J. ISSAAS Vol. 32, No. 1:188-203 (2026)

FACTORS IMPACTING CONSUMER SATISFACTION FOR HYDROPONICALLY GROWN TOMATOES IN HINO CITY, JAPAN

Hettige Samitha Lakshan Gunasekara[*1], Nina N. Shimoguchi[2], Rika Terano[2], Ramadhona Saville[2] and Katsumori Hatanaka[2],
[1]Graduate School of International Food and Agricultural Studies
Tokyo University of Agriculture, Tokyo, Japan
[2]Faculty of International Agriculture and Food Studies,
Tokyo University of Agriculture
1-1-1 Sakuragaoka, Setagaya-ku, Tokyo, Japan, 156-8502
[*]Corresponding author: 13823001@nodai.ac.jp

(Received: March 7, 2025; Accepted: May 28, 2026)

ABSTRACT

Small-scale tomato farmers play a significant role in Japan, where understanding consumer preferences is essential to optimize production and meet market demand. This study aimed to identify the key attributes that contribute to consumer satisfaction and to determine how demographic and purchasing behaviors affect preferences for hydroponically grown tomatoes from a small-scale farm in Hino City, Tokyo, using a data-driven decision-making approach. Data were collected from 154 respondents using a structured questionnaire. Factor analysis revealed two primary dimensions of satisfaction: appearance (freshness, color, and size) and taste (flavor and sweetness). Demographic factors such as age and income significantly influenced satisfaction. Younger consumers prioritized taste, older consumers prioritized appearance, and higher-income groups expressed greater satisfaction with the visually appealing tomatoes. Distribution channels, such as unstaffed vegetable shops and supermarkets, enhanced consumers' perceptions of appearance. These findings demonstrated how data-driven approaches can help small-scale farmers meet consumer demands better and enhance profitability and sustainability. The methodology of this study was found to be applicable to other regions, particularly in Southeast Asia, where a high density of small-scale farmers could use these insights to optimize production, improve marketing strategies, and strengthen resilience in competitive markets.

Key words: agribusiness, consumer behavior, data-driven decision making

INTRODUCTION

Agriculture remains the primary source of food and nutrition globally, with small-scale farmers supplying approximately 80% of the world's food demand (Samberg et al. 2016). In Asia, particularly Southeast Asia, small-scale farmers are the backbone of agricultural production and play a critical role in ensuring food security for rapidly growing populations (UNCTAD 2015). However, these farmers face increasing challenges, including climate variability, changing consumer behavior, and intensifying competition within agri-food markets (Falvey 2019; Mikolajczyk et al. 2021; Sebastian and Bernardo 2019). These pressures have heightened the need for production and marketing strategies that are both resilient and responsive to local consumer demand.

Greenhouse-based and hydroponic production systems have emerged as important technological responses to environmental uncertainty by enabling controlled growing conditions and more stable yields (Savvas and Gruda 2018). Across Asia, small-scale farmers are increasingly adopting greenhouse technologies to improve productivity and reduce climate-related risks. Empirical studies have demonstrated the effectiveness of greenhouse cultivation for crops such as onions in the Philippines (Pascual et al. 2018), leafy vegetables in Indonesia (Athifa et al. 2019), and urban lettuce production (Manongko et al. 2023). In Japan, greenhouse systems account for approximately 80% of national tomato production, reaching 720,000 metric tons in 2021 (MAFF Japan 2022). Despite this technological advancement, many new entrants to greenhouse tomato farming, particularly in urban and peri-urban areas, continue to face economic difficulties, including challenges in market positioning and recovery of initial investment costs.

For small-scale greenhouse producers, understanding consumer behavior and satisfaction is essential for aligning production and marketing decisions with local demand. Prior research indicates that consumer evaluation of fresh vegetables is influenced by multiple attributes, including taste, freshness, appearance, variety, production origin, and certification, with preferences varying across regions and marketing channels (Duc et al. 2023; Grunert 2024). Such heterogeneity makes it difficult for small-scale farmers to accurately identify the most influential satisfaction drivers based solely on intuition or informal observation. Misinterpretation of consumer preferences can lead to inappropriate strategies and investments, increasing financial risks. In particular, previous studies highlight that consumers often associate higher satisfaction with product diversity, store atmosphere, and short supply chain channels, while factors such as location may play a less significant role depending on the context (Azhari et al. 2023; Platania et al. 2015). Furthermore, studies on direct marketing and retail distribution channels emphasize the importance of understanding where consumers purchase products, as channel choice significantly shapes perceived quality, freshness, and consumer satisfaction (Gunden et al. 2010).

Several studies have examined agricultural development and tomato consumer behavior in Hino City, Tokyo, using a comprehensive analytical perspective. Institutional and municipal support systems for new farmers, focusing on policy frameworks, land access, and subsidy mechanisms, were investigated (Terano et al. 2023). Building on the institutional context, Shimoguchi et al. (2024) analyzed tomato purchasing behavior, consumer satisfaction, and brand familiarity among consumers who had prior experience purchasing from a specific new farm (NF Farm). Using the same survey framework and study location, this research was extended by examining the broader local tomato market through consumer segmentation analysis, incorporating all valid consumer responses regardless of farm-specific purchasing experience (Gunasekara et al. 2024).

Data-driven decision-making (DDDM) offers a systematic approach to understanding complex consumer behavior by grounding managerial decisions in empirical evidence rather than assumptions based on personal experience alone. DDDM emphasizes the structured collection, analysis, and interpretation of data to support strategic and operational decisions, enabling organizations to improve accuracy, efficiency, and consistency in decision processes (Joubert 2024). Empirical research across multiple sectors demonstrates that organizations adopting data-driven approaches achieve superior performance outcomes, innovation capacity, and more effective resource allocation compared to intuition-based decision systems (ZareRavasan 2021).

Evidence from non-agricultural industries further highlights the broad applicability of DDDM. In advanced manufacturing systems, data-driven decision frameworks have been shown to improve productivity, process stability, and operational efficiency by enabling real-time monitoring, analytical modeling, and evidence-based managerial control (Zhang et al. 2016). Similarly, further studies in the financial sector report a positive and statistically significant relationship between DDDM practices and organizational productivity, underscoring the value of data analytics for performance improvement even in highly regulated and service-oriented environments (Prakash 2024). These findings suggest that

the principles of DDDM are transferable across sectors when appropriately adapted to context-specific constraints and decision needs. Within food systems, data-driven approaches have also demonstrated strong potential to enhance planning, monitoring, and policy responsiveness. Data-driven models integrating market prices, climatic indicators, and demographic variables have significantly improved the timeliness and spatial precision of food insecurity crisis prediction compared to expert-based assessment frameworks alone (Lentz et al. 2019).

Despite these demonstrated benefits, the application of DDDM within small-scale agribusiness, particularly at the farm level, remains limited. Small-scale farmers often face significant barriers to adoption, including limited financial resources, technical capacity, data management skills, and institutional support (Brandy 2023; John et al. 2023). Furthermore, data analytics is often associated with large-scale big-data infrastructures, machine learning, or artificial intelligence, which can discourage adoption among smallholders who lack the experience or resources to implement such systems (Joubert 2024). However, prior research studies emphasize that effective DDDM does not necessarily require complex, data-intensive models. Even relatively simple analytical techniques such as descriptive statistics, regression analysis, and multivariate analysis can generate meaningful and practical insights when aligned with clearly defined decision objectives and modest data availability (Lentz et al. 2019).

Consequently, there remains a critical research gap in demonstrating how DDDM can be practically adopted to the realities of small-scale consumer-oriented agribusinesses. In particular, there is limited empirical evidence on how small-scale agribusinesses can use consumer data to systematically identify drivers of satisfaction, reduce decision uncertainty, and support market-oriented production and marketing strategies. Addressing this gap is essential to enabling small-scale farmers to leverage data analysis as a practical decision-support tool.

This study adopted a case study approach focusing on a small-scale hydroponic tomato farm (NF Farm) located in Hino City, Tokyo. NF Farm represented a typical example of urban, consumer-oriented greenhouse farming, where production technologies are relatively advanced, but market-oriented decision support remains limited. Therefore, this study sought to examine how DDDM can be applied in practice to support small-scale agribusiness through a case study of a hydroponic tomato farm, by identifying critical drivers of consumer satisfaction and translating them into practical production and marketing strategies. This research contributed empirically and methodologically to the literature while offering practical value for small-scale farmers by adapting data-driven methods typically used in large-scale agribusiness to a small-farm context. Beyond the case setting, the approach provides a replicable framework for small-scale agribusiness, particularly in Southeast Asia, where localized consumer insights are essential for long-term profitability and sustainable farm management.

MATERIALS AND METHODS

This study was based on the NF Farm, a small-scale hydroponic greenhouse tomato producer in Hino City, Tokyo, Japan. This farm was selected as the focus of this study because it represents a new entrant in the Japanese tomato agribusiness sector that utilizes smart hydroponic technologies. NF Farm primarily serves the local market in Hino City, distributing its tomatoes through a variety of channels, including local supermarkets, direct farmers shop (DFS) (in Japanese, “choku-bai-jo”), and unstaffed vegetable sales shop (UVSS) (in Japanese, “mujin-ten”).

(a) Supermarket (b) Unstaffed vegetable sales shop

Figure 1. Multiple distribution channels of NF Farm

Data collection. The study sample comprised consumers who purchased tomatoes from NF Farm. By approaching these buyers through various local distribution channels, including local supermarkets, DFS, and UVSS, this sampling strategy captured a highly diverse participant profile. Data were collected between May 1 and June 30, 2022, using a structured questionnaire via face-to-face at selected market locations. QR codes linked to Google Forms were also utilized to facilitate online participation; these were displayed on tomato shelves in DFS and UVSS outlets, printed on NF Farm product packages, and advertised on farm's business website and social media platforms. The questionnaire was designed to gather information on consumer demographics (e.g., age, gender, family structure, and annual household income), purchasing behavior (e.g., purchase location, spending per purchase, and frequency of buying tomato types), and satisfaction with NF Farm tomatoes. Participants were asked to rate eight tomato attributes-including freshness, color, peel hardness, flavor, acidity level, sweetness, price, and size, using a 4-point Likert scale ranging from 1 (very unsatisfied) to 4 (very satisfied).

Data for this study were obtained from a broader consumer survey (N = 470 total responses) conducted in Hino City. Distinct subsamples from this survey have been used across related studies depending on research objectives and analytical requirements. For instance, a consumer segmentation study analyzed 316 valid responses from local tomato consumers to evaluate overall market structure and consumer heterogeneity, regardless of farm-specific purchasing experience (Gunasekara et al. 2024). Conversely, a consumer satisfaction and brand familiarity study focused exclusively on 213 respondents who had prior experience purchasing tomatoes from NF Farm (Shimoguchi et al. 2024). For the present study, an initial subset of 169 responses from NF Farm consumers were extracted; following data cleaning to remove incomplete and invalid responses, 154 valid responses were retained for the final analysis. These sample size variations reflect purposeful screening procedures aligned with distinct research objectives rather than inconsistencies in data collection.

Data analysis. Descriptive statistics were first utilized to summarize respondents' demographic characteristics and purchasing behaviors, establishing a baseline overview of the consumer sample. Factor analysis (FA) was subsequently conducted to identify the latent dimensions underlying consumer satisfaction with the hydroponically grown tomatoes. The suitability of the dataset for factor extraction was verified using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Kaiser 1974; Bartlett 1950). Factors were extracted based on cumulative explained variance, and variables with factor loadings greater than 0.7 were retained, following the established guidelines for interpretive strength (Hair et al. 2010). In addition, both Varimax and Promax rotation methods were tested to enhance factor interpretability and confirm the robustness of the factor structure.

Analysis of Variance (ANOVA) was performed to examine differences in the identified satisfaction factors across demographic groups and purchasing behavior categories. Wherever significant differences were detected, Tukey's honestly significant difference test was used for post-hoc pairwise comparisons (Wilcox et al. 2000). In addition, cross-tabulation and Chi-square tests of independence were used to examine associations between categorical variables for groups showing significant or notable differences, with statistical significance established at the 5% level (Hair et al. 2010).

RESULTS AND DISCUSSION

This section presents and discusses empirical findings in relation to existing literature and their implications for small-scale hydroponic tomato farming, with a focus on NF Farm.

Respondents profile. The descriptive results of the respondents' demographic characteristics (Table 1) show that those within the age groups of 40–59 years (51.94%), alongside the 20–39 years and 60–79 years (22.08% each), represent a relatively mature population, with an average age of 49.5 years. Younger (< 19 years) and older (> 80 years) participants comprised minor proportions of the study population, accounting for 2.60% and 1.30%, respectively. Respondents were predominantly female (74.68%) and most belonged to families with children (54.55%), followed by couples (27.92%) and single individuals (17.53%). Regarding annual household income, upper-tier earners making of over 7 million JPY represented the largest segment at 38.31%, followed by those earning between 3.01 and 5 million JPY (24.68%) and 5.01 and 7 million JPY (20.78%). This profile indicates that NF Farm's consumer base mainly consists of middle-aged, family-oriented, and relatively high-income households, which is relevant when interpreting subsequent satisfaction and preference patterns.

Table 1. Demographic results of respondents (n = 154)

Demographic Variable	Percentage (%)
Age	
Below 19	2.60
20 to 39	22.08
40 to 59	51.94
60 to 79	22.08
Over 80	1.30
Gender	
Female	74.68
Male	25.32
Family Type	
Single	17.53
Husband and wife	27.92
Family with kids	54.55
Annual Household Income (Million JPY)	
Below 2	5.19
2.01 to 3	11.04
3.01 to 5	24.68

Demographic Variable	Percentage (%)
5.01 to 7	20.78
Over 7.01	38.31

Source: Survey results by author 2022

Satisfaction attributes. Table 2 presents the average satisfaction scores and standard deviations (SD) for the tomato attributes. Freshness received the highest satisfaction score of 3.56 (SD = 0.57), followed by color at 3.49 (SD = 0.60) and flavor at 3.44 (SD = 0.68). The lower SD for freshness and color suggests a highly consistent perception of these qualities across respondents. Attributes such as size and acidity were rated slightly lower, yielding scores of 3.40 (SD = 0.61) and 3.32 (SD = 0.62), respectively, but still reflected moderate satisfaction. On the other hand, price scored the lowest at 3.01 (SD = 0.70), demonstrating that consumers were least satisfied with this aspect. Collectively, these results indicate that appearance, quality and freshness contribute much more strongly to consumer satisfaction than price. This finding is consistent with previous studies highlighting the importance of appearance and freshness in fresh produce evaluation (Causse et al. 2010; Grunert 2024; Gunden et al. 2010).

Table 2. Descriptive statistics of consumer satisfaction attributes for hydroponically grown tomatoes (n=154)

Variable	Mean	Standard Deviation (SD)
Freshness	3.56	0.57
Color	3.49	0.60
Flavor	3.44	0.68
Size	3.40	0.61
Acidity	3.32	0.62
Hardness of peel	3.27	0.66
Sweetness	3.27	0.66
Price	3.01	0.70

Source: Survey results by Author 2022

Underlying dimensions of consumer satisfaction.

Factor analysis suitability test. Before conducting factor analysis (FA), the suitability of the dataset was assessed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO value was 0.89, indicating adequate sampling, and Bartlett's test was statistically significant ($\chi^2 = 980.03$, df = 28, $p < 0.001$), confirming that the data matrix was appropriate for factor modelling. Based on these results, factor analysis was conducted, and the results are presented in Table 3.

Factor 1 is defined by robust loadings for freshness (0.81), color (0.80), and size (0.78), clearly representing the "appearance quality" dimension of tomatoes. Factor 2 is defined by sweetness (0.84) and flavor (0.76), representing "taste quality" dimension. These two dimensions align with previous research identifying visual cues as primary drivers of fresh produce evaluation (Causse et al. 2010;

Grunert 2024), while sweetness and flavor are widely recognized as key determinants of tomato preference and purchasing decisions (Bawajeeh et al. 2020; Hoffman et al. 2016).

This clear separation is also consistent with retail-based studies showing that product-related attributes, particularly appearance and taste, are dominant determinants influencing consumer satisfaction (Azhari et al. 2023). Following factor extraction, average factor scores were computed to examine how satisfaction levels across these two dimensions varied across consumer demographics and purchasing behavior.

Table 3. Factor loadings of attributes on appearance and taste satisfaction (n=154).

Variable	Factor 1	Factor 2
Freshness	**0.81**	0.36
Color	**0.80**	0.40
Size	**0.78**	0.39
Hardness of peel	0.63	0.53
Acidity	0.59	0.59
Price	0.44	0.47
Flavor	0.37	**0.76**
Sweetness	0.36	**0.84**

Demographic influences on appearance and taste satisfaction. Table 4 presents the average satisfaction scores for appearance and taste segmented by demographic characteristics. Younger consumers below 19 years old exhibited a strong preference for taste (0.61) and a slight preference for appearance (0.09). In contrast, older consumers over 80 years old showed a higher preference for appearance (0.31) while showing a strong negative directional preference for taste (-1.81, $p < 0.01$). This is consistent with earlier findings that revealed age-related changes in taste perception often led older consumers to focus more on visual and textual attributes than on flavor (Methven et al. 2012; Ogawa et al. 2017). However, no statistical significance was observed between age and taste satisfaction. Thus, it is noteworthy that this finding did not reach true statistical significance due to the small sample size. Further research using a larger sample of older consumers is required to confirm these findings.

With regards to gender, the appearance and taste scores for both males and females were close to zero, suggesting that gender did not significantly influence satisfaction. Additionally, family composition showed no strong or statistically significant relationship with either appearance or taste satisfaction factors, yielding highly similar baseline across groups and indicating that family type may not be the primary driver of tomato satisfaction.

In contrast, notable variations in appearance satisfaction can be identified according to income level. High-income households earning over 7 million JPY reported a significantly higher satisfaction score for appearance (0.21, $p < 0.05$), which may be attributed to their greater access to and expectation of premium quality products. Conversely, while statistically insignificant, the middle-to-high income group earning 5.01 to 7 million JPY recorded negative mean scores for both appearance and taste attributes of the NF Farm tomatoes.

While these localized ANOVA revealed specific significant and directional trends were observed, some categorical associations were not confirmed by Chi-square tests, suggesting that broad demographic effects across the full sample should be interpreted cautiously. Nevertheless, these trends remain practically and highly relevant for localized market targeting strategies at NF Farm. Overall, these findings are consistent with previous studies indicating that demographic characteristics, specifically age and income, exert a powerful influence on consumer satisfaction, perceived quality benchmarks, and willingness to pay (Platania et al. 2015).

Table 4. Average scores of appearances and taste satisfaction by demographic factors (n=154).

Variable	Appearance factor score	Taste factor score
Age (years)		
Below 19	0.09	0.61
20 to 39	0.08	0.09
40 to 59	0.03	-0.03
60 to 79	-0.17	0.01
Over 80	0.31	-1.81*
Gender		
Male	0.07	0.01
Female	-0.02	0.00
Family type		
Single	0.06	0.09
Husband and wife	-0.09	0.01
Family with kids	0.03	-0.03
Annual Household Income (Million JPY)		
Below 2	-0.04	0.24
2.01 to 3	-0.41	0.15
3.01 to 5	0.12	0.01
5.01 to 7	-0.29	-0.27
Over 7.01	0.21*	0.07

Note: Significance code explanation * $p \leq 0.05$

Purchasing behavior and satisfaction patterns. The average satisfaction is based on spending per purchase, purchase location, and tomato type (Table 5). The relationship between spending levels and satisfaction demonstrates that moderate consumers, specifically those who spent 501–700 JPY and 701–1,000 JPY were satisfied with both appearance and taste attributes. However, consumers who spent more than 1,001 JPY showed higher dissatisfaction with taste (-2.70), despite only a slight drop in appearance satisfaction (-0.18). This pronounced mismatch between appearance satisfaction and taste dissatisfaction at higher price levels suggests that expectations increase with price, highlighting the importance of aligning sensory quality with premium positioning to retain the high-value consumer segment. This finding is consistent with previous research indicating that higher price levels increase consumer expectations regarding taste and overall quality (D'Amico et al. 2024).

Furthermore, the distribution channels significantly influenced satisfaction levels. Tomatoes

from UVSS outlets achieved significantly higher appearance satisfaction (0.13, $p \leq 0.001$), likely driven by heightened consumer perception of fresher, locally sourced products. This finding aligns with studies on direct marketing channels, in which consumers associate local and direct purchase outlets with higher perceptions of freshness and quality (Gunden et al. 2010; Platania et al. 2015). In contrast, the differences between tomatoes from DFS outlets and supermarkets were not significant, though supermarket consumers had a high baseline satisfaction with the appearance of tomatoes (0.31). Notably, DFS consumers recorded negative mean factor scores, indicating low satisfaction with both appearance (-0.05) or taste (-0.12) of the NF Farm tomatoes.

Satisfaction levels also varied explicitly across product varieties (Table 5). Among the different tomato types, medium tomatoes yielded significantly lower taste satisfaction (-0.25, $p \leq 0.01$), suggesting an immediate need to improve their flavor profile. In contrast, big tomatoes were rated highest across both satisfaction dimensions, generating positive scores for appearance (0.15) and taste (0.35). This indicates that big tomatoes are successfully meeting consumer expectations for sensory quality. This aligns directly with previous studies showing that consumers who purchase large tomatoes strongly prioritize firmness, juiciness, and flavor (Oltman et al. 2014).

Table 5. Average scores of appearances and taste satisfaction by tomato purchasing behavior (n=154)

Variable	Appearance Factor Score	Taste Factor Score
Paying Price per Purchase [JPY]		
Below 100	-0.97	0.27
101 to 300	-0.04	-0.06
301 to 500	-0.03	-0.03
501 to 700	0.14	0.35
701 to 1000	0.36	0.16
Over 1001	-0.18	-2.70
Tomato distribution channels		
Direct Farmers Shop	-0.05	-0.12
Unstaffed Vegetable Sales Shop	0.13**	0.02
Supermarket	0.31	0.00
Tomato Type		
Cherry	-0.02	0.02
Medium	0.03	-0.25*
Big	0.15	0.35

Note: Significance code explanation * $p \leq 0.05$

Taste satisfaction by age group. The cross-tabulation frequencies present the distribution of respondents' taste satisfaction across age groups (Fig. 2). In the age group below 19 years, three of the four respondents reported being satisfied, suggesting that younger individuals tend to respond positively to the taste of tomatoes. However, the 20–39, 40–59, and 60–79 years age groups had higher

numbers of unsatisfied responses than satisfied responders; over 80 years age group responses were evenly split, with one unsatisfied and one satisfied, due to the small sample size, which should be interpreted with caution. The association between age and taste satisfaction was not statistically significant (χ^2 = 2.31, p = 0.67). Although not statistically significant, these observed patterns are consistent with previous findings on age-related variation in taste perception (Methven et al. 2012).

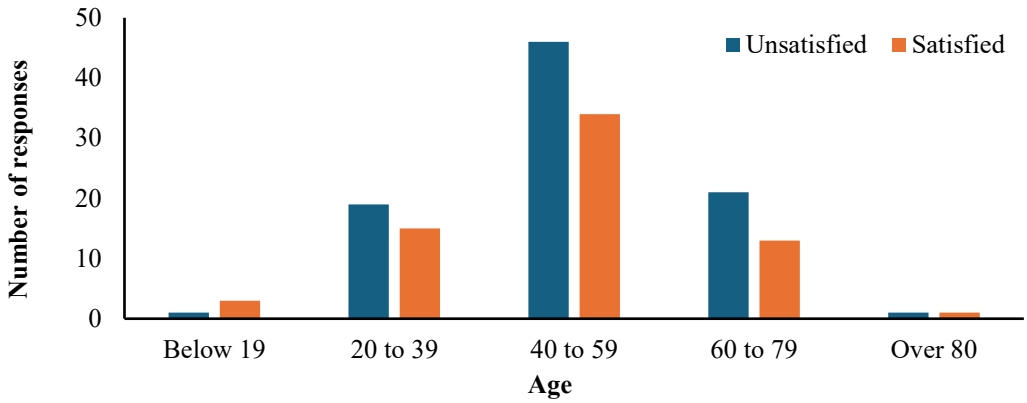

Figure 2. Taste satisfaction by age group
Note: No statistically significant association between age group and taste satisfaction (χ^2 = 2.31, df = 4, p = 0.67).

Appearance satisfaction by income levels. Respondents' satisfaction with tomato appearance varied across annual household income categories (Fig. 3). In this category, more respondents were satisfied than unsatisfied, suggesting that all household income groups were satisfied with the appearance of tomatoes. The Chi-square test results (χ^2 = 9.11) and p-value (0.058) are slightly above the conventional threshold of 0.05, indicating that the results are not statistically significant but suggest a potential association. The marginal significance suggests a possible association between income and satisfaction with appearance, which may become clearer with a larger sample size. This trend is consistent with previous studies indicating that higher-income consumers tend to place greater importance on appearance and quality attributes (Grunert 2024; Platania et al. 2015).

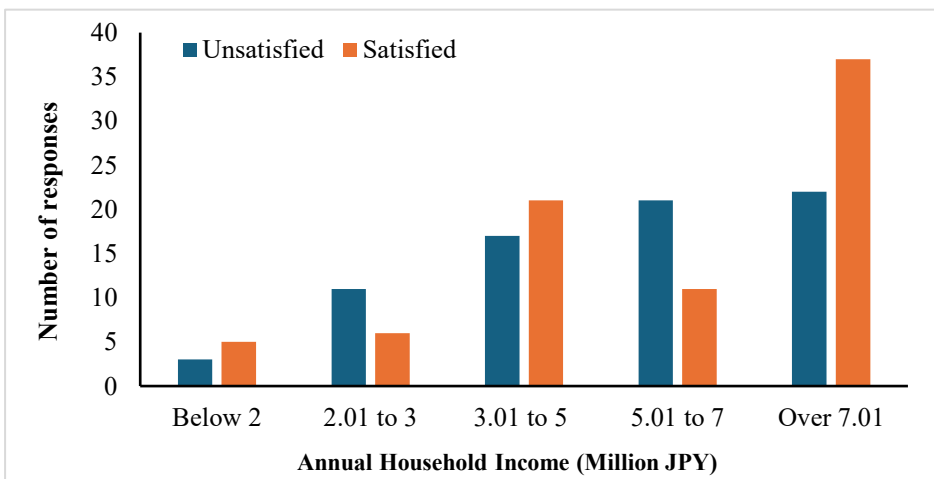

Figure 3. Appearance satisfaction by income level
Note: Marginally non-significant association between income level and appearance satisfaction (χ^2 = 9.11, df = 4, p = 0.058).

Taste satisfaction by tomato type. When examining the distribution of consumer responses (Fig. 4), cherry tomatoes received the highest overall volume of responses. While consumers generally prefer smaller tomatoes for their perceived taste and sweetness (Casals et al. 2018), cherry tomatoes in this study received slightly more unsatisfied responses than satisfied responses. It is noteworthy that Japanese consumers commonly use cherry tomatoes in practical daily lunchboxes ("Bento"). This indicates that, while they are highly appreciated for their convenient size and utility, they do not currently generate strong positive consumer evaluations of taste. Medium tomatoes similarly experienced more dissatisfaction than satisfaction. Big tomatoes were proportionally more satisfactory than medium and cherry tomatoes, though their overall response rate was low. Ultimately, cross-tabulation analysis did not reveal a statistically significant categorical relationship between tomato type and taste satisfaction ($\chi^2 = 1.90$, df = 2, p = 0.39). This suggests that while localized differences exist, the preference patterns are not strong enough to signify a consistent, sample-wide association.

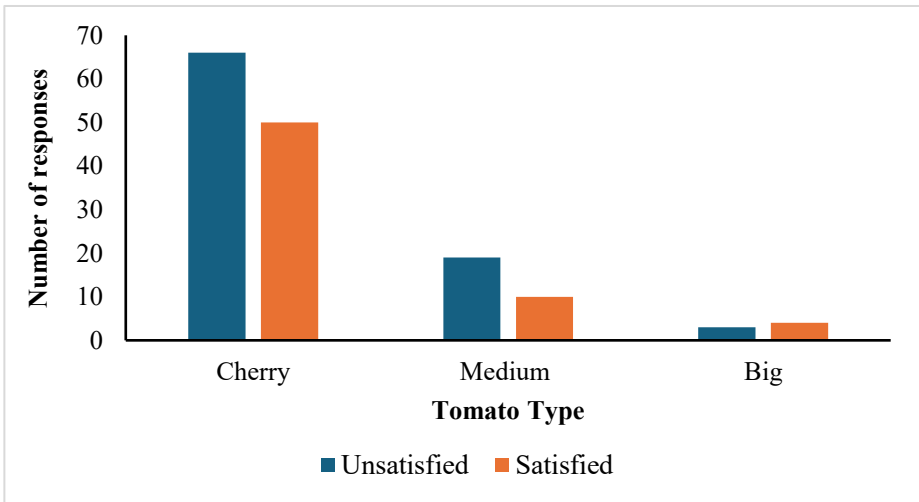

Figure 4. Taste satisfaction by tomato type
Note: No statistically significant association between tomato type and taste satisfaction ($\chi^2 = 1.90$, df = 2, p = 0.39).

Appearance satisfaction and distribution channels. Across purchase locations (Fig. 5), the unstaffed vegetable sales shop (UVSS) yielded the largest proportion of respondents satisfied with the tomato appearance. This favorable response is likely driven by the perception of fresher, locally sourced products. Specifically, the UVSS is located directly in front of the tomato farm, allowing the farmer to refill the stall with freshly harvested tomatoes multiple times a day, thereby minimizing transportation time and maximizing visible freshness. In contrast, the direct farmers' shop (DFS) showed nearly balanced satisfaction scores, even though previous literature indicates that consumers who use DFS outlets typically value local production and freshness (Bavorova et al. 2015). Supermarket purchasers, representing a smaller segment of the sample, were similarly split between satisfied and unsatisfied. Ultimately, a Chi-square test indicated no statistically significant categorical association between distribution channels and overall appearance satisfaction ($\chi^2 = 0.56$, df = 2, p = 0.76). This suggests that while the UVSS model offers a highly favorable consumer experience, the statistical variance across groups was not dominant enough to signify a sample-wide association (Ramadhan et al. 2024).

This finding suggests that while purchase location may influence perceived quality, the strength of this relationship is not statistically significant in this sample. This result is consistent with previous studies showing that purchase location can influence consumer perceptions of product quality and freshness, although the strength of this relationship may vary depending on context and consumer characteristics (Gunden et al. 2010).

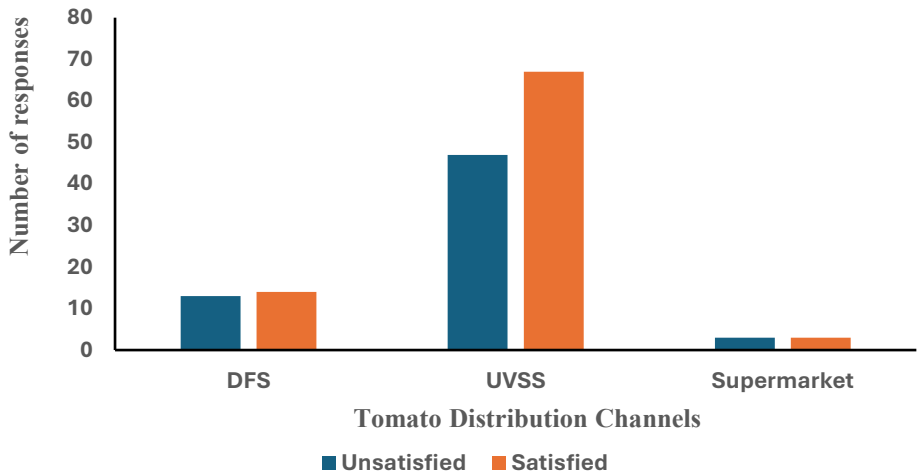

Figure 5. Appearance satisfaction by distribution channels
Note: No statistically significant association between distribution channels and appearance satisfaction ($\chi^2 = 0.56$, df = 2, p = 0.76).

Strategic implications for NF Farm and other small-scale farmers. The findings of this study offered valuable insights for NF Farm and other hydroponic tomato farms. To enhance consumer satisfaction, NF Farm should maintain high standards of appearance and taste, particularly in premium products (D'Amico et al. 2024). Enhancing the flavor profile of medium tomatoes, possibly through selective breeding (Matsukura 2016) and improved nutrient management (Sato et al. 2006), can increase consumer satisfaction. Additionally, expanding distribution through UVSS outlets, where consumers report higher satisfaction, may boost NF Farm's appeal by emphasizing freshness and local sourcing, particularly for high-income consumers. Furthermore, NF Farm should further investigate the reasons why certain income groups and consumers purchasing through DFS are dissatisfied with its tomatoes. Overall, improving the appearance and taste attributes can contribute to building consumer loyalty, which is essential for sustaining market success.

Even though some consumers reported moderate dissatisfaction with certain attributes, purchasing behavior remained positive. Informal interactions during survey administration revealed that several respondents continued to purchase NF Farm tomatoes to support the farmer. This suggests that social support motives and local loyalty may complement product-based satisfaction in shaping repeat purchasing decisions. For small-scale urban farms, maintaining strong community relationships may therefore be as important as improving product attributes.

Although this study was conducted in Japan, its methodology and insights are widely applicable. Factor analysis to assess consumer satisfaction and identify influential attributes is relevant to tomatoes and offers valuable guidance for small-scale farmers in Southeast Asia and other regions with local preferences and market conditions. Using data-driven approaches, farmers can make informed decisions regarding product development, marketing, and resource allocation by understanding

consumer needs (Lentz et al. 2019). This adaptable methodology allows small-scale farmers to align production with consumer demand, optimizing profitability and sustainable practices, regardless of the crop or region.

CONCLUSION

This study investigated the determinants of consumer satisfaction with hydroponically grown tomatoes from a small-scale farm in Hino City, Tokyo, using a DDDM approach. Based on 154 valid consumer responses, factor analysis identified two main dimensions of satisfaction: appearance quality (freshness, color, and size) and taste quality (sweetness and flavor). These findings confirm that both appearance and sensory attributes significantly shape consumer evaluation of fresh tomatoes, with appearance emerging as a particularly influential factor.

Consumer satisfaction patterns were distinctly shaped by demographic characteristics and purchasing behaviors. Younger consumers showed relatively stronger preference for taste attributes, whereas older consumers emphasized appearance characteristics. Higher-income households reported greater satisfaction with appearance, suggesting that appearance quality plays a critical role in premium market segments. Distribution channels also affected perception, with unstaffed vegetable sales shops associated with higher appearance satisfaction, likely due to freshness cues and proximity to production. Methodologically, this study demonstrates that small-scale farms can use practical, accessible data-driven analytical tools without relying on complex big-data systems. Even with moderate sample sizes, structured statistical techniques can generate actionable managerial insights by translating consumer feedback into empirical evidence, thereby reducing decision uncertainty and aligning production strategies with market demand.

This study has several limitations that should be considered when interpreting the results. This research was conducted based on a single case study site (NF Farm in Hino City, Tokyo) and focused solely on hydroponically grown tomatoes. Therefore, these findings may not be generalizable to other geographic regions, farming systems, or crop types. Although this study demonstrates DDDM's potential to enhance consumer satisfaction, many small-scale farmers face challenges understanding or implementing it due to limited technical knowledge or resource constraints.

For further study, replication of this methodology across multiple regions and crops is suggested to address these limitations and validate its applicability and adaptability. Additionally, collaborative efforts involving third-party organizations, agricultural extension services, and digital platforms may also be explored to provide small-scale farmers with accessible, affordable, and user-friendly data analysis tools, helping bridge the gap between data availability and practical decision-making and ultimately supporting more inclusive and sustainable agribusiness development.

ACKNOWLEDGEMENT

The authors thank the NF Farm proprietors, student enumerators at the Tokyo University of Agriculture, and the respondents for their insightful feedback and active participation in planning and execution, which helped shape the study findings. This research received no external funding.

CONFLICT OF INTEREST

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript. All authors confirm that they have complied with the Code of Ethics of the Journal of the International Society for

Southeast Asian Agricultural Sciences (J ISSAAS) and affirm that the research presented is original, free from plagiarism, and ethically conducted in accordance with the journal's guidelines.

REFERENCES CITED

Athifa, R. I., Astuti, A., and Wibowo, A. S. 2019. Analisis ekonomi usahatani sayuran oriental dengan sistem hidroponik NFT tanpa naungan greenhouse. Jurnal Agribisnis Terpadu. 12(1):15–27. https://doi.org/10.33512/jat.v12i1.5531

Azhari, A., A. Firman, A. Khalik and A.R. Oktaviani. 2023. The effect of location, product diversity, and store atmosphere on increasing customer satisfaction. Adv. Bus. Ind. Mark. Res. 1(4):108-116.

Bartlett, M. S. 1950. Tests of significance in factor analysis. British Journal of Statistical Psychology. 3(2):77–85. https://doi.org/10.1111/j.2044-8317.1950.tb00285.x

Bavorova, M., Unay-Gailhard, I., and Lehberger, M. 2015. Who buys from farmers' markets and farm shops: The case of Germany. International Journal of Consumer Studies. 40(1):107–114. https://doi.org/10.1111/ijcs.12220

Bawajeeh, A. O., Albar, S. A., Zhang, H., Zulyniak, M. A., Evans, C. E. L., and Cade, J. E. 2020. Impact of taste on food choices in adolescence: Systematic review and meta-analysis. Nutrients. 12(7):1985. https://doi.org/10.3390/nu12071985

Brandy, S. 2023. Overcoming challenges and unlocking the potential: Empowering small and medium enterprises with data analytics solutions. International Journal of Information Technology and Computer Science Applications. 1(3):150–160.

Casals, J., Rivera, A., Sabaté, J., Del Castillo, R. R., and Simó, J. 2018. Cherry and fresh market tomatoes: Differences in chemical, morphological, and sensory traits and their implications for consumer acceptance. Agronomy. 9(1):9.

Causse, M., Friguet, C., Coiret, C., Lépicier, M., Navez, B., Lee, M., Holthuysen, N., Sinesio, F., Moneta, E., and Grandillo, S. 2010. Consumer preferences for fresh tomatoes at the European scale: A common segmentation of taste and firmness. Journal of Food Science. 75(9):S531–S541.

D'Amico, A., De Boni, A., Palmisano, G. O., Morea, E., Acciani, C., and Roma, R. 2024. Consumers' perception and willingness to pay for hydroponic tomatoes: The effects of sustainability and quality attributes. British Food Journal. 126(13):573–592.

Duc, N. X., Uchiyama, T., Saville, R., Shimoguchi, N. N., and Terano, R. 2023. Factors influencing VietGAP certified vegetable purchasing intention of Vietnamese consumers. Journal of the International Society for Southeast Asian Agricultural Sciences. 29(2):131–145.

Falvey, L. 2019. Food, agriculture and small farmers in Asia. In James, H. (ed.). Population, Development, and the Environment. Palgrave Macmillan, Singapore. pp. 45–63.

Grunert, K. G. 2024. Measuring the meaning of food in life. In Encyclopedia of Food and Agricultural Ethics. Springer, Cham.

Gunasekara, H. S. L., Shimoguchi, N. N., Terano, R., Saville, R., and Hatanaka, K. 2024. Tomato consumer behavior in Hino City, Japan: Application of multiple correspondence and k-means cluster analyses. International Journal of Environmental and Rural Development. 15(2):157–166.

Gunden, C., B. Türkekul, B. Miran, C. Abay and S. Akgüngör. 2010. Consumer preferences for purchase places of organic fruits and vegetables in Turkey. J. Food Agric. Environ. 8(1):144-149.

Hair, J. F., Black, W. C., Babin, B. J., and Anderson, R. E. 2010. Multivariate Data Analysis. 7th ed. Pearson Prentice Hall, Upper Saddle River, New Jersey. 816 p.

Hoffman, A. C., Salgado, R. V., Dresler, C., Faller, R. W., and Bartlett, C. 2016. Flavour preferences in youth versus adults: A review. Tobacco Control 25(Suppl 2):ii32–ii39.

John, D., Hussin, N., Shahibi, M. S., Ahmad, M., Hashim, H., and Ametefe, D. S. 2023. A systematic review on the factors governing precision agriculture adoption among small-scale farmers. Outlook on Agriculture. 52(4):469–485.

Joubert, S. 2024. Data-driven decision making: A primer for beginners. Graduate Blog, Northeastern University. Available at: https://graduate.northeastern.edu/resources/data-driven-decision-making/

Kaiser, H. F. 1974. An index of factorial simplicity. Psychometrika. 39(1):31–36.

Lentz, E. C., Michelson, H., Baylis, K., and Zhou, Y. 2019. A data-driven approach improves food insecurity crisis prediction. World Development. 122:399–409.

Manongko, K. G., Tangkere, E. G., and Loho, A. E. 2023. Analysis of household-scale hydroponic lettuce farming in Kakaskasen II Village, Tomohon Sub-District. Journal of Agribusiness and Rural Development. 5(1):100–108.

Matsukura, C. 2016. Sugar accumulation in tomato fruit and its modification using molecular breeding techniques. In Biotechnology in Agriculture and Forestry. Springer, Berlin. pp. 141–154.

Methven, L., Allen, V. J., Withers, C. A., and Gosney, M. A. 2012. Ageing and taste. Proceedings of the Nutrition Society. 71(4):556–565.

Mikolajczyk, S., Mikulcak, F., Thompson, A., and Long, I. 2021. Unlocking smallholder finance for sustainable agriculture in Southeast Asia. Germany:Climate Focus and World Wide Fund (WWF).

Ministry of Agriculture, Forestry and Fisheries (MAFF Japan). 2022. Statistics on vegetable production. Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan. https://www.maff.go.jp/j/tokei/kouhyou/sakumotu/sakkyou_yasai/ (Accessed 2024 July 25)

Ogawa, T., Annear, M. J., Ikebe, K., and Maeda, Y. 2017. Taste-related sensations in old age. Journal of Oral Rehabilitation. 44(8):626–635.

Oltman, A., Jervis, S., and Drake, M. 2014. Consumer attitudes and preferences for fresh market tomatoes. Journal of Food Science. 79(10):S2091–S2097.

Pascual, M. P., Lorenzo, G. A., and Gabriel, A. G. 2018. Vertical farming using hydroponic system toward sustainable onion production in Nueva Ecija, Philippines. Open Journal of Ecology. 8(1):25–41.

Platania, M., M. Rizzo and D. Vecchio. 2015. Consumer preferences for traditional products and place of purchase. Results of a survey on direct sales in Italy. Qual. Access Success. 16(S1):158-164.

Prakash, D. 2024. Data-driven management: The impact of big data analytics on organizational performance. International Journal for Global Academic & Scientific Research. 3(2):12–23. https://doi.org/10.55938/ijgasr.v3i2.74

Ramadhan, M. A. R., Wanto, H. S., and Wisnujati, N. S. 2024. Unlocking consumer satisfaction: How product quality, service quality, and preferences drive hydroponic lettuce purchases. Aurora. 1(2):60–74.

Samberg, L. H., Gerber, J. S., Ramankutty, N., Herrero, M., and West, P. C. 2016. Subnational distribution of average farm size and smallholder contributions to global food production. Environmental Research Letters. 11(12):124010.

Sato, S., Sakaguchi, S., Furukawa, H., and Ikeda, H. 2006. Effects of NaCl application to hydroponic nutrient solution on fruit characteristics of tomato. Scientia Horticulturae. 109(3):248–253.

Savvas, D., and Gruda, N. 2018. Application of soilless culture technologies in the modern greenhouse industry – A review. European Journal of Horticultural Science. 83(5):280–293.

Sebastian, L., and Bernardo, E. B. 2019. Making smallholder farmers in Southeast Asia climate smart. In Shirato, Y., and Hasebe, A. (eds.). Climate Smart Agriculture for Small-Scale Farmers in the Asian and Pacific Region. FFTC and NARO, Taipei. pp. 201–226.

Shimoguchi, N. N., Terano, R., Saville, R., Gunasekara, H. S. L., and Hatanaka, K. 2024. Improving the farm business and resilience of new farmers: Case of a greenhouse tomato farmer in H City, Tokyo. International Journal of Environmental and Rural Development. 15(1):72–78.

Terano, R., Shimoguchi, N. N., Saville, R., Gunasekara, H. S. L., and Hatanaka, K. 2023. Agricultural support for new farmers in H City, Tokyo, Japan. International Journal of Environmental and Rural Development. 14(1):74–81.

United Nations Conference on Trade and Development (UNCTAD). 2015. Commodities and Development Report 2015: Smallholder Farmers and Sustainable Commodity Development. United Nations, Geneva.

Wilcox, R. R., Keselman, H. J., Muska, J., and Cribbie, R. 2000. Repeated measures ANOVA: Comparing trimmed means and means. British Journal of Mathematical and Statistical Psychology. 53(1):69–82.

ZareRavasan, A. 2021. Boosting innovation performance through big data analytics. Journal of Information Science. 49(5):1293–1308.

Zhang, Y., Ren, S., Liu, Y., and Si, S. 2016. A big data analytics architecture for cleaner manufacturing and maintenance processes of complex products. Journal of Cleaner Production. 142:626–641.

Authorship contributions:

Conceptualization: HSLG, NNS, RT, RS, KH; Study design: HSLG, NNS, RT, RS; Sample collection: HSLG, NNS, RT, RS; Conduct of experiment:-data curation: HSLG; Visualization: HSLG; Formal analysis: HSLG, NNS, RT, RS, KH; Supervision: NNS, RT, RS, KH; Writing – Original draft preparation: HSLG; Writing – Review and editing: HSLG, NNS, RT, RS, KH