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INVESTIGATING CONSUMER PURCHASING BEHAVIOUR AND WILLINGNESS TO PAY FOR PLANT FACTORY CURLY KALE IN MALAYSIA

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ABSTRACT

The global concern around pesticide residues is significant, given the well-documented adverse impacts of pesticides on both the environment and human health. As a result, the demand for organic or pesticide-free products is increasing. While, in Malaysia, there is very little information on the acceptability of plant factory product. Research on the plant factory product acceptance is crucial to meet consumer and grower expectations and market potential. Therefore, this study aimed to explore the market potential of plant factories by measuring consumers' knowledge and purchase intention. Furthermore, this paper also includes identification of the factors affecting the Willingness to Pay (WTP) for curly kale from plant factories using the Contingent Valuation Method (CVM). The binary logistic regression is employed to determine the significant factors. Results suggested that consumers were willing to pay RM8.37/100 g pesticide-free curly kale. In addition, the model suggested that price, packaging and labelling for plant-factory curly kale, organic consumers as well as health consciousness significantly influenced consumer willingness to pay for plant factory curly kale. These findings suggest that there is a potential market for pesticide-free vegetables in Malaysia and that consumers are willing to pay a premium for these products.

Introduction

Pesticides have played a crucial role in modern agriculture by boosting crop yields and enhancing food security (Cooper & Dobson, 2007; Popp *et al.*, 2013; Hedlund *et al.*, 2019). However, their extensive use has raised serious environmental and health concerns. Pesticides are among the leading causes of biodiversity loss through non-target exposure while long-term soil and water contamination continues to threaten ecosystems (Geiger *et al.*, 2010; Sánchez-Bayo & Wyckhuys, 2019; Pelosi *et al.*, 2021). In addition, residues detected in food and air, present significant risks to human health (Jacquet *et al.*, 2022). These consequences have prompted many governments to reduce reliance on pesticides and explore safer alternatives (Lee *et al.*, 2019).

In Malaysia, pesticide usage between 2011 and 2019 ranged from 41,000 to 60,000 metric tonnes annually, with particularly high use in paddy and vegetable cultivation (Sabran & Abas, 2021; Statista Research Department, 2022). Farmers often rely on traditional, calendar-based spraying practices, leading to pesticide overuse and limited attention to residue levels or safety measures (Oh *et al.*, 2003; Halimatunsadiah *et al.*, 2016). This overreliance not only disrupts ecological balance but also exposes farmers and

consumers to health hazards through ingestion, inhalation, and skin exposure (Parveen, 2010; Mohammad *et al.*, 2018; Ho, 2023). These issues highlight the urgent need for sustainable food production systems that minimise pesticide use.

One promising approach is the plant factory, an indoor agricultural system integrating hydroponics, vertical farming, automation, and artificial lighting (Nichols, 2015; Shamshiri *et al.*, 2018). By cultivating crops in a controlled environment, plant factories can eliminate the need for pesticides while ensuring stable production and higher food safety (Watanabe, 2011; Shimizu *et al.*, 2011; Huang, 2019). Other benefits include efficient land use, reduced logistics when located near urban centres, and consistent supply of high-quality vegetables (Specht *et al.*, 2014; Ahmad *et al.*, 2024). Despite these advantages, challenges such as high energy consumption and consumer concerns about cost and nutritional value remain barriers to widespread adoption (Graamans *et al.*, 2018; Noor *et al.*, 2023).

Consumer perceptions and purchasing behaviour are therefore central to the success of plant factory produce. Past studies have shown that many consumers value freshness, health, and pesticide safety and are willing to pay more for such attributes (Bruhn, 1994; Govindasamy *et al.*, 1997; Kurihara *et al.*, 2014). Willingness to Pay (WTP) is a widely used measure to evaluate how much consumers value additional product attributes beyond the market price such as pesticide-free production or local sourcing (Breidert *et al.*, 2006; Suanmali, 2020). Findings across multiple countries consistently indicate strong consumer demand and willingness to pay (WTP) for pesticide-free and organic produce (Buzby *et al.*, 1995; Buzdar *et al.*, 2020; Pandit *et al.*, 2021) nevertheless, limited empirical evidence exists concerning Malaysian consumers' perceptions of plant factory products.

Therefore, this study aims to examine Malaysian consumers' Willingness to Pay (WTP) for pesticide-free curly kale produced in a plant factory. Specifically, it evaluates the additional value consumers place on attributes such as pesticide-free production, controlled-environment agriculture, and local sourcing, thereby contributing to sustainable food production strategies.

Materials and Methods

Survey Design and Valuation Scenario

In this study, the Contingent Valuation Method (CVM) was applied to estimate consumers' Willingness to Pay (WTP) for plant factory-grown curly kale, a premium leafy vegetable produced using Controlled-environment Agriculture (CEA) technology. The valuation scenario was designed to reflect a realistic market context in which curly kale is offered as a safer, pesticide-free, and sustainably produced alternative to conventionally farmed vegetables.

To ensure clarity and relevance, respondents were presented with a hypothetical but plausible purchasing situation. They were asked to imagine that curly kale grown in a plant factory is now available at selected supermarkets or online grocery platforms. They were then asked whether they would be willing to purchase this product at a specific price point, compared to similar conventional leafy greens. The product was described as having better hygiene, consistent quality, longer shelf life, and reduced pesticide use, but at a slightly higher price due to the advanced production technology.

The valuation scenario also specified the payment vehicle, which in this case was the market price per 100-gram pack of curly kale. Respondents were reminded to consider their household budget and actual purchasing behaviour before responding. By framing the valuation in this way, the scenario aimed to minimise hypothetical bias and elicit a realistic measure of consumer preferences.

Sampling and Data Collection

This study used quantitative methods and collected primary data through structured face-to-face interviews with n = 554 consumers

between September 2021 and September 2022. The consumer survey's target audience consisted of Malaysians aged 18 and older who are responsible for their families' food purchases. To ensure the sample's applicability, individuals were chosen by a random sampling methodology. Urban Malaysians were polled in Klang Valley, Johor Bahru, Georgetown, and Kota Kinabalu. Participants typically completed surveys in about 10 to 15 minutes. The participants were asked about their demographics, consumption habits, and attitudes towards fresh vegetables, as well as their thoughts and attitudes concerning vegetables cultivated in plant factories and their willingness to buy such vegetables.

Ethical Consideration

The ethical underpinning of any research involving human participants is built on principles that prioritise their rights, well-being, and privacy. In interview-based studies, where personal information is frequently revealed, maintaining secrecy becomes critical. At the start of the interview, a robust informed consent process was followed. This included explicitly describing to participants the nature of the study, its objectives, and specifics about data collection, storage, and data usage. The protection of privacy is an essential ethical responsibility. Participants are expressly notified that their identities will be protected and any information they provide will be anonymised for analysis and reporting. The goal is to protect participants from potential harm or unintended consequences resulting from the publication of personal information.

Descriptive Statistics

The descriptive analysis method was performed for initial analysis to understand the data and determine the purchasing behaviour of plant factory products in Malaysia. In addition, this paper also employed the Chi-Square independent test to determine the difference between levels of socio-demographics in purchasing plant factory curly kale.

Elicitation Method (Single Bounded Dichotomous Choice) and Bid Design

To elicit respondents' Willingness to Pay (WTP) for plant factory curly kale, a single-bounded dichotomous choice contingent valuation format was adopted. In this format, each respondent was presented with a yes-or-no question regarding their willingness to purchase the product at a specific price (bid) level.

The bid amounts were predetermined based on a combination of a pilot study and market observation of leafy vegetable prices in urban supermarkets. Three bid values were selected, which are RM7.00, RM8.00, and RM9.00 per 100 g pack. These values were chosen to reflect a realistic price range and to capture variation in consumer WTP.

During the survey, each respondent was randomly assigned one bid level to ensure unbiased estimation and to satisfy the requirement of the single-bounded format. Respondents were then asked: "Would you be willing to pay RM8.00 for a 100 g pack of plant factory curly kale, which is pesticide-free and grown in a controlled environment?" The responses were binary coded, with "1" indicating a "Yes" response (willing to pay the bid) and "0" for a "No" response. The bid values served as the key independent variable in the logit model used to estimate WTP.

Furthermore, visual materials such as product images and information cards were included to enhance respondent understanding. A brief "cheap talk" script was also read before the WTP question to encourage respondents to answer as if they were making a real purchase decision, thereby reducing hypothetical bias.

Econometric Model Specification

Binary logistic regression was employed in this study to estimate the probability that a respondent would be willing to pay for plant factory curly kale, as required by the single-bounded dichotomous choice Contingent Valuation Method (CVM). A bidding process

was utilised conceptually to determine the worth of willingness to pay (Suanmali, 2020). The data was analysed using a single-bounded dichotomous choice contingent valuation model. Logistic regression is well suited for this type of analysis because the dependent variable is categorical and dichotomous (i.e., 1 = "Yes", willing to pay; 0 = "No", not willing to pay).

In this study, SPSS version 26 was employed to perform binary logistic regression analysis. The model was developed using the Enter method. Model fit was evaluated using diagnostic measures such as the Hosmer-Lemeshow goodness-of-fit test and Nagelkerke R Square. Additionally, multicollinearity diagnostics were conducted to assess the independence of predictor variables.

The logit model includes a cumulative probability function that can deal with a dependent variable to determine whether an event will occur or not by predicting a binary dependent result from a set of independent variables (Starovoytova & Namango, 2018). The logistic regression model or logit model to identify consumer's willingness to pay for plant factory curly kale can be stated as:

$$P(Y = 1) = \frac{1}{1+exp^{-z}} \quad (1)$$

where $P(Y = 1)$ = the probability that the respondent is willing to pay for plant factory curly kale. The summation of explanatory variables multiplied by their coefficients is stated in Equation (2):

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon_i \quad (2)$$

where:

β_0 = The intercept which is constant
$\beta_1 \ldots \beta_n$ = Regression coefficient of the explanatory variables
$X_1 \ldots X_n$ = Set of explanatory variables
ε_i = Error term

Therefore, the average WTP value can be estimated using Equation (3).

$$WTP = -\left[\frac{\beta_0 + \sum_n^1 \beta_{n+1}(X_{n+1})}{\beta_1(X_1)}\right] \quad (3)$$

For example, if freshness increases WTP, the coefficient for freshness will be positive. While $\beta_1(X_1)$ is the coefficient of the price variable denoted as (X_1). It shows how sensitive consumers are to changes in price. Because WTP is derived from this price response, it appears in the denominator. The larger the (absolute value of the) price coefficient, the smaller the WTP, and vice versa.

The average WTP is calculated by taking the sum of the baseline preference (intercept) and the effects of various influencing factors (product attributes, socio-demographics) and dividing this by the sensitivity to price. This gives an estimate of how much, on average, a consumer is willing to pay for the product, accounting for all observed characteristics. The negative sign appears because the price coefficient is typically negative. For example, as price increases, willingness to pay decreases.

One advantage of logistic regression is that it makes fewer assumptions than linear regression. For example, it does not require that the independent variables be normally distributed or that the relationship between variables to be linear (Weaver & Wuensch, 2013). In addition, it allows for the inclusion of both continuous and categorical explanatory variables, which aligns with the nature of the dataset in this study which includes variables such as bid amount (continuous), income (continuous), and education level (categorical) as in Figure 1.

Given the binary outcome of the WTP decision and the mix of predictor variable types, logistic regression was determined to be the most appropriate modelling technique to identify statistically significant factors influencing Willingness to Pay and to estimate the mean WTP value from the resulting coefficients.

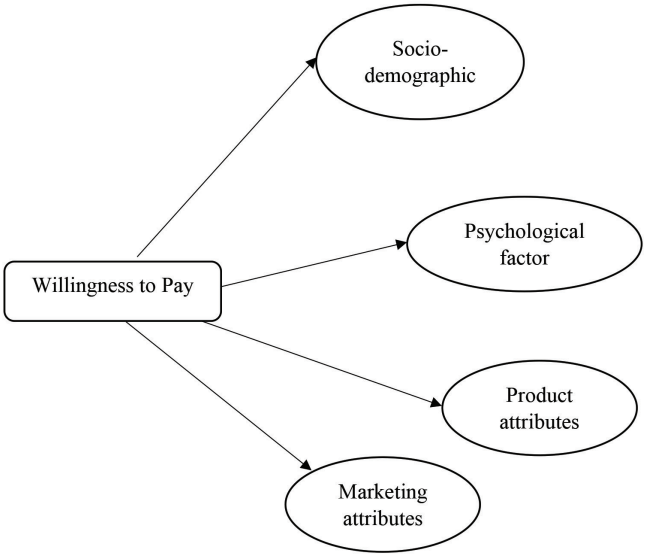

Figure 1: Conceptual framework

Results and Discussion

Socio-demographic

Table 1 provides comprehensive socio-demographic information for the respondents. The research was conducted using data collected from 558 respondents. The proportion of male respondents was 42.0%, whereas female respondents constituted 58.0% of the total. Around 37.4% of the participants fell between the age range of 31 to 40. Malays constituted the largest proportion of respondents, accounting for 71.0%, followed by Chinese at 21.0%. Indians and other ethnicities made up the remaining 3.0% and 5.0%, respectively. The survey results indicate that 73.0% of the participants have a tertiary education.

In addition, the proportion for secondary school was 25.0%. Government employees make up a minimum of 22.0% of the respondents. However, the private sector employs the majority of respondents, accounting for 50.0%. The majority of respondents reported a monthly income ranging from RM2,501.00 to RM4,850.00, accounting for 28.1% of the total. Approximately 24.7% of the respondents had a monthly income ranging from RM4,851.00 to RM7,100.00. Four to five household members represent the largest percentage of respondents, accounting for 43.9%.

Monthly Vegetable Expenses and Dietary Practices

Table 2 demonstrates that the majority of respondents (35.5%) spend RM150.00 or more on veggies each month. However, the frequency of consumption over the month was uncertain (52.0%). Only a small proportion of responders follow a specific diet, including 10.0% vegetarian, 4.0% vegan, and 1.0% keto diet. The remainder (85.0%) of respondents did not follow any specific diet. The main reasons for consuming vegetables among the respondents were health (59.0%) and the inclusion of vegetables in a well-balanced diet (15.0%). Furthermore, tastefulness (12.0%) and high vitamin content (10.0%) were among the reasons given by respondents for eating veggies. The remainder was for the beauty of the skin (4.0%).

Table 1: Respondent demographics (n = 558)

	Category	Percentage (%)
Gender	Male	42.0
	Female	58.0
Age (years old)	18–30	27.9
	31–40	37.4
	41–50	23.9
	51–60	7.4
	61 or older	3.4
Race	Malay	71.0
	Chinese	21.0
	Indian	3.0
	Others	5.0
Highest level of education	Primary education	2.0
	Secondary education	25.0
	Tertiary education	73.0
Occupation	Government sector	22.0
	Private sector	50.0
	Self-employed	14.0
	Not working includes housewives	7.0
	Student	4.0
	Retired	2.0
	Others	1.0
Household income	Below RM2,500.00	18.8
	RM2,501.00 to RM4,850.00	28.1
	RM4,851.00 to RM7,100.00	24.7
	RM7,101.00 to RM10,970.00	18.4
	RM10,971.00 or more	10.0
Household members	1	6.7
	2–3	31.6
	4–5	43.9
	6 or more	17.8

Knowledge of Plant Factory Technology and Vegetables

Among the participants, 51.4% possess knowledge about the method of vegetable cultivation in plant factories while 44.6% are aware of the availability of vegetable goods produced using this technology in the market (Table 3). Social media is regarded as a key platform for promoting plant factory technology and products. This is reinforced by the survey results, which show that 30.4% of respondents get their plant factory information from social media, 21.9% from people they know, and 15.3% from exhibitions and seminars. The remaining 9.6% came from print media and 8.3% from market surveys.

Table 2: Vegetable expenses and dietary practices

Category		Percentage (%)
Estimated vegetable expenses (RM/month)	Below RM50.00	25.9
	RM51.00 to RM100.00	28.4
	RM101.00 to RM150.00	10.2
	RM150.00 or more	35.5
Frequency of vegetable consumption in a month	Everyday	3.3
	Every week	37.2
	Every two weeks	7.7
	Uncertain	52.0
Dietary habits	1 = Do not follow a specific diet	85.0
	2 = Vegetarian	10.0
	3 = Vegan	4.0
	4 = Keto diet	1.0
Vegetable consumption factor	Health	59.0
	Balanced diet	15.0
	Tastefulness	12.0
	Rich in vitamins	10.0
	Good for skin	4.0

Table 3: Knowledge of plant factory technology and vegetables

Category		Percentage (%)
Knowledge of vegetable cultivation technology in plant factories	Yes	51.4
	No	48.6
Awareness of plant factory products in the market	No	44.6
	Yes	55.4
Information dissemination	Electronic media	14.5
	Social media	30.4
	Print media	9.6
	Exhibitions and seminars	15.3
	Supermarket	8.3
	Local residents	21.9

Consumption and Purchase of Plant Factory Vegetables

Of all respondents (n = 558), only 22.8% had consumed plant factory vegetables, once every two weeks (Table 4). The main factors that drive the consumption of this plant factory vegetable are its freshness (27.1%) and pesticide-free (25.2%). In addition, respondents believe that the vegetables of this plant factory are safe to eat (18.3%). The rest are nutritious (11.4%) and reasonably priced (8.8%).

One of the main reasons why the respondents have never eaten plant factory vegetables (77.2%) is that most of them do not

Table 4 : Frequency and factors of plant factory vegetable consumption

Category		Percentage (%)
Plant factory vegetable consumption	Yes	22.8
	No	77.2
Factors affecting plant factory vegetable consumption	Freshness	27.1
	Safe to eat	18.3
	Reasonable price	8.8
	Nutritional	11.4
	Good taste	9.0
	Free pesticide	25.2
A factor of not consuming plant factory vegetables	Expensive	12.9
	Not tasty	2.8
	Hard to find	31.9
	Not interested	4.8
	No knowledge of plant factory	47.6
The frequency of plant factory vegetable intake in a month	Everyday	15.8
	Every two weeks	29.2
	Every three weeks	9.2
	Every month	25.8
	Uncertain	20.0

know about plant factory products (47.6%). In addition, the factor of availability should be emphasised because this vegetable is difficult to obtain (31.9%). Apart from the good qualities of this plant factory vegetable, advertising in a suitable place is very important to gain the interest of consumers.

Purchasing Scenario of Plant Factory Vegetables

Table 5 comprises the purchase scenario of plant factory vegetables. In this study, only a small proportion of respondents have ever purchased vegetables from a plant factory, 18.6% (n = 104). The study further revealed that a significant proportion of the participants, up to 32.2%, opt to acquire plant factory veggies via online transactions. The most common platform for advertising and selling plant factory vegetables is online. Furthermore, vegetable purchasers prioritise specialist stores (27.6%) for purchasing this product. A speciality store exclusively offers organic and pesticide-free food products. The remaining participants also get plant factory veggies through various channels, including hypermarkets (15.1%), supermarkets (12.5%), and direct purchases from the producer (12.5%).

Majority of respondents typically allocate a budget ranging from RM10.00 to RM20.00 every month for the purchase of vegetables at the plant factory. The main justification in purchasing vegetables from plant factories are the aspects of quality, such as freshness (27.0%), pesticide-free (24.4%), safe-to-eat (17.4%) and nutritional value (11.6%). Therefore, it can be concluded that the distinctive attributes of this pesticide-free vegetable can serve as a compelling marketing proposition for plant factory producers. Additionally, the pricing component accounts for 9.9% while delicious contributes to 9.6% of the overall importance when considering the purchase of vegetables from a plant factory.

Table 5: Purchasing scenario of plant factory vegetables

Category		Percentage (%)
Plant factory vegetable purchase	Yes	18.6
	No	81.4
Marketing channel for plant factory vegetable	Hypermarket	15.1
	Supermarket	12.5
	Specialty shop	27.6
	Online	32.2
	Direct selling	12.5
Monthly expenditure for plant factory vegetable (RM/month)	Below RM10.00	20
	RM10.00 to RM20.00	36.2
	RM20.00 to RM40.00	26.7
	RM40.00 to RM60.00	10.5
	RM60.00 or above	6.7
Factor affecting intention to purchase plant factory	Freshness	27.0
	Safe to eat	17.4
	Reasonable price	9.9
	Nutritious	11.6
	Delicious	9.6
	Pesticide-free	24.4

Socio-demographic Differences in Preference for Plant Factory Vegetables

To check which categories of consumers are purchasing plant factory products, the chi-square independent test was employed to see the difference between each level of socio-demographic factors in purchasing plant factory products. The chi-square independent test revealed that the household income factor is statistically significant in the purchasing of plant factory products (x^2= 10.813, $p < 0.05$). These results indicate that for each level of household income, there is a significant difference in the purchasing of plant factory products where the majority of plant factory consumers earn an income between RM4,851.00 to RM7,100.00 (31.7%) (Table 6).

Willingness to Pay for Plant Factory Curly Kale

The data of 554 respondents who are making decisions to buy vegetables are analysed using binary logistic regression to determine the significant factors that influence consumer Willingness to Pay (WTP) for curly kale produced from a plant factory. The parameters of the binary logistics model are estimated using the maximum likelihood estimates computed using SPSS version 26. The value of Nagelkerke R Square is 0.127, indicating that the probability of consumers willing to pay is 12.7%.

Based on Table 7, five significant variables at a 5% level are estimated based on the Contingent Valuation Method (CVM) dichotomous choice

Table 6: Demographic profile of plant factory consumer

Category		Percentage (%)	χ^2	*p*-value
Gender	Male	55.8	0.277[a]	0.599
	Female	44.2		
Age (years old)	18–30	22.1	8.829[a]	0.066
	31–40	44.2		
	41–50	28.8		
	51–60	3.8		
	61 or older	1.0		
Race	Malay	80.8	6.615[a]	0.085
	Chinese	13.5		
	Indian	2.9		
	Others	2.9		
Highest level of education	Primary education	1.9	1.968[a]	0.74
	Secondary education	21.2		
	Tertiary education	76.9		
Occupation	Government sector	32.7	11.955[a]	0.063
	Private sector	46.2		
	Self-employed	13.5		
	Not working includes housewives	1.0		
	Student	1.0		
	Retired	5.8		
	Others	0.0		
Household income	Below RM2,500.00	9.6	10.813[a]	0.029**
	RM2,501.00 to RM4,850.00	24.0		
	RM4,851.00 to RM7,100.00	31.7		
	RM7,101.00 to RM10,970.00	22.1		
	RM10,971.00 or more	12.5		

Note: **Estimates are statistically significant at the 5% level.

concerning the consumer willingness to pay for curly kale produced from a plant factory. The bid price coefficient was negative (-0.094), demonstrating that a price increase will decrease the consumer's utility (Joya *et al.*, 2022). The consumer attitude on the price of plant factory products also shows a negative association with the WTP (-0.622). This relationship indicates that consumers who are more concerned about the price believe that the price of plant factory is higher than conventional vegetables, which leads to not being willing to pay for plant factory products. Furthermore, the decision-making process for purchasing vegetables is complex as the appearance of the vegetables is more likely regardless of the cultivation method, consumers seeking good value for money and quality produce at an affordable price (Singh & Neeraj, 2018).

In this study, socio-demographic factors such as income, age, and gender were tested to see if they influenced consumers' Willingness to Pay (WTP) for plant factory-produced curly kale. However, these factors were not found

Table 7: The result from binary logistic regression

	B	Standard Error	*p*-value	Exp(B)	WTP
Bid price	-0.094**	0.045	0.035	0.909	RM8.32/100 g
Household income	0.000	0.000	0.582	1.000	
Price of the plant factory product	-0.622***	0.170	0.000	0.529	
Packaging and labelling of the plant factory product	0.671***	0.190	0.000	1.971	
Organic consumer	-1.196***	0.215	0.000	0.295	
Health consciousness	-0.583**	0.238	0.018	0.570	
Health consciousness x age (below 40)	0.028	0.050	0.579	1.028	
Health consciousness x gender (male)	-0.074	0.047	0.119	0.929	
Knowledge on plant factory technology	0.158	0.287	0.581	1.172	
Availability on plant factory products in the markets	-0.293	0.291	0.314	0.746	
Constant	2.517***	0.955	0.006	13.469	

Note:-2 Log likelihood=628.02, Nagelkerke R square = 0.127.
,*Estimates are statistically significant at the 5% and 1% level.

to be statistically significant. This means that consumers' decisions to pay a higher price for the product may not be strongly linked to their background characteristics.

It is also possible that the lack of significance was due to limited variation in the sample or a sample size that was not large enough to detect differences. Therefore, it is suggested that future research include more detailed behavioural and attitudinal variables or use qualitative methods to better understand what drives consumer preferences for plant factory products.

Consumer purchasing of plant factory vegetables is influenced by a variety of marketing factors, with price being a key determinant (Huang, 2019). Besides, this study also revealed that the packaging and labelling of the plant factory product (0.671) positively influenced consumer willingness to pay for plant factory curly kale. As far as this study is concerned, Malaysian plant factory products are labelled as pesticide-free. In a recent study by Nohara (2024), consumers did not care about the colour nor the shape of the vegetables as long as they were pesticide-free. Research consistently shows that the packaging and labelling of pesticide-free vegetables can positively influence consumer willingness to pay. Zhang *et al.* (2018) found that consumers were more willing to pay a premium for safe vegetables, with packaging and label trust being key factors. Similarly, Khachatryan *et al.* (2017) demonstrated that pollinator-friendly labels increased consumer preferences and willingness to pay for plants. Kavoosi *et al.* (2017) also reported a positive impact of organic labels on consumer willingness to pay for leafy vegetables. However, Haghjou *et al.* (2020) highlighted the need for increased awareness of pesticide-free produce, particularly in developing countries.

The binary logistic analysis reveals a negative (-1.196) and highly significant coefficient for organic consumers. Organic farming projects have been in existence since the 1920s, but the concept of a plant factory was initially introduced in 1980 as a pioneering technique created in Japan (Csambalik *et al.*, 2023). In Malaysia, organic cultivation was introduced in the early 1990s while the concept of plant factories, utilising IR 4.0 technology

in agriculture for controlled cultivation and production management is relatively new (Suhaimee *et al.*, 2016; Dardak *et al.*, 2022). The soilless approach in the plant industry is in contrast to the concept of organics, resulting in an ongoing debate and leading to individual bias (Csambalik *et al.*, 2023). The data indicates that although both organic and plant factory customers may place importance on sustainability and health, their distinct preferences and attitudes towards these aspects may vary.

Surprisingly, the coefficient for consumer health consciousness is -0.583, indicating a negative relationship. Huang (2019) found that while over half of consumers appreciate the value of plant factory technology, concerns about environmental pollution and food safety are prevalent. This suggests that consumers are health-conscious but also cautious about the potential negative impacts of these products. Lea *et al.* (2005) highlighted the misalignment between consumers' beliefs about plant factories and the perceptions of farmers and food processors, indicating a potential gap in understanding consumer health consciousness.

Ghvanidze *et al.* (2019) and Li *et al.* (2021) both emphasised the importance of health consciousness and ecological effect in influencing purchase intention, with the latter also noting the moderating role of perceived consumer effectiveness. These findings suggest that consumer perceived health consciousness for plant factory products is influenced by a range of factors, including concerns about environmental and food safety and the perceived effectiveness of their own actions. However, the interaction between health consciousness and socio-demographics gives different findings.

The coefficient on the interaction between health consciousness and lower age (40 years and below) is positive (0.028) while the interaction between health consciousness and gender (male) shows a negative value (-0.074). Although these two factors are not significant the sign of the coefficient indicates that the consumers that are 40 years old and below are likely concerned with food safety issues and view the positive impact of curly kale plant factories compared to older generations. Meanwhile, women are more likely to have a positive view of plant factory products in terms of health consciousness rather than men.

Other factors considered in this willingness-to-pay model include consumer awareness of the plant factory system and the accessibility of plant factory items in the market. While these criteria may not have significant effects on customers' willingness to pay for plant-factory curly kale, consumer understanding and product availability play a crucial role in promoting plant-factory products in Malaysia.

In addition, the binary logistic regression result in Table 7 can be used to determine the consumer willingness to pay for plant factory curly kale. According to Kavosi *et al.* (2018), the factors that did not show a significant correlation with willingness to pay were omitted. Thus, by using Equations (3) and (4), the consumer's average WTP for plant factory curly kale can be calculated.

$$WTP = -\left[\frac{\beta_0(Constant)+\beta_1(X_1)+\beta_2(X_2)+\beta_3(X_3)+\beta_4(X_4))}{\beta_1(BID)}\right] \quad (4)$$

where

X_1 = Price of the plant factory product
X_2 = Packaging and labelling plant factory product
X_3 = Organic consumer
X_4 = Health-conscious consumer

These variables capture how much value consumers place on different product attributes or personal characteristics. The denominator shows how sensitive consumers are to the price. Since higher prices usually reduce the chance of purchase, this value is negative. To turn the result into a positive WTP value, the negative sign is added in front of the equation. By dividing the total utility from product attributes by the price sensitivity, the average amount that consumers are willing to pay for 100 grams of the product can be estimated by RM8.37/100 grams.

The use of a basic logistic regression model inherently assumes homogeneity in consumer preferences, meaning that it treats all individuals in the sample as responding in a uniform way to the explanatory variables. This assumption simplifies the estimation process but may not adequately reflect the true diversity in how consumers make purchasing decisions. In reality, preferences for novel food products such as plant factory-produced curly kale are often influenced by unobserved individual-level characteristics such as personal values, prior experience, health consciousness, or environmental attitudes. By ignoring this heterogeneity, the model potentially overlooks important variation in consumer behaviour, which can lead to biased parameter estimates and consequently, oversimplified or misleading estimates of Willingness to Pay (WTP).

For example, some consumers may place a higher value on locally grown or pesticide-free attributes while others may prioritise price or appearance. A homogeneous model cannot distinguish between these differing preference structures. As a result, the average WTP derived from a basic logit model might misrepresent the true valuation of specific consumer subgroups, masking potential market segments that are highly receptive or resistant to the product.

Advanced models such as mixed logit or latent class models are specifically designed to address this issue by incorporating random parameters or class-based segmentation, allowing for a more flexible and accurate representation of heterogeneous consumer preferences (Train, 2009; Hensher *et al.*, 2015). While such models were not implemented in the current study due to data constraints, acknowledging this limitation is crucial for interpreting the results appropriately and for guiding future research toward more robust and nuanced modelling approaches.

Conclusions

This study revealed that approximately 48.6% of respondents were unaware of plant factory cultivation practices and only 22.8% had previously consumed vegetables from such systems, underscoring the need for increased public awareness. Limited accessibility to plant factory products further stresses the importance of targeted promotion, particularly highlighting health benefits like pesticide-free and high-quality produce. Marketing strategies should focus on affluent and health-conscious consumers in major urban areas while ensuring supply levels are well-regulated to prevent oversaturation and price drops.

The estimated Willingness to Pay (WTP) for curly kale produced in a plant factory was RM8.37 per 100 grams, reflecting a strong market potential when properly positioned. The use of the logit model proved effective in analysing consumer WTP, as it accurately reflects probability-based decision-making. However, future studies should consider mixed logit models and discrete choice experiments to better capture consumer preference heterogeneity and derive more robust WTP estimates. Overall, the findings provide valuable insights for stakeholders aiming to promote high-tech, sustainable agriculture in Malaysia.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

Ahmad, A. A., Nik Omar, N. R., Yusoff, M. M., & Ahmad, M. A. (2024). From farm to table concept: The profile and dynamics

of urban farming on agrofood supply chain in Malaysia. *FFTC Journal of Agricultural Policy*, *2*, 17–34. https://doi.org/10.56669/GPUJ3824

Breidert, C., Hahsler, M., & Reutterer, T. (2006). A review of methods for measuring willingness-to-pay. *Innovative Marketing*, *2*(4), 8–32.

Bruhn, C. M. (1995). Consumer attitudes and market response to irradiated food. *Journal of Food Protection*, *58*(2), 175–181. https://doi.org/10.4315/0362-028x-58.2.175

Buzby, J. C., Ready, R. C., & Skees, J. R. (1995). Contingent valuation in food policy analysis: A case study of a pesticide-residue risk reduction. *Journal of Agricultural and Applied Economics*, *27*(2), 613–625.

Buzdar, S. U., Khair, S. M., & Shah, S. M. (2020). Consumers' willingness to pay for fresh-water grown leafy vegetables. *Journal of Applied Economics and Business Studies*, *4*(4), 117–134.

Cooper, J., & Dobson, H. (2007). The benefits of pesticides to mankind and the environment. *Crop Protection*, *26*, 1337–1348. https://doi.org/10.1016/j.cropro.2007.03.022

Csambalik, L., Divéky-Ertsey, A., Gál, I., Madaras, K., Sipos, L., Székely, G., & Pusztai, P. (2023). Sustainability perspectives of organic farming and plant factory systems—From divergences towards synergies. *Horticulturae*, *9*(8), Article 895.

Dardak, R. A., Tahir, M. A. M., Shafie, K. A., & Muhamad, R. M. (2022). Transfer of smart agriculture technology from MARDI to young agropreneurs in Malaysia: The case of high-value vegetable production by AgroCube. *FFTC Journal of Agricultural Policy*, *3*, 14–26.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W. W., Emmerson, M., Morales, M. B., Ceryngier, P., Liira, J., Tscharntke, T., Winqvist, C., Eggers, S., Bommarco, R., Pärt, T., Bretagnolle, V., Plantegenest, M., Clement, L. W., Dennis, C., Palmer, C., Oñate, J. J., … Inchausti, P. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology*, *11*, 97–105. https://doi.org/10.1016/j.baae.2009.12.001

Ghvanidze, S., Velikova, N., Dodd, T. H., & Oldewage-Theron, W. (2019). Are sustainable consumers health conscious? A segmentation study of wine consumers. *Journal of Food Products Marketing*, *25*(6), 690–711.

Govindasamy, R., Italia, J., & Liptak, C. (1997). *Quality of agricultural produce: Consumer preferences and perceptions* (No. 1326-2016-103612). Rutgers University, Department of Agricultural, Food and Resource Economics. https://doi.org/10.22004/ag.econ.36739

Graamans, L., Baeza, E., Van Den Dobbelsteen, A., Tsafaras, I., & Stanghellini, C. (2018). Plant factories versus greenhouses: Comparison of resource use efficiency. *Agricultural Systems*, *160*, 31–43.

Haghjou, M., Hayati, B., & Pishbahar, E. (2020). Factors affecting consumers' awareness of pesticides-free fruits and vegetables. In M. Rashidghalam (Ed.), *The economics of agriculture and natural resources: Perspectives on development in the Middle East and North Africa (MENA) region*. Springer. https://doi.org/10.1007/978-981-15-5250-2_9

Halimatunsadiah, A. B., Mazlan, N., Omar, D., & Kamarulzaman, N. H. (2016). Application of pesticide in pest management: The case of lowland vegetable growers. *International Food Research Journal*, *23*, 85–94.

Hedlund, J., Longo, S., & York, R. (2019). Agriculture, pesticide use, and economic development: A global examination (1990–2014). *Rural Sociology*, *85*, 519–544. https://doi.org/10.1111/ruso.12303

Hensher, D. A., Rose, J. M., & Greene, W. H. (2015). *Applied choice analysis*. Cambridge University Press.

Ho, Y. B. (2023). Exposures of pesticides and health impact on the agricultural (paddy) community in Malaysia. *Malaysian Journal of Medicine and Health Sciences*, *19*(3), 1–4. https://doi.org/10.47836/mjmhs19.3.1

Huang, L. C. (2019). Consumer attitude, concerns, and brand acceptance for the vegetables cultivated with sustainable plant factory production systems. *Sustainability*, *11*(18), Article 4862.

Jacquet, F., Jeuffroy, M. H., Jouan, J., Le Cadre, E., Litrico, I., Malausa, T., Reboud, X., & Huyghe, C. (2022). Pesticide free agriculture as a new paradigm for research. *Agronomy for Sustainable Development*, *42*(1), Article 8.

Joya, K., Ramli, N. N., Shamsudin, M. N., & Kamarulzaman, N. H. (2022). Consumers' willingness to pay for food safety attributes of tomato. *British Food Journal*, *124*(3), 701–717.

Kavoosi, K. M., Pourfarzad, A., Ghaibi, S., Allahyari, M. S., Surujlal, J., & Borsellino, V. (2017). Urban consumers' attitudes and willingness to pay for functional foods in Iran: A case of dietary sugar. *AIMS Agriculture & Food*, *2*(3), 310–323.

Kavoosi, K. M., Sadeghpour, H., Allahyari, M. S., Surujlal, J., & Ghorbandoust, M. (2017). Evaluation of urban consumer willingness to pay for organic leafy vegetables. *International Journal of Vegetable Science*, *23*, 195–206.

Kavosi, Z., Jafari, A., Keshtkaran, V., & Pourahmadi, E. (2018). Estimating willingness to pay for an improved service delivery to patients referring Namazi Hospital chemical therapy ward in Iran using contingent valuation. *Asian Pacific Journal of Cancer Prevention*, *19*(7), 1817.

Khachatryan, H., Rihn, A. L., Campbell, B. L., Yue, C., Hall, C. R., & Behe, B. K. (2017). Visual attention to eco-labels predicts consumer preferences for pollinator-friendly plants. *Sustainability*, *9*, Article 1743.

Kurihara, S., Ishida, T., Suzuki, M., & Maruyama, A. (2014). Consumer evaluation of plant factory produced vegetables. *Focusing on Modern Food Industry*, *3*(1), 1–9.

Lea, E. J., Worsley, A., & Crawford, D. (2005). Food industry awareness of consumers' plant food beliefs. *British Food Journal*, *107*, 556–571.

Lee, R., den Uyl, R., & Runhaar, H. (2019). Assessment of policy instruments for pesticide use reduction in Europe: Learning from a systematic literature review. *Crop Protection*, *126*, Article 104929. https://doi.org/10.1016/j.cropro.2019.104929

Li, G., Yang, L., Zhang, B., Li, X., & Chen, F. (2021). How do environmental values impact green product purchase intention? The moderating role of green trust. *Environmental Science and Pollution Research*, *28*, 46020–46034.

Mohammad, N., Abidin, E. Z., How, V., Praveena, S. M., & Hashim, Z. (2018). Pesticide management approach towards protecting the safety and health of farmers in Southeast Asia. *Reviews on Environmental Health*, *33*(2), 123–134.

Nichols, M. (2015). Plant factories — the ultimate in controlled environment agriculture. *Acta Horticulturae*, *1176*, 17–22. https://doi.org/10.17660/ActaHortic.2017.1176.3

Nohara, K. (2024). Willingness to pay for pesticide-free vegetables in Hokkaido, Japan: The relationship between appearance and pesticide use. *Humanities and Social Sciences Communications*, *11*, Article 12. https://doi.org/10.1057/s41599-023-02515-y

Noor, A. Y. M., Toiba, H., Setiawan, B., Wahib Muhaimin, A., & Nurjannah, N. (2023). Indonesian consumers' preferences and willingness to pay for certified vegetables:

A choice-based conjoint approach. *Journal of International Food & Agribusiness Marketing*, 1–26.

Oh, K., Ihm, Y., Oh, H. K., Lee, B., Kyung, K. S., Kim, N., Kim, B., Kim, J. W., & Ryu, G. (2003). Survey on pesticide usage for the development of pesticide use indicator in fruit vegetables. *The Korean Journal of Pesticide Science*, *7*(1), 66–73.

Pandit, J., Regmi, P. P., K.C., G. B., Paudel, B., & Gauchan, D. (2021). Willingness to pay for pesticide-safe vegetables in Nepal. *International Journal of Environment, Agriculture and Biotechnology*, *6*(5), 153–162.

Parveen, S. (2010). Rice farmers' knowledge about the effects of pesticides on environmental pollution in Bangladesh. *Bangladesh Research Publication Journal*, *3*(4), 1214–1227.

Pelosi, C., Bertrand, G., Daniele, M., Coeurdassier, P., Benoit, S., Nélieu, F., Lafay, V., Bretagnolle, S., Gaba, E., Vulliet, C., & Fritsch, C. (2021). Residues of currently used pesticides in soils and earthworms: A silent threat? *Agriculture, Ecosystems & Environment*, *305*, Article 107167. https://doi.org/10.1016/j.agee.2020.107167

Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security: A review. *Agronomy for Sustainable Development*, *33*, 243–255. https://doi.org/10.1007/s13593-012-0105-x

Sabran, S. H., & Abas, A. (2021). Knowledge and awareness on the risks of pesticide use among farmers at Pulau Pinang, Malaysia. *SAGE Open*, *11*(4). https://doi.org/10.1177/21582440211064894

Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation*, *232*, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Shamshiri, R. R., Kalantari, F., Ting, K. C., Thorp, K. R., Hameed, I. A., Weltzien, C., Ahmad, D., & Shad, Z. M. (2018). Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture. *International Journal of Agricultural and Biological Engineering*, *11*(1), 1–22.

Shimizu, H., Saito, Y., Nakashima, H., Miyasaka, J., & Ohdoi, K. (2011). Light environment optimization for lettuce growth in plant factory. *Proceedings of the 18th IFAC World Congress*, *44*(1), 605–609. https://doi.org/10.3182/20110828-6-IT-1002.02683

Specht, K., Siebert, R., Hartmann, I., Bela, J., Freisinger, U., & Sawicka, M. (2014). Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. *Agriculture and Human Values*, *31*, 33–51. https://doi.org/10.1007/s10460-013-9448-4

Statista Research Department. (2022). *Malaysia: Pesticide use volume*. https://www.statista.com/statistics/1101033/malaysia-pesticide-use-volume

Suhaimee, S., Ibrahim, I. Z., & Abd Wahab, M. A. M. (2016). *Organic agriculture in Malaysia*. FFTC Agricultural Policy.

Suanmali, S. (2020). Determinants of a customer's willingness to pay (WTP) for organic fruits and vegetables: An empirical study in the Bangkok Metropolitan Area. *International Journal of Trade, Economics and Finance*, *11*(4), 71–76.

Starovoytova, D., & Namango, S. (2018). Solid waste management at university campus (Part 4/10): Perceptions, attitudes, and practices of students and vendors. *Journal of Environment and Earth Science*, *8*, 2224–3216.

Train, K. (2009). *Discrete choice methods with simulation*. Cambridge University Press.

Watanabe, H. (2011). Light-controlled plant cultivation system in Japan — Development of a vegetable factory using LEDs as a light source for plants. *Acta Horticulturae*, *907*, 37–44.

Weaver, B., & Wuensch, K. L. (2013). SPSS and SAS programs for comparing Pearson correlations and OLS regression coefficients. *Behaviour Research Methods*, *45*, 880–895.

Zhang, B., Fu, Z., Huang, J., Wang, J., Xu, S., & Zhang, L. (2018). Consumers' perceptions, purchase intention, and willingness to pay a premium price for safe vegetables: A case study of Beijing, China. *Journal of Cleaner Production*, *197*, 1498–1507.