ISSN: 2347-467X, Vol. 14, (Special Issue) 2026, Pg. 617-629

Current Research in Nutrition and Food Science

www.foodandnutritionjournal.org

Consumer Acceptance and Valuation of Controlled-Environment Agriculture (CEA) Lettuce: An Integrated Analysis of Willingness to Buy and Willingness to Pay

GOPALAN KATHIRAVAN[1]*, JESSICA CHURAMAN[2] and NKOSI FELIX[2]

[1]Department of Animal Husbandry Statistics and Computer Applications, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai, India
[2]Department of Agricultural Economics and Extension, Faculty of Food and Agriculture, The University of the West Indies, St. Augustine, Trinidad and Tobago

Abstract

Increasing global demand for safe, pesticide-free produce has intensified interest in controlled-environment agriculture (CEA) as an alternative production system. Given the novelty of CEA technology in Trinidad and Tobago and its relatively high production costs, this study examines consumer willingness to buy (WTB) and willingness to pay (WTP) a premium for CEA-grown lettuce. Data were collected through a supermarket-intercept survey of lettuce-purchasing consumers across four regions of Trinidad and Tobago (n = 160). Consumer decisions were analysed using a binary logistic regression model for willingness to buy and a Tobit regression model for willingness to pay a price premium. Results indicate that several factors influencing willingness to buy also influence willingness to pay a premium. The analysis demonstrates that there is a similar directionality of key predictors. Household income and food-safety concerns emerged as the most significant determinants of both WTB and WTP. Higher income levels were associated with greater willingness to purchase premium products, while concerns regarding pesticide residues and food safety increased stated willingness to pay for CEA produce. Education also showed a positive association with consumer acceptance, suggesting that awareness and knowledge influence valuation of CEA-grown produce. The complementary findings indicate that CEA lettuce exhibits substantial market promise, predominantly among knowledgeable, wealthy, health-oriented, and safety-conscious urban consumers. These findings provide empirical evidence on consumer acceptance and valuation of CEA produce in Trinidad and Tobago, offering insights for pricing, marketing, and policy strategies aimed at supporting emerging controlled-environment agriculture systems.

Article History
Received: 18 December 2025
Accepted: 13 March 2026

Keywords
Controlled-Environment Agriculture (Cea);
Food Safety Concern;
Household Income;
Willingness to Buy;
Willingness to Pay.

CONTACT Gopalan Kathiravan drkathir@tanuvas.org.in Department of Animal Husbandry Statistics and Computer Applications, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai, India

Doi: https://dx.doi.org/10.12944/CRNFSJ.14.Special-Issue-June.08

Abbreviations

WTB	Willingness to buy
WTP	Willingness to pay

Introduction

Lettuce (*Lactuca sativa*) is an extensively consumed leafy vegetable that is rich in vitamins, providing nearly two and a half times the recommended daily intake of vitamin A and 4,443 µg beta-carotene for humans. Lettuce is widely consumed by people in Trinidad and Tobago. The country produced approximately 1.2 million kg of lettuce in 2024, equivalent to roughly 80,000 heads per week nationwide, according to the Central Statistical Office of the Ministry of Planning and Development. Some of the consumption demand of lettuce is addressed with domestic production and other supply is imported primarily from the United States of America.

Lettuce is primarily domestically produced by traditional open-field cultivation. Greenhouse systems of other Protected Agriculture (PA) crops, for example, were developed for the purpose of reducing pesticide use and protecting crops from adverse weather conditions by changing their growing zones. However, early in the Caribbean, poor control of internal temperatures led to reduced production.[1] Later inventions, such as high-investment structures equipped with fans, misting systems, heat-tolerant cultivars and improved management techniques to ease challenges with climate variability, helped address some of these. However, PA requires a high level of capital expenditure and many manufacturers have to face enormous challenges.[2]

Controlled Environment Agriculture (CEA), a further improvement derived from these technologies, allows for a significant level of control over light, temperature, humidity, carbon dioxide, and nutrient supply.[3] CEA systems offer a steady yield of produce and high quality, with minimal environmental damages, through the ability to grow the crop year-round in high density with minimal use of pesticides.[4] Comparison has shown that vertical CEA systems will use less water and yield 5 million heads of lettuce per acre compared to greenhouse yields of 1.6 million and open-field yields of only 50,000 heads.[5] Due to the increased recognition of the adverse impacts of synthetic chemicals on human health and the environment, the need for vegetables grown with no pesticides has gained popularity worldwide.[6,7] Due to its high perishability and exposure to disease and pests lettuce is generally treated with pesticides extensively.[8]

Consumers' willingness to buy (WTB) and willingness to pay (WTP) for lettuce grown in controlled environments are valuable for inform adoption strategies, pricing decisions, and regulatory interventions.[9,10] Previous research has indicated consumers are often willing to pay a premium for more reliable, sustainable products.[11] Past studies reported that willingness to pay for leafy vegetables was positively related to environmental consciousness and income growth.[12-14] Some research highlights the impact of socio-economic elements like education, income, age, and family structure in level of WTP.[15–18]

A growing body of empirical research from the United States has examined consumer willingness to pay (WTP) premiums for vegetables produced using alternative production systems, including greenhouse and controlled-environment agriculture (CEA). These studies provide useful benchmarks for both the magnitude of price premiums and the socio-economic determinants of consumer valuation. Evidence from U.S. markets suggests that consumers often exhibit positive WTP for produce associated with attributes such as local production, reduced pesticide use, and enhanced food safety. Previous studies have reported measurable premiums for vegetables produced under alternative or environmentally controlled production systems, with income, education, and food safety perceptions emerging as important determinants of valuation.[19–21]

Against this background, and considering the high production costs and innovative nature of CEA technology in Trinidad and Tobago, this study aims to assess consumers' Willingness To Buy (WTB) and Willingness To Pay (WTP) a premium for lettuce produced under controlled environments. While substantial international evidences exist

on willingness to pay for organic and pesticide-free vegetables, empirical evidence specific to Controlled-Environment Agriculture (CEA) leafy greens remains limited, particularly in Small Island Developing States (SIDS) like Trinidad and Tobago. Also, most prior studies estimated WTP independently of adoption behaviour, without examining whether determinants of purchase intention align with monetary valuation, and no study has jointly modelled WTB and WTP for CEA lettuce in the Caribbean context. By integrating Binary Logit and Tobit models within a unified empirical framework, this study contributes novel evidence on both adoption and premium allocation, while positioning findings within the broader international literature on safety-differentiated produce.

Materials and Methods

The study was carried out in Trinidad and Tobago, a twin island country between 10°02′ and 10°50′ N latitude and 60°55′ to 61°56′ W longitude. With a maritime climate typical of the tropics, this country experiences a wet season from May until December and then a dry season from December to May. Average annual rainfall is around 2,000 mm. Night-time temperatures lie from 22-25°C with daytime temperatures ranging from 30-32°C. The varying landscapes of the islands range from rolling ridges and swamps and three mountains, into five physiographic regions. Most soils are fertile or vegetable rich with the exception of sandy or unstable soils.[22]

Data were obtained through a cross-sectional supermarket-intercept survey conducted across four major regions of Trinidad (West, East, Central, and South). In each region, one large-format supermarket was selected using a stratified regional sampling approach from the official registry of retail outlets maintained by the Consumer Affairs Division (CAD), Ministry of Trade and Industry. From each regional list, one large-format supermarket with consistent fresh-produce sales was selected to represent the regional retail market. This design enhanced geographic coverage, though full population representativeness could not be assured. Adult shoppers (≥19 years) purchasing lettuce were systematically recruited using a fixed-interval protocol, whereby every third shopper selecting lettuce was approached. In cases of refusal, the next eligible shopper was invited to participate to maintain procedural consistency. A total of 184 shoppers were approached, of whom 160 consented to participate, yielding a response rate of 86.9%. For premium allocation analysis, five incomplete WTP responses were excluded, resulting in 155 valid observations for estimation in the Tobit model. No imputation procedures were applied. Respondents were presented with the following standardized information script: *"Controlled environment is a dark room with electric lights that deliver photosynthetically active radiation. The enclosed systems allow production during the year to restrict light, water, CO_2 and temperature. Pest and disease management is conducted within the controlled environment, which may reduce the need for conventional pesticide applications."* Care was taken to avoid emphasising superiority claims or promotional language. Respondents were then asked whether they would consider purchasing CEA lettuce if available in their supermarket. Respondents were subsequently asked two key valuation questions. The first elicited willingness to buy (WTB) by asking whether they would purchase CEA-grown lettuce if it were available in the supermarket. The second question elicited willingness to pay (WTP) by asking respondents how much more they would be willing to pay for lettuce produced using controlled-environment agriculture compared with conventionally produced lettuce. Willingness to pay was measured using a payment card format, in which respondents selected their preferred premium from a set of values ranging from TT$0 to TT$3.50 above the prevailing market price of conventional lettuce, which averaged approximately TT$4.50 per head across the surveyed supermarkets during the fieldwork period. Fieldwork was conducted typically during peak shopping periods between 4:00 pm and 7:00 pm on weekdays and weekends, when lettuce purchases were most frequent. Participation in the survey was voluntary and anonymous, and informed consent was obtained from all respondents prior to participation. No personally identifiable information was collected.

Contingent Valuation Method (CVM)

The Contingent Valuation Method (CVM) framework was employed to elicit two outcomes: (i) willingness to buy (WTB) and (ii) willingness to pay (WTP) a premium relative to the prevailing market price of conventional lettuce. WTB was measured as a binary variable (1 = willing to buy, 0 = not willing

to buy). WTP was elicited from all respondents, irrespective of WTB response, using a payment card that included: TT$0 (no premium), TT$0.50, TT$1.00, TT$1.50, TT$2.00, TT$2.50, TT$3.00, and TT$3.50. The explicit inclusion of TT$0 allowed respondents to indicate zero premium willingness. Forty-four respondents selected TT$0, resulting in left-censoring at zero in the WTP distribution. Because the study relies on a contingent valuation framework using hypothetical purchase scenarios, responses may be subject to hypothetical bias, whereby stated willingness to pay exceeds actual behaviour. This issue has been widely documented in stated-preference literature. To mitigate this concern, respondents were provided with realistic purchasing contexts and a bounded payment card format reflecting plausible market premiums. Nevertheless, the estimated WTP values should be interpreted as indicative stated preferences rather than revealed market behaviour, as stated willingness-to-pay values obtained through hypothetical survey formats may be subject to upward bias.[7]

Modelling Approaches

Binary Logit Regression: Willingness to Buy

WTB was analysed using a binary Logit model:

$$\text{Ln } p/1\text{-}p = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n$$

where p is the probability of being willing to buy CE lettuce and X are socio-demographic and awareness variables. Odds ratios were computed to assess the relative effect of each explanatory variable.[7,23,24] Odds ratios and associated standard errors were used to interpret the magnitude and direction of effects.

Tobit Regression: Willingness to Pay

WTP values were analysed using a Tobit model to account for zero-censoring:

$$WTP_i = \{X_i\beta + u_i \text{ if } X_i\beta + u_i > 0 \; 0 \text{ if } X_i\beta + u_i \leq 0\}$$

Marginal effects were computed to assess the influence of explanatory variables on expected WTP.[25–27]

Because WTP was elicited from all respondents, including those indicating no purchase intention, a single-equation Tobit specification was used rather than a hurdle or selection model. Since the valuation question was asked independently of the binary WTB question, a small number of respondents indicated a positive premium despite stating that they would not currently purchase the product. Such responses may reflect hypothetical valuation rather than immediate purchase intention. In the Tobit specification, these responses were treated as valid monetary valuations rather than inconsistencies. The Tobit framework assumes that zero premiums represent corner solutions rather than non-participation. Robust standard errors were computed.

The assumptions underlying the econometric models were considered during estimation. The logistic regression model assumes independence of observations and correct specification of the functional relationship between predictors and the log-odds of the outcome. The Tobit model assumes a normally distributed error term and censoring at zero for the willingness-to-pay premium. Multicollinearity among explanatory variables was assessed using Variance Inflation Factors (VIF). The VIF values were within acceptable limits, indicating that multicollinearity was not a serious concern in the estimated models.

Study Limitations

The study design incorporated several strengths, including regional stratification to ensure coverage across Trinidad's four major regions and systematic shopper recruitment using a fixed-interval protocol, which enhanced consistency and reduced interviewer discretion. These features strengthen internal validity and provide a robust basis for analysis.

At the same time, certain considerations are important for cautious generalisation. The supermarket-intercept approach reflects the behaviour of active lettuce purchasers in large-format outlets, and results should be extended to other consumer groups with care. As a stated-preference method, WTP estimates may be influenced by hypothetical bias and payment-card anchoring, though reminders about the likely higher retail price of CEA lettuce were included to mitigate such effects. Finally, zero-premium responses were retained as valid corner solutions; future applications of experimental auctions or double-hurdle models could provide additional robustness checks and enhance external validity. Because the survey was conducted among supermarket lettuce purchasers in large retail outlets, the results primarily reflect the preferences

of urban supermarket consumers rather than the entire national population.

Results

The demographic and socio-economic characteristics of the respondents is presented in Table 1. The sample was relatively diverse across age groups, with the largest proportion of respondents aged 29–40 years (30.96%), followed by those below 29 years (25.81%). Males constituted 54.19% of the sample, while females accounted for 45.81%. In terms of ethnicity, Indian respondents formed the largest group (39.35%), followed by African (27.74%) and other ethnic groups (32.90%).

Table 1: Demographic and socio-economic characteristics of respondents

Characteristic	Category	Number (n)	Percentage (%)
Age	< 29 years	40	25.81
	29–40 years	48	30.96
	40–50 years	34	21.94
	> 50 years	33	21.29
Gender	Female	71	45.81
	Male	84	54.19
Ethnicity	African	43	27.74
	Indian	61	39.35
	Others	51	32.90
Marital status	Married	66	42.58
	Unmarried	89	57.42
Household size	≤ 4 members	71	45.81
	> 4 members	84	54.19
Monthly income (TT$)	< 10,000	50	32.26
	10,000–17,999	47	30.32
	18,000–23,999	19	12.26
	≥ 24,000	39	25.16
Education	< Secondary	30	19.35
	Secondary	41	26.45
	Tertiary	84	54.19

A majority of respondents were unmarried (57.42%), and 54.19% reported household sizes greater than four members. With respect to income, 32.26% earned less than TT$10,000 per month, while 25.16% reported incomes of TT$24,000 or higher. Educational attainment was relatively high, with 54.19% possessing tertiary-level education, indicating a relatively well-educated consumer sample.

The two-step process of consumer choice in relation to new food technologies consists of adoption as either a binary measure of willingness to buy (WTB), followed by a continuous value of the product as willingness to pay (WTP). Of the 155 valid respondents, 120 (77.4%) indicated willingness to purchase CEA-grown lettuce, whereas 35 (22.6%) reported that they would not purchase the product if introduced in supermarkets. WTB was analysed using a Binary Logistic Regression model in this study, while we analysed WTP using a Tobit regression to consider censoring at the lower end of the premium price. Importantly, 44 of the 155 participants reported a zero premium, stressing the need for censored regression.

Statistically, both models performed well. As mentioned, the logistic regression model for WTB was highly significant statistically ($\chi^2 = 79.102$) and showed high explanatory value (Nagelkerke $R^2 = 0.651$). As shown in Table 2, the model correctly predicted WTB outcomes in 89.0% of cases. The classification accuracy was greatest among willing to buy consumers (96.7% of consumers who indicated willingness to buy and 62.9% of consumers that were not willing to purchase were correctly classified).

Table 2: Logit regression analysis classification table

Observed	Predicted	Predicted	Percentage Correct
Willingness To Buy	No	Yes	
No	22	13	62.9
Yes	4	116	96.7
Overall Percentage			89.0

The Tobit Regression for WTP also proved very successful. We observed a high robustness of the model (Prob > χ^2 = 0.000; LR χ^2 = 74.14) indicating that the explanatory variables included in the analysis were effective in capturing determinants of the premium that consumers are willing to pay for lettuce grown under controlled conditions. These conclusions indicate the accuracy that the modelling method achieves in interpreting both adoption decisions and valuation results.

Comparative patterns across WTB and WTP Models

The Pathway to Coherence for the Consumer Choice highlights the significant alignment between the outputs of both models, which is a crucial factor for empirical indication supporting the theoretical framework. Coherence here refers to the degree to which the economic and cognitive elements driving consumers' discrete adoption decision (WTB) are consistent with the elements influencing their continuous monetary valuation (WTP). This agreement demonstrates that the psychological reasons behind purchase decision-making are the same factors that consumers recognize and financially reward when determining the premium they are willing to accept.

The WTB Logit regression results are reported in Table 3, while Tobit regression estimates for WTP are presented in Table 4. A comparative overview of the main findings is summarized in Table 5, which illustrates the structural consistency observed between the models. Taken together, these findings confirm that consumer adoption and valuation may be related processes of a unified decision-making pathway.

Table 3: Logit regression estimates for Willingness To Buy lettuce from Controlled Environment

Explanatory variables		B	S.E.	Wald	p value	Odds Ratio
X1	Age: 29-40 yearsa	2.566**	1.151	4.967	.026	13.014
X2	Age: 40-50 yearsa	0.357	0.945	0.143	.705	1.429
X3	Age: Over 50 yearsa	0.649	1.055	0.378	.539	1.913
X4	Genderb	-1.527**	0.702	4.733	.030	0.217
X5	Ethnicity: Africanc	-2.531**	1.089	5.406	.020	0.080
X6	Ethnicity: Indianc	1.993**	0.909	4.809	.028	7.340
X7	Marital status	-1.678**	0.754	4.949	.026	0.187
X8	Household size (> 4)	-0.501	0.641	0.610	.435	0.606
X9	Income: $10000-17999d	-2.576***	0.806	10.217	.001	0.076
X10	Income: $18000-23999d	4.045***	1.651	5.999	.014	57.103
X11	Income: $24000 and mored	2.204**	1.075	4.203	.040	9.08
X12	Education: Secondarye	3.067***	1.001	9.398	.002	21.487
X13	Education: Tertiarye	2.171***	0.844	6.606	.010	8.763
X14	Consume lettuce daily	-0.812	1.004	0.654	.419	0.444
X15	Pesticides hazardous to health	3.242**	1.616	4.024	.045	25.576
X16	Lettuce prone to pests/diseases	1.222*	0.693	3.105	.078	3.394
X17	Aware of pesticide use in traditional lettuce	-2.499**	1.010	6.125	.013	0.082
X18	Pesticides damaging to environment	3.921***	1.102	12.669	.000	50.460
X19	Controlled environment lettuce costly	0.172	0.758	0.052	.820	1.188
Constant	-4.657	2.098	4.928	.026	.009	

Model Summary: -2 Log likelihood = 79.102; Cox & Snell R^2 = 0.428; Nagelkerke R^2 = 0.651
*Significant (P ≤ 0.05); ** Highly significant (P ≤ 0.01); *** Highly significant (P ≤ 0.001)
Reference Categories: a - Age < 29 years; b - Male; c - Others; d - Income < $10000; e - Less than secondary education.

Table 4: Tobit regression estimates of Willingness To Pay for lettuce from Controlled Environment

Explanatory variables		Tobit Coefficients	S.E.	Marginal effects for the probability being uncensored	Marginal effects for E(WTP | 0< WTP)
X_1	Age: 29-40 yearsa	0.429	0.348	0.071	0.281
X_2	Age: 40-50 yearsa	0.546	0.397	0.085	0.366
X_3	Age: Over 50 yearsa	0.539	0.398	0.084	0.362
X_4	Genderb	-0.135	0.242	-0.024	-0.086
X_5	Ethnicity: Africanc	-0.491	0.345	-0.094	-0.301
X_6	Ethnicity: Indianc	0.899***	0.290	0.147***	0.591***
X_7	Marital status	-0.524*	0.289	-0.095*	-0.329*
X_8	Household size (> 4)	-0.177	0.237	-0.031	-0.113
X_9	Income: $10000-17999d	-0.721**	0.300	-0.140**	-0.437**
X_{10}	Income: $18000-23999d	0.715*	0.393	0.101**	0.497*
X_{11}	Income: $24000 and mored	0.654**	0.318	0.101**	0.439*
X_{12}	Education: Secondarye	0.804**	0.382	0.122**	0.545**
X_{13}	Education: Tertiarye	0.966***	0.331	0.175***	0.607***
X_{14}	Consume lettuce daily	-0.093	0.404	-0.017	-0.059
X_{15}	Pesticides hazardous to health	1.831***	0.643	0.468***	0.864***
X_{16}	Lettuce prone to pests/diseases	0.731***	0.242	0.130***	0.463***
X_{17}	Aware of pesticide use in traditional lettuce	-0.615**	0.282	-0.101**	-0.404**
X_{18}	Pesticides damaging to environment	1.513***	0.416	0.364***	0.782***
X_{19}	Controlled environment lettuce costly	0.632**	0.277	0.123**	0.382**
Constant	-3.086	0.947			
Sigma	1.341	0.096			

No. of observations = 155; No. of censored observations = 44; LR chi2 = 74.14; Prob > chi2 = 0.000; Pseudo R^2 = 0.142
*Significant (P ≤ 0.05); ** Highly significant (P ≤ 0.01); *** Highly significant (P ≤ 0.001)
Reference Categories: a - Age < 29 years; b - Male; c - Others; d - Income < $10000; e - Less than secondary education.

Table 5: Comparative Summary of Key Determinants across WTB (Logistic) and WTP (Tobit) Models

Predictor Variable	WTB (Logistic Model)	WTP (Tobit Model)	Coherent behaviour and Interpretation
Household Income	Significant (Substantially greater odds)	Highly Influential (Substantially more willing to pay)	Economic flexibility contributes to initial adoption (WTB) as well as premium value (WTP), both of which are essential in accessing quality-differentiated merchandise[25]
Education Level	Strong Positive Predictor (Markedly higher likelihood)	Significant Positive Effect	Facilitates processing of complex technology and safety information, positively affecting receptivity and perceived value[34]
Food Safety Concern	Strongest Predictor	Largest Marginal Effect	Primary psychological driver; consumers monetize risk reduction, seeking CEA as a guaranteed, hygienic alternative[35]
Perceived Benefits (Quality, Safety, Sustainability)	Not the primary focus of WTB model	Significant Positive Influence	Intrinsic and extrinsic claims directly influence the premium that consumers are willing topay, which serves to support the perceived utility[37]
Age	Mixed / weak effects	Slight positive association	Age effects are relatively weak and inconsistent[38]

Determinants of Willingness to Buy (WTB) and Willingness to Pay (WTP)

Results of the regression analysis showed a clear connection between determining factors for purchasing controlled environment agriculture (CEA) lettuce (WTB) and variables influencing consumers' willingness to pay a premium (WTP). Both decisions are highly influenced by socioeconomic status, level of cognition and perceptions of health and safety. Income emerged as the strongest predictor in all models.

Within the context of the WTB scheme (Table 3),

households with an income between $18,000 and $23,999 (X10) were far more likely to buy CEA lettuce (OR = 57.103, $p < 0.01$). In fact, the upper group ($24,000+, X11) showed significantly higher odds (OR = 9.08, $p < 0.05$).

Respondents were asked to indicate the price premium they would be willing to pay for CEA-grown lettuce relative to conventionally produced lettuce using a payment card ranging from TT$0 to TT$3.50 above the prevailing market price. A substantial share of respondents indicated willingness to pay a positive premium, reflecting perceived benefits such as improved food safety and reduced pesticide exposure. However, as noted in the contingent valuation literature, stated willingness to pay in hypothetical surveys may be subject to upward bias and should therefore be interpreted as indicative rather than exact measures of market demand.

This financial impact carried through to the WTP model (Table 4). Higher-income households were always more willing to pay more, indicated by positive marginal effects in both upper income brackets (X10: ME = 0.497, $p < 0.05$; X11: ME = 0.439, $p < 0.05$). By comparison, the middle-low-income group ($10,000–$17,999, X9) was significantly negatively related to WTB (OR = 0.076, $p < 0.001$) and WTP (ME = –0.437, $p < 0.01$).

Education proved to be an influential factor. Those with secondary education (X12) had odds of 21.487 ($p < 0.01$), while individuals with tertiary education (X13) had odds of 8.763 ($p < 0.01$). This advantage extended to WTP, where tertiary-educated consumers (X13) experienced the strongest marginal premium willingness increment (ME = 0.607, $p < 0.001$).

Food-safety concerns were also among the strongest motivational drivers. Concern that pesticides harm the environment (X18) showed very high odds (OR = 50.460, $p < 0.001$), followed by concern about the health impacts of pesticides (X15, OR = 25.576, $p < 0.05$). Even perceptions that lettuce is susceptible to pests and diseases (X16) marginally significant at the 10% level ($p = 0.078$) and is interpreted cautiously.

These safety considerations resulted in the strongest financial valuations in the WTP model. The marginal effect of concern about pesticides hazardous to health (X15) was the strongest (ME = 0.864, $p < 0.001$), whereas concern about environmental damage (X18) produced the second highest marginal effect (ME = 0.782, $p < 0.001$).

Other factors showed mixed effects. Knowledge of pesticide application in traditional lettuce (X17) correlated negatively with WTB (OR = 0.082, $p < 0.05$) and WTP (ME = –0.404, $p < 0.01$). Age effects were generally weak, with significance only for the 29–40 age group (X1) (OR = 13.014, $p < 0.05$). Female consumers (X4) were less likely to purchase (OR = 0.217, $p < 0.05$).

Perceived cost (X19) had a small effect on WTB but showed a positive relationship with WTP (ME = 0.382, $p < 0.01$). Indian consumers (X6) had positive relationships with WTB (OR = 7.340, $p < 0.05$) and WTP (ME = 0.591, $p < 0.001$), whereas consumers of African origin (X5) showed negative associations with WTB (OR = 0.080, $p < 0.05$). Marital status (X7) was negatively associated, while household size (X8) and daily lettuce consumption (X14) were insignificant.

Discussion

The results indicate that income plays a dominant role in shaping both adoption decisions (Table 3) and valuation (Table 4) outcomes. The significantly higher likelihood of purchasing CEA lettuce among middle- and upper-income households supports the premise that consumers with greater disposable income are more inclined to adopt differentiated, high-quality food products.[25] The negative relationship observed for the $10,000–$17,999 income group further confirms that price barriers continue to limit market entry for middle-income consumers, consistent with prior findings that premiums restrict adoption among price-sensitive households.[29-31] The positive relationship between household income and both willingness to buy and willingness to pay suggests that affordability remains a key constraint for wider adoption of CEA-produced lettuce. Policy measures such as targeted support for CEA production systems, investment incentives, or technological subsidies could help reduce production costs and improve price accessibility for a broader consumer base.

Education also emerged as a key determinant (Tables 3 and 4), suggesting that higher educational attainment enhances consumers' capacity to evaluate complex credence attributes such as

chemical safety, climate resilience and production consistency. This aligns with earlier research indicating that informed consumers are more receptive to technological food innovations and are better equipped to assess long-term benefits.[32,33]

Food safety perceptions were the most powerful psychological drivers influencing both WTB (Table 3) and WTP (Tables 4). High concern regarding pesticide-related environmental and health risks translated into strong adoption likelihood and the highest premium valuations. This suggests that many surveyed consumers are willing to pay a defensive premium to mitigate perceived food safety risks, reinforcing existing evidence that safety assurance can command economic value in fresh produce markets.[32-34]

Expressed as a percentage of the prevailing market price, the estimated premium falls within the range reported in previous studies on pesticide-free or hydroponic vegetables, although methodological and contextual differences limit direct comparability. Consumers in prior research have been found willing to pay premiums of roughly 10–30% above conventional prices, depending on production attributes and market context. Previous studies reported approximately 9–13% premiums for hydroponic vegetables,[35] about 16% premiums for pesticide-free vegetables,[36] and around 20–24% premiums for aquaponic vegetables in European markets.[37]

The negative influence of knowledge regarding pesticide application in conventional lettuce suggests heightened risk awareness or reliance on lower-cost alternatives among certain consumers. Gender and age effects were limited, indicating that demographic characteristics play a secondary role relative to economic capability and safety cognition.

Overall, the findings reaffirm that adoption and premium decisions are driven primarily by value-based considerations rather than conventional demographic segmentation. The broad alignment observed between WTB and WTP confirms that both decisions are part of a unified consumer choice pathway characterized by financial capacity, education, and health-oriented motivations.

Because the information script described controlled-environment production as potentially reducing pesticide use, it is possible that this framing influenced respondents' valuation by emphasising food-safety benefits. Consequently, the estimated premiums may partly reflect the framing of safety attributes in the information script rather than purely independent consumer perceptions. Controlled-environment lettuce thus appeals predominantly to an urban, informed and affluent segment that prioritizes food safety and technological assurance. These results provide clear guidance for industry and policymakers. Marketing strategies should emphasize pesticide-free production, hygiene, and certified risk reduction rather than positioning CEA lettuce merely as an alternative product.[38] Clear labeling and communication of credence attributes such as water efficiency and climate resilience can further justify price premiums among educated consumers.

Policy support in the form of standardized certification and traceability systems is essential to reinforce consumer trust and validate environmental and safety claims. Public health messaging that highlights risks associated with conventional farming can strengthen perceived value, while the capacity of CEA systems to deliver year-round fresh produce supports broader food security and sustainability objectives.[39]

Conclusion

Within the surveyed supermarket-intercept sample, household income and food-safety-related perceptions emerged as significant determinants of both stated willingness to buy and willingness to pay a premium for CEA lettuce. These findings are consistent with international evidence showing that consumer valuation for safety-differentiated fresh produce is strongly influenced by perceived food safety risks and socio-economic characteristics. When expressed as a percentage of the prevailing market price, the estimated premium falls within the range reported internationally for safety-differentiated leafy vegetables. This suggests that consumer valuation in the present context is broadly comparable with evidence reported in other markets, despite differences in production systems, information environments, and survey methods.

However, given the stated-preference design and the supermarket-intercept sampling framework, the results should be interpreted as indicative rather than definitive measures of market demand. Future

research employing non-hypothetical valuation approaches such as experimental auctions, more representative sampling designs, and alternative econometric specifications (e.g., double-hurdle or mixed logit models) would help strengthen external validity and provide more precise estimates of consumer demand and price responsiveness for CEA produce.

Acknowledgement
The authors are thankful to the Faculty of Food and Agriculture, The University of the West Indies, for the facilities provided to analyse the data.

Funding Sources
The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest
The author(s) do not have any conflict of interest.

Data Availability Statement
This statement does not apply to this article.

Ethics Statement
This study involved survey-based social science research with no identifiable personal data collected. In accordance with the ethical guidelines of The University of the West Indies (UWI Policy on Research Ethics, Page 11, Point 3 – "Surveys or Interviews"), St.Augustine, Trinidad, surveys or interviews in which researchers' private data, field notes, and published materials are so encoded that there is no likelihood that the identity of human subjects will be revealed are normally exempt from review, unless the questions could cause distress or harm. Participation was voluntary and informed consent was obtained from all participants.

Informed Consent Statement
All participants in this study provided informed consent and took part voluntarily. They received clear information regarding the study's objectives and procedures. Participation was entirely optional, and individuals retained the right to withdraw or refrain from submitting the survey at any stage without any consequences. The study adhered strictly to ethical guidelines to safeguard participants' rights and privacy.

Clinical Trial Registration
This research does not involve any clinical trials.

Permission to reproduce material from other sources
Not Applicable

Authors Contributions
- **Gopalan Kathiravan:** Writing – Original Draft, Review and Editing– Supervision, Methodology, Formal Analysis, Data Curation, Conceptualization.
- **Jessica Churaman:** Writing – Original Draft, Project Administration, Investigation, Formal Analysis, Data Curation, Conceptualization.
- **Nkosi Felix:** Resources, Project Administration, Investigation, Data curation.

References

1. Martin CCG St., Bedasie S, Ganpat WG, Orrigio S, Isaac WAP, Brathwaite RAI. Greenhouse technology is once again washing the Caribbean- can we ride the wave this time around ? In: *Proceedings of the International Congress on Tropical Agriculture* [Internet]. 2009. Available from: https://uwispace.sta.uwi.edu/server/api/core/bitstreams/1bb557cc-b18b-4837-83c8-9dd8d4cafd45/content
2. Espitia JJ, Velázquez FA, Rodriguez J, Gomez L, Baeza E, Aguilar-Rodríguez CE, *et al*. Solar Energy Applications in Protected Agriculture: *A Technical and Bibliometric Review of Greenhouse Systems and Solar Technologies. Agronomy* [Internet]. 2024 Nov 25;14(12):2791. Available from: https://www.mdpi.com/2073-4395/14/12/2791
3. Gómez C, Currey CJ, Dickson RW, Kim HJ, Hernández R, Sabeh NC, *et al*. Controlled Environment Food Production for Urban Agriculture. *Hort Science* [Internet]. 2019 Sep;54(9):1448–58. Available from: https://journals.ashs.org/view/journals/hortsci/54/9/article-p1448.xml
4. Heuvelink E, Hemming S, Marcelis LFM. Some recent developments in controlled-environment

agriculture: on plant physiology, sustainability, and autonomous control. *J Hortic Sci Biotechnol* [Internet]. 2025 Sep 3;100(5):604–14. Available from: https://www.tandfonline.com/doi/full/10.1080/14620316.2024.2440592

5. Touliatos D, Dodd IC, McAinsh M. Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics. *Food energy Secur* [Internet]. 2016 Aug;5(3):184–91. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27635244
6. Oaya CS, Malgwi AM, Degri MM, Samaila AE. Impact of synthetic pesticides utilization on humans and the environment: an overview. *Agric Sci Technol* [Internet]. 2019 Dec;11(4):279–86. Available from: https://agriscitech.eu/impact-of-synthetic-pesticides-utilization-on-humans-and-the-environment-an-overview/
7. Kathiravan G, Duraisamy S, Chowdhury A, Ganpat W. Determinants of Willingness-to-Pay A Premium Price for Integrated Pest Management Produced Fruits and Vegetables in Trinidad. *Agro Ekon* [Internet]. 2020 Nov 19;31(1). Available from: https://jurnal.ugm.ac.id/jae/article/view/58213
8. Haile FJ, Kerns DL, Richardson JM, Higley LG. Impact of Insecticides and Surfactant on Lettuce Physiology and Yield. *J Econ Entomol* [Internet]. 2000 Jun 1;93(3):788–94. Available from: https://academic.oup.com/jee/article-lookup/doi/10.1603/0022-0493-93.3.788
9. Chang KL, Xu P, Warmann J, Lone T, Munzimi ZS, Opoku E. Consumer Characteristics and Willingness to Pay for Locally Produced Product: A Case Study of Rib-eye Steaks in the Northern Great Plains. *J Agric Food Syst Community Dev* [Internet]. 2013 Nov 6;99–121. Available from: https://foodsystemsjournal.org/index.php/fsj/article/view/239
10. Gedikoğlu H, Gedikoğlu A. Consumers' awareness of and willingness to pay for HACCP-certified lettuce in the United States: Regional differences. *Food Control* [Internet]. 2021 Dec;130:108263. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0956713521004011
11. Vidogbéna F, Adégbidi A, Tossou R, Assogba-Komlan F, Martin T, Ngouajio M, *et al*. Consumers' Willingness to Pay for Cabbage with Minimized Pesticide Residues in Southern Benin. *Environments* [Internet]. 2015 Oct 1;2(4):449–70. Available from: https://www.mdpi.com/2076-3298/2/4/449
12. Cobbinah MT, Donkoh SA, Ansah IGK. Consumers' willingness to pay for safer vegetables in Tamale, Ghana. *African J Sci Technol Innov Dev* [Internet]. 2018 Nov 10;10(7):823–34. Available from: https://www.tandfonline.com/doi/full/10.1080/20421338.2018.1519062
13. Nitzko S, Bahrs E, Spiller A. Consumer willingness to pay for pesticide-free food products with different processing degrees: Does additional information on cultivation have an influence? *Farming Syst* [Internet]. 2024 Jan;2(1):100059. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2949911923000618
14. Cerda A, García L, Viscay A, López B. Willingness to pay and consumer preferences for organic lettuce (*Lactuca sativa* L). Rev la Fac Agron Univ del Zulia [Internet]. 2021 Oct 1;38(4):1087–107. Available from: https://produccioncientificaluz.org/index.php/agronomia/article/view/36810
15. Owusu V, Anifori MO. Consumer willingness to pay a premium for organic fruit and vegetable in Ghana. *Int Food Agribus Manag Rev.* 2013;16(1):67–86.
16. Yang SH, Hu W, Mupandawana M, Liu Y. Consumer Willingness to Pay for Fair Trade Coffee: A Chinese Case Study. *J Agric Appl Econ.* 2012;44(1):21–34.
17. Maruthesha AM, Vijayalakshmi D, Jayalaxmi B, Patil R. Impact of socio-economic status on food consumption pattern of rural farm women. *Asian J Dairy Food Res* [Internet]. 2019 Apr 21;(of). Available from: http://arccjournals.com/journal/asian-journal-of-dairy-and-food-research/DR-1366
18. 1. Wu L, Wang S, Zhu D, Hu W, Wang H. Chinese consumers' preferences and willingness to pay for traceable food quality and safety attributes: The case of pork. *China Econ Rev* [Internet]. 2015 Sep;35:121–36. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1043951X15000851
19. 1. Darby K, Batte MT, Ernst S, Roe B. Decomposing local: A conjoint analysis of locally produced foods. *Am J Agric Econ* [Internet]. 2008 May;90(2):476–86. Available from: https://doi.org/10.1111/j.1467-8276.2007.01111.x
20. Yue C, Tong C. Organic or local? Investigating

consumer preference for fresh produce using a choice experiment with real economic incentives. *HortScience* [Internet]. 2009 Apr;44(2):366–71. Available from: https://journals.ashs.org/view/journals/hortsci/44/2/article-p366.xml

21. Gedikoğlu H, Gedikoğlu A. Consumers' awareness of and willingness to pay for HACCP-certified lettuce in the United States: Regional differences. *Food Control* [Internet]. 2021 Dec;130:108263. Available from: https://doi.org/10.1016/j.foodcont.2021.108263
22. Ekwue EI, Bachan DC, Ali CF, Ekwue EI, Bachan DC, Ali CF. *Density-moisture Relations of Some Trinidad Soils Determined Using a Hammer-type Vibratory Compactor.* 2021;49(1):47–54. Available from: https://www.researchgate.net/publication/359175097
23. Anderson RP, Jin R, Grunkemeier GL. Understanding logistic regression analysis in clinical reports: an introduction. *Ann Thorac Surg* [Internet]. 2003 Mar;75(3):753–7. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0003497502046830
24. Chao-Ying Joanne Peng, Kuk Lida Lee, Gary M. Ingersoll. An Introduction to Logistic Regression Analysis and Reporting. *J Educ Res.* 2002 September/October; 96(1):3–14.
25. Cho Y, Easter KW, McCann LMJ, Homans F. Are rural residents willing to pay enough to improve drinking water quality? *J Am Water Resour Assoc* [Internet]. 2005 Jun;41(3):729–40. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2005.tb03767.x
26. Greene WH. Econometric Analysis. 4th ed. Upper Saddle River, *N.J.: Prentice Hall;* 2000.
27. Kathiravan G, Thirunavukkarasu M, Selvam S. Are farmers willing to pay for quality improvements in livestock services delivery? Evidence from South India. *Indian J Anim Sci.* 2012;82(6):634–9.
28. Lancaster KJ. A New Approach to Consumer Theory. *J Polit Econ* [Internet]. 1966 Apr; 74(2):132–57. Available from: https://www.journals.uchicago.edu/doi/10.1086/259131
29. Didier T, Lucie S. Measuring consumer's willingness to pay for organic and Fair Trade products. *Int J Consum Stud* [Internet]. 2008 Sep 13;32(5):479–90. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1470-6431.2008.00714.x
30. Zhang G, Zhang Q, Yang X, Fang R, Wu H, Li S. Living environment shaped residents' willingness to pay for ecosystem services in Yangtze River Middle Reaches Megalopolis, *China. Geogr Sustain* [Internet]. 2023 Sep;4(3):213–21. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2666683923000196
31. Yue C, Tong C. Organic or Local? Investigating Consumer Preference for Fresh Produce Using a Choice Experiment with Real Economic Incentives. *Hort Science* [Internet]. 2009 Apr;44(2):366–71. Available from: https://journals.ashs.org/view/journals/hortsci/44/2/article-p366.xml
32. Wield D, Tait J, Chataway J, Mittra J, Mastroeni M. Conceptualising and practising multiple knowledge interactions in the life sciences. *Technol Forecast Soc Change* [Internet]. 2017 Mar;116:308–15. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0040162516303547
33. Li R, Lee HY, Lin YT, Liu CW, Tsai PF. Consumers' Willingness to Pay for Organic Foods in China: Bibliometric Review for an Emerging Literature. *Int J Environ Res Public Health* [Internet]. 2019 May 16;16(10):1713. Available from: https://www.mdpi.com/1660-4601/16/10/1713
34. Brewer MS, Rojas M. Consumer attitudes toward issues in food safety. *J Food Saf* [Internet]. 2008 Feb;28(1):1–22. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1745-4565.2007.00091.x
35. Lusk JL, Briggeman BC. Food values. *Am J Agric Econ* [Internet]. 2009 Feb;91(1):184–196. Available from: https://academic.oup.com/ajae/article/91/1/184/102858
36. Yiridoe EK, Bonti-Ankomah S, Martin RC. Comparison of consumer perceptions and preference toward organic versus conventionally produced foods: A review and update of the literature. *Renew Agric Food Syst* [Internet]. 2005 Dec; 20(4):193–205. Available from: https://doi.org/10.1079/RAF2005113
37. Bourn D, Prescott J. A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. *Crit Rev Food Sci Nutr* [Internet]. 2002 Jan;42(1):1–34. Available from: https://www.tandfonline.com/doi/abs/10.1080/10408690290825439

38. Nesheim MC, Oria M, Yih PT. A framework for assessing effects of the food system. *A Framework for Assessing Effects of the Food System.* 2015. 1–430 p.

39. Trautman D, Goddard E, Nilsson T. Traceability - a Literature Review. Rural Econ [Internet]. 2008;08–02:1–148. Available from: http://ageconsearch.umn.edu/handle/52090