availability of waste facilities, significantly affects participation in waste sorting, and the probability of participation increases when people perceive satisfaction with the availability, user-friendliness, and accessibility of these facilities [25]-[27]. Things encouraging pro-environment activities are influenced by the presence of facilities, knowledge, opportunities, and inconvenience [28], [29]. The gap analysis found that 78.9% of respondents still experience management difficulties (Table 2), directly reflecting the consequences of inadequate infrastructure, confirming that without tangible physical support systems, even well-intentioned communities face significant barriers to effective waste management [30]-[32].

The case of Faganel and Streicher [33] provides additional comparative insight, as their structural model demonstrates that waste infrastructure directly impacts the consistency of waste separation behavior. Their use of Spearman's correlation coefficient to test the relationship between knowledge of waste separation and consistent waste separation behavior parallels the analytical approach employed in the present study, reinforcing the methodological robustness of using non-parametric correlation techniques for ordinal and non-normally distributed data in waste management research [33], [34].

Public knowledge, while statistically significant ($\beta = 0.152$, $p = 0.007$), contributed the least among the three predictors, with an effective contribution of only 5.41% and a relative contribution of 13.94% (Table 5). The Spearman correlation between knowledge and perception was moderate ($rs = 0.356$, $p < 0.01$). The gap analysis paints a particularly concerning picture of the knowledge dimension: knowledge of the utilization of valuable products recorded the highest gap at 76.1%, followed by awareness of recycling programs (75.0%), participation in management programs (73.9%), understanding the benefits of recycling (71.7%), and awareness of environmental effects (68.3%). Only the indicator of knowledge of onion by-products showed a relatively lower gap at 50.6%.

These findings are consistent with the meta-analysis by Rousta *et al.* [15], who reported that knowledge has a positive but relatively weak correlation ($r = 0.14$) with waste sorting participation in developing countries, and that despite its influence, knowledge alone is insufficient to drive behavioral change without complementary factors such as infrastructure and governmental support. Inaku *et al.* [13] similarly found that knowledge had a significant but weak positive correlation with public perception of plastic waste management ($r = 0.184$), noting that the basis for individuals to build perceptions of events in the surrounding environment is knowledge, but that this relationship is moderated by environmental and institutional factors. A Moderate-positive correlation (0.512) between community knowledge level and littering behavior suggests that while knowledge is an important domain, it is not the only one in shaping behavior [35].

The relatively low contribution of knowledge compared to the government role and infrastructure can be explained by the sociodemographic profile of the respondents. Table 1 shows that 57.2% of respondents had only an elementary school education, and 46.7% earned less than IDR 2,000,000. This low educational attainment likely constrains the community's capacity to acquire and process information about waste management technologies and recycling benefits. As Inaku *et al.* [13] observed, low education ultimately causes knowledge about waste processing to be very lacking, particularly when not all levels of education include curriculum on waste processing. Mabadahanye *et al.* [36] also found a complex relationship between education and environmental awareness, noting that education level showed a significant negative correlation with awareness of wastewater treatment plants, suggesting that the relationship between formal education and environmental knowledge is not always clear and may be context-dependent.

The universally positive perception observed in this study may reflect a strong moral norm or social expectation within the community regarding waste management, even when practical engagement remains limited. Suryanti *et al.* [37] found a similar dynamic in Surakarta City, where public perception of waste management showed a significant negative correlation with waste volume ($r = -0.598$), indicating that higher perceptions of waste management were associated with lower waste volumes, but also highlighting that perception alone does not guarantee effective management outcomes.

The correlation analysis (Table 4) reveals that sociodemographic variables play a relatively minor role compared to institutional and infrastructure factors. Education correlates significantly but weakly with perception ($rs = 0.203$, $p < 0.01$), while age shows no significant relationship ($rs = 0.124$, $p > 0.05$). Income shows a modest significant correlation with perception ($rs = 0.187$, $p < 0.05$). These findings are consistent with the meta-analysis by Rousta *et al.* [15], who concluded that socio-demographic factors have the weakest influence on participation in waste sorting in developing countries despite a large body of research on such factors. Lukman *et al.* [38] similarly found that education level showed a significant correlation with environmental perception in Karimunjawa, Indonesia, using Spearman rank analysis, but that the relationship was complex and context-dependent.

The key determinants of public perception of shallot by-product management, ranked by predictive strength, are: government role ($\beta = 0.342$, SE = 18.74%), infrastructure availability ($\beta = 0.298$, SE = 14.96%), and public knowledge ($\beta = 0.152$, SE = 5.41%). The robustness of these relationships is confirmed through triangulation of multiple linear regression, Spearman rank correlation, and effective contribution analyses, all yielding consistent hierarchical patterns. Regarding community nutrition implications, shallot by-products contain bioactive compounds including flavonoids, quercetin, and organosulfur compounds with documented antioxidant and anti-inflammatory properties that hold potential for food fortification and nutraceutical development. The gap analysis reveals that 76.1% of respondents lack knowledge of valuable product utilization, suggesting that substantial nutritional resources embedded in shallot waste remain unexploited. Strengthening government-led programs and infrastructure for by-product processing could simultaneously reduce agricultural waste and enhance community access to nutrient-rich derived products, thereby linking waste management improvements directly to nutritional outcomes in production center communities.

5. CONCLUSION

This study provides a scientific contribution in the form of a predictive model for shallot waste management based on a socio-infrastructural approach in agrarian communities. The respondent profile was dominated by productive age (mean 42.59 years) with low education (57.2% elementary school) and a majority employed (85.6%). Gap analysis revealed substantial deficiencies in knowledge, experience, and infrastructure (50.0–78.9%), although community perception had reached ideal conditions (gap 0.0%), rendering it a strategic social capital as a leverage point for intervention. Multiple linear regression confirmed that government role ($\beta = 0.342$, SE = 18.74%), infrastructure ($\beta = 0.298$, SE = 14.96%), and knowledge ($\beta = 0.152$, SE = 5.41%) significantly influenced waste management perceptions ($F = 37.18$, $p < 0.001$, Adj. $R^2 = 0.378$).

For practical implementation, it is recommended that: i) Local governments formulate integrated shallot waste management regulations embedded within village-level policies; ii) Communal composting facilities be established as priority infrastructure; and iii) Participatory extension-based education programs be developed targeting low-literacy populations. These findings are directly linked to food and nutrition policies, as sustainable shallot waste management supports food safety by reducing agricultural environmental contamination and enabling waste valorization into organic fertilizer, thereby enhancing horticultural productivity and nutritional quality.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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