

# Consumers' perception and willingness to pay for hydroponic tomatoes: the effects of sustainability and quality attributes

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## Abstract

**Purpose** – The agricultural sector is facing pressure due to concerns about its impact on the environment. Farmers must adapt to ensure high-quality, sustainable production. This requires efficient techniques such as soilless farming. The development of agricultural innovations depends on social acceptance; thus, it is crucial to identify the factors that influence consumers' purchasing decisions. The aim of this paper is to analyse consumers' perceptions of hydroponic cultivation techniques and their willingness to pay (WTP) a premium price for hydroponic tomatoes certified as “nickel-free” and “zero-residue”.

**Design/methodology/approach** – The survey was conducted in Italy using tomatoes as a case study. Data were collected through an online questionnaire from a convenience sample of 292 respondents and were analysed using statistical analysis and a multiple linear regression model.

**Findings** – The results showed that WTP was influenced by frequency of purchase, familiarity with soilless technology, environmental sustainability, income and education. Consumers place a high value on the sustainability of the hydroponic production process and their perception of increased safety positively influences WTP. It is therefore recommended that marketing strategies focus on the environmental sustainability and safety of hydroponic products. In addition, it may be beneficial to implement a certification system specific to hydroponic cultivation, in addition to the existing “nickel-free” and “zero-residue” certifications.

**Originality/value** – This study introduces several novel elements: it is the first to assess the Italian consumers' perceptions and WTP for a hydroponic product. Secondly, it assesses WTP in relation to several aspects of increasing relevance related to health claims, namely “nickel-free” and “zero-residue”.

**Keywords** Willingness to pay, Consumer perception, Soilless cultivation, Hydroponic tomatoes, Nickel-free, Zero-residue

**Paper type** Research paper

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## 1. Introduction

Agriculture faces many environmental challenges as a result of continued adverse climatic events and the increasing scarcity of natural resources, such as clean water and arable land. Strategies are therefore needed to maximise resource efficiency while minimising the effects on the environment. Greenhouse cultivation in a controlled environment is an alternative technique that has been developed to ensure agricultural production in an increasingly hostile environment (Jensen, 2002). This system allows efficient management of temperature, irrigation process, humidity and light and protects crops from pest attacks (Ramin Shamsiri *et al.*, 2018). In this way, having more control over growing conditions allows for better yields (Li *et al.*, 2022). However, agriculture is responsible for around 23% of man-made greenhouse gas emissions and consumes up to 92% of the world's freshwater (Gibbs and Cappuccio, 2022; Ritchie *et al.*, 2022), so production techniques need to become more productive and sustainable. Sustainability is a crucial aspect in the development of the agri-food sector to promote development and increase the competitiveness of business. Transitioning to more sustainable agriculture is a key priority of the 17 Sustainable Development Goals (SDGs) under the UN's 2030 Agenda. Measures include promoting resource efficiency, protecting biodiversity and reducing pollution and emissions. The drive towards sustainable practices in agriculture stems not only from the direction given by national and international standards but also from the growing consumers' attention to these issues. An increasing number of consumers are now aware that a more sustainable lifestyle also depends on their purchasing choices. As a result, many people are choosing organic, local and seasonal products, which are perceived to have a lower environmental impact, and they prefer certified foods, which are perceived to be safer and more controlled (Thøgersen *et al.*, 2019; Wu *et al.*, 2021). There is a growing emphasis on environmental issues among agricultural companies, with sustainability becoming a core value within the context of their corporate culture (Epstein *et al.*, 2017; Gadanakis *et al.*, 2015; Repar *et al.*, 2017). The impact of climate change is a significant factor limiting the farmers' ability to produce food. The effects of climate change are being observed in alterations to growing seasons, limitations on water availability, the proliferation of weeds and pests and a reduction in crop productivity (Malhi *et al.*, 2021; Raza *et al.*, 2019). It is imperative that farmers adapt to these changes while simultaneously reducing greenhouse gas emissions from agriculture through the adoption of climate-smart practices (Bocean, 2024). For farms committed to reducing their environmental impact, sustainability and innovation are intertwined, as reducing environmental impact requires investment in technology. The increased digitalisation of agriculture has the potential to enhance the overall efficiency of the entire agri-food system (Bahn *et al.*, 2021; Panetto *et al.*, 2020). Furthermore, the technological efficiency of cutting-edge farming systems allows for the improvement of intrinsic product qualities by minimising pesticide residues and heavy metals through more effective control of growing conditions (Organisation des Nations Unies pour l'alimentation et l'agriculture *et al.*, 2013). In recent years, innovation has led to the adoption of more environmentally friendly and technological solutions characterised by the sustainable use of energy and the reuse of water and nutrients (Karanisa *et al.*, 2022; Maraveas *et al.*, 2023). This requires increasing investments and adoption of productivity-enhancing technologies. New technologies have the potential to change the global food production system, reducing its impact on the climate and environment. When considering global sustainability, it is worth exploring innovative techniques that can address environmental issues. In recent years, there has been an interesting shift in cultivation techniques from soil-based to soilless methods. Soilless cultivation system (SCS) is an agronomic technique in which plants are grown in a controlled environment using nutrient solutions, with or without substrates such as gravel, vermiculite, rockwool, peat or coconut fibre as a support medium (Hoesterey *et al.*, 2023). SCS represents a technological advance that combines sustainable technologies to increase the efficiency of

the production process, reduce the carbon footprint and improve product quality (Fussy and Papenbrock, 2022). SCS is an efficient method as it requires less space and input consumption, resulting in higher yields (Kalaivanan *et al.*, 2023; Küfeoğlu, 2021). One of the advantages is the possibility to automate the management of the main greenhouse parameters, temperature, water and nutrients, through the use of decision support system (DSS) that monitors and ensures ideal conditions for plant development (Dhanaraju *et al.*, 2022; Hati and Singh, 2021). Another important aspect is the sustainable approach to energy consumption through the use of photovoltaic panels, which reduces dependence on fossil fuels and greenhouse gas emissions (Carreño-Ortega *et al.*, 2017; Ezzaeri *et al.*, 2018; Maraveas *et al.*, 2021).

Several studies have shown that SCS have the potential to improve the environmental performance of greenhouse production (Barrett *et al.*, 2016; D'Amico *et al.*, 2023; Pomoni *et al.*, 2023). The need to accelerate the transition to affordable and sustainable production systems can be met by soilless cultivation technologies. Farmers are under increasing pressure from society to reduce the environmental impact of the production processes, increase the nutritional value of crops and reduce chemical residues in crops and the environment. Therefore, this technology represents a strategy capable of achieving the objectives set by the SDGs. In the agricultural context, the development of innovation also depends on the social acceptance of products, as consumer needs and expectations influence the market success of a product. In recent years, there has been an increasing focus on healthy and quality food. Studies have consistently shown that consumers are concerned about the safety of the food they consume and that sustainable practices drive purchasing preferences (Joshi and Rahman, 2015). The quality of a product is commonly associated with intrinsic characteristics such as colour, shape or the absence of aesthetic defects, which strongly influence consumer preferences and demand. However, there are other extrinsic aspects, credence attributes, that are not immediately perceived, either at the time of purchase or after consumption, such as food safety and sustainability of the production process and so on, Ercilla-Montserrat *et al.* (2019). The development of hydroponic techniques is an effective innovation to achieve environmentally friendly production and to answer to the environmentally conscious purchasing tendencies of citizens. Moreover, soilless techniques improve the intrinsic qualities of vegetables through the technical control of growing conditions and the use of inert substrates, allowing for reduced use of agrochemicals and products free of pesticide residues and heavy metals (Fussy and Papenbrock, 2022). It is therefore possible to obtain “zero-residue” and “nickel-free” certifications (Mancuso *et al.*, 2024). “Zero-residue” certification, starting with the use of sustainable farming methods, limits the use of synthetic chemicals to avoid chemical residues (Djekic *et al.*, 2023). The concept of “nickel-free” refers to all products containing low levels of nickel, below the analytical limit of quantification of 0.01 mg/kg (Ahlström *et al.*, 2019). One of the principal advantages of soilless cultivation is the production of high-quality hydroponic vegetables free of pesticide residues (Gumisiriza *et al.*, 2022; Rubio-Asensio *et al.*, 2020). The results of several studies indicated that the health risks associated with the consumption of hydroponically grown vegetables are lower than those associated with conventionally grown vegetables that are cultivated in soil (Chen *et al.*, 2024; Sela Saldinger *et al.*, 2023). The result of SCS is a guarantee of the use of sustainable cultivation methods meeting the consumers' needs for the quality and the health in the product they buy. The trend towards “free from . . .” foods is growing and consumer demand for these products is increasing. It is therefore time to upgrade cultivation methods to increase production and produce safer products without chemical residues.

Meanwhile, dietary habits are evolving and changing worldwide as a result of lifestyle changes. Consumers, particularly in developed countries, are increasingly looking for quality food that is healthier, safer and more environmentally friendly (Hoek *et al.*, 2017; Petrescu

*et al.*, 2019). Along with changes in consumer demand, the way companies produce is also changing. In the greenhouse horticulture sector, companies are increasingly encouraged to adopt and develop strategies that place greater emphasis on quality and sustainability attributes. For example, “nickel-free” and “zero-residue” certifications for hydroponic fresh vegetables. These attributes are being used as a means of innovation and product differentiation and can enable companies to expand their market share in domestic and foreign markets.

Given consumer concerns about the environmental impact of food production and the production of high-quality products, more environmentally friendly production strategies, such as soilless technology, are an effective tool of achieving greener production and reinforcing consumers’ environmentally conscious purchasing trends. However, it is still unclear how consumers perceive and value soilless production. The potential for increasing food production and improving quality while reducing resource use is limited if society at large is unable to recognise the environmental and health benefits. To date, consumers are unable to distinguish soilless products from others as there are currently no “soilless” or “hydroponic” labels or certifications. Food packaging and labelling are becoming increasingly important. Consumers want to be enabled to distinguish ingredients, nutritional value, origin and other information. These requirements could be met by greater transparency and availability of information. The literature review showed that society is willing to buy greener products (Joshi and Rahman, 2015; Wijekoon and Sabri, 2021; Zhuang *et al.*, 2021). However, there is a gap between attitudes and behaviour due to several factors, mainly due to a lack of consumer trust or negative perceptions caused by companies’ inability to disseminate simple and user-friendly information on green products (Vermeir and Verbeke, 2006). Providing adequate information on environmental performance is crucial to gaining customers’ trust and persuading them to buy products (Luo *et al.*, 2023). In order to actively contribute to the achievement of sustainable development goals, consumers need to be provided with information that enables them to become aware of the sustainability impacts of their consumption choices. Entrepreneurs must develop information tools to communicate the sustainability of their products and processes to consumers. This will enable them to be rewarded in the marketplace for their commitment to providing safe and healthy food, to meet the ever-increasing demand for sustainable products and corporate social responsibility and to be compensated for higher production costs. Based on these assumptions, it was deemed appropriate to investigate whether consumers can appreciate products grown using soilless techniques, focusing specifically on tomato, as it is the most consumed vegetable and the most widely grown hydroponically. With a production of 180 m tonnes, tomatoes are the second most important vegetable crop in the world (FAOSTAT, 2023). The many health benefits have made tomatoes a key product in the Mediterranean diet, considered one of the healthiest diets in the world (Zakira Naureen *et al.*, 2022). In recent years, there has been a growing trend towards soilless tomato production in greenhouses. This is due to several advantages, including the absence of soil-borne pathogens, the ability to recycle water and nutrients and higher yields (Anzalone *et al.*, 2022).

Soilless cultivation represents a small area of agricultural practice, with a total of 95,000 hectares globally devoted to this technique. Countries at the forefront of hydroponic technology development include the Netherlands, Australia, France, England, Israel, Canada and the United States. The Netherlands has long been a world leader in the use of hydroponic technology, with 13,000 ha of tomatoes, peppers, cucumbers and cut flowers grown hydroponically. Soilless cultivation represents a novel approach to vegetable production in Italy. It currently represents only a small proportion of the surface area devoted to such crops in greenhouses (Fussy and Papenbrock, 2022) and can therefore be considered a niche market. The limited adoption of this system in Italy can be attributed to three main factors:

the lack of technical assistance, the relatively small size of farms and the inadequacy of greenhouse systems to support soilless cultivation (Di Lorenzo *et al.*, 2013).

In today's highly competitive business environment, understanding consumer behaviour is essential for companies to improve customer satisfaction, boost sales and gain a competitive advantage in the marketplace. Consumer behaviour can be influenced by a variety of factors, including psychological, social, cultural and personal factors. Market research is a valuable tool for companies to obtain useful information for defining their marketing strategies. The horticultural sector demands high-quality products with essential features such as high organoleptic, nutritional and functional properties. These attributes characterise the concept of quality in this sector (Kyriacou and Roupael, 2018). WTP is strongly associated with a positive perception of product value in terms of intrinsic quality and environmental sustainability of the production process. Therefore, the study of consumer acceptability and the factors influencing it is crucial for realising the potential of innovative and sustainable production processes. A survey was conducted to investigate consumer perceptions and purchasing behaviour, followed by a willingness-to-pay (WTP) analysis to assess the existence of a price premium that consumers would be willing to pay for soilless tomatoes over conventionally grown tomatoes. The aim of the research was twofold: firstly, to investigate the influence of information about hydroponics on consumer perceptions; secondly, to identify which attributes determine the willingness to pay a price premium for the safer hydroponic tomato with "nickel-free" and "zero-residue" certifications. The results will be used to provide consumers with reliable information and to develop effective marketing strategies.

### 1.1 Literature review

A literature review was conducted to investigate whether consumers are willing to pay a premium for healthier and more environmentally friendly agricultural products. Given the extensive existing literature on consumer attitudes towards a wide range of food products, this study focused on hydroponics and related topics as well as products with sustainability attributes and pesticide-free vegetables. The studies reviewed showed that consumers are increasingly concerned about climate change and that environmental concerns positively influence their WTP more for green products (García-Salirrosas *et al.*, 2024; Gomes *et al.*, 2023; Laroche *et al.*, 2001; Zaidi *et al.*, 2022). As shown in the studies conducted by Sogari *et al.* (2016) and Mauracher *et al.* (2019), the adoption of environmentally friendly practices by wine producers has resulted in consumers being willing to pay a premium of around 20% for the product. Likewise, the literature has consistently shown that consumers are willing to pay more for organic food due to perceived health benefits, such as reduced exposure to pesticides, and the positive environmental impact of farming practices (Gundala and Singh, 2021). Katt and Meixner (2020) conducted a systematic review of WTP for organic food. The authors have highlighted that labelling and certification are highly valued by consumers and are therefore determinants factors of increased WTP. The study found that consumer confidence is significantly influenced by the perceived credibility and clarity of information provided.

Previous research has shown that consumers who place a high value on the health benefits of food are more likely to consume foods with superior nutritional qualities. A study conducted in China on pesticide-free celery found that consumers concerned about pesticide residues were willing to pay a higher price for a chemical-free product of Wang *et al.* (2022). Nitzko *et al.* (2024) used the contingent valuation method to determine that German consumers are willing to pay between 38.3 and 93.7% more for pesticide-free products than for conventional products. Similarly, a study of Italian consumers found that the majority of respondents were willing to pay a premium price of between 6 and 10% (Boccaletti, 2000). However, a lack of trust or information can negatively influence consumer behaviour.

Several studies have shown that the inclusion of health claims on food labels can increase WTP (Aschemann-Witzel *et al.*, 2013; Miller and Cassady, 2015; Van Kleef *et al.*, 2005). This highlights the importance of certification in communicating the intrinsic properties of food, including health benefits, and in enhancing knowledge and appreciation of different products available on the market. There is an extensive literature on the analysis of consumer choice, with a wealth of theoretical models and empirical analyses covering a wide range of product categories. Hydroponics is a relatively new food production technique, with the majority of studies focusing on resource use and production. As such, a research gap has been identified in relation to the lack of available information on consumer perceptions, acceptance and WTP for hydroponic products. To date, to the best of our knowledge, only a limited number of studies have examined consumer WTP for hydroponic vegetables. In general, studies have shown that the majority of respondents were willing to pay more for hydroponically grown vegetables and familiarity, perceived health benefits and income have been identified as the most influential factors (Ezri Balqiah *et al.*, 2020; Gilmour *et al.*, 2018; Mancuso *et al.*, 2024; Narine *et al.*, 2014).

Given that WTP can be influenced by a range of variables, the independent variables employed in the analysis of the correlation between consumer attitudes and WTP were drawn from the existing literature, where they have been most frequently used (Eichhorn and Meixner, 2020; Joshi and Rahman, 2015; Kim and Kim, 2023). The main variables used to estimate WTP were sociodemographic variables (such as age, gender, education, income, family size and purchase frequency) and consumer perception variables (e.g. sustainability, quality, healthiness and familiarity with the analysed product). A better understanding of consumer WTP for hydroponic produce could help to identify the key attributes that influence customer purchase behaviour and provide companies with useful information for defining marketing strategies.

## 2. Materials and methods

An online survey was conducted in Italy between October and November 2022, using a convenience sampling strategy to select respondents who were easily accessible and available (Golzar *et al.*, 2022). Only the respondents who reported buying tomatoes were included in the survey. The invitation link to the questionnaire was distributed via the Google Forms platform. A total of 292 complete records from participants were registered and used for the analysis. Only informed consent was obtained from all subjects involved in the study, as approval by the Institutional Review Board of our university is only required for experimental protocols involving humans or animals in clinical trials to ensure their safety. In this case, only information and opinions were collected from the respondents. The questionnaire consisted of 31 items and was divided into four sections: the first part investigated food purchasing habits (frequency, average price paid, place of purchase, etc.). The second section provided a brief description of soilless cultivation techniques, which were described as a method of conserving soil, minimising water and nutrient loss, reducing pesticide use, saving energy and with supplementary LED lighting allowing almost continuous production cycles; this was done to provide respondents with additional information to ensure a better knowledge of the essential elements of this cultivation method in order to obtain informed responses. The statements were designed to measure – using a Likert scale from 1 (very negative) to 7 (very positive) – the perceived impact of these techniques on the environment (soil conservation, water and fertiliser savings) and product characteristics (taste, colour and shelf-life). Respondents were presented with a series of items and asked to indicate their degree of agreement or disagreement with each statement (Joshi *et al.*, 2015). The level of agreement/disagreement with the statements used in the questionnaire is measured on a Likert scale.

Consumers were then asked whether they would be willing to pay a premium price for hydroponic tomatoes with “nickel-free” and “zero-residue” certifications. Respondents were given the opportunity to indicate the premium on a percentage scale, including the values 0.5, 10, 20 and 50%. WTP estimation is a commonly used method to evaluate consumers’ opinions and purchase behaviour towards food attributes. The estimate represents the maximum monetary amount or price premium a consumer is willing to pay for a product or good (Li and Kallas, 2021).

Finally, we collected data on sociodemographic characteristics including gender, age, education level, household income and level of specific knowledge about the topic (Ali and Ali, 2020; Mauracher *et al.*, 2019) to assess whether consumers’ socioeconomic and demographic features may influence their food quality perceptions and WTP. The results of this assessment may be useful for companies to develop marketing strategies based on consumers’ opinions and demographic data. Data analysis was carried out in two phases, and data management and statistical analyses were performed using the SPSS Statistics 20.0 software. The first stage allowed a descriptive analysis of the sample of consumers. A multiple linear regression model was used to analyse characteristics that influence WTP for hydroponic tomatoes. The formal specification of the model used is as follows:

$$WTP = \beta_0 + \alpha_i X_i + \dots + \alpha_{ij} X_{ij} + \varepsilon \quad (1)$$

where: WTP is the willingness to pay a premium price;  $\beta_0$  is the constant;  $\alpha_i$  and  $\alpha_{ij}$  are the coefficients;  $X_i$  and  $X_j$  are the independent variables and  $\varepsilon$  is the error.

### 3. Results

The majority of the respondents were female (65%); the sample presented a prevalence of young people (age group 20–34, 42%), due to their greater familiarity with the use of social media through which the questionnaire was disseminated. The level of education was high (64% had a university degree); the respondents mainly belonged to households with four (31.5%) and three (24.3%) members; moreover, the majority (51%) reported a high income level, the rest being evenly distributed. All the respondents are buyers of cherry tomatoes, and the frequency of purchase was high: 46% of the interviewees declared to buy cherry tomatoes “once a week” and 30% “once a fortnight”. Finally, the respondents’ knowledge of hydroponic techniques was analysed. The results showed that the familiarity with hydroponics was low: 58% said they were unfamiliar with hydroponics, while only 17% stated that they were familiar with hydroponics.

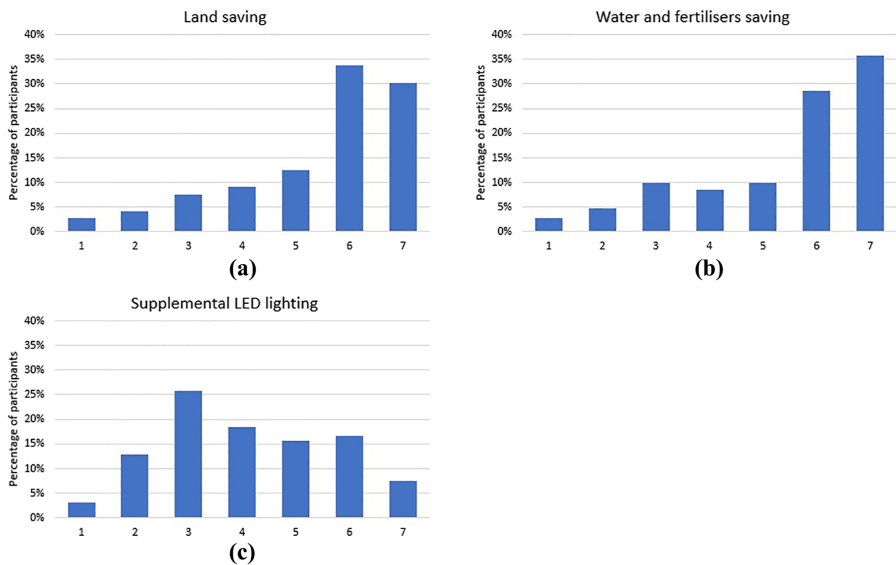
A summary of the descriptive statistical analysis is shown in Table 1.

In line with the research objective of investigating consumer perceptions of the impact of soilless technology on tomato quality and the environment, analysis of the results led to the identification of six variables describing consumer perceptions. These variables are shown in Figures 1 and 2. Some heterogeneity was detected in consumers’ perceptions of environmental and quality benefits associated with soilless techniques. Based on the results of the analysis, most of the respondents indicated positive environmental perceptions (Figure 1): regarding the possibility of avoiding soil erosion and saving land, the majority of the respondents (77%) considered that the soilless technique has positive effects (ratings of 7, 6 and 5) (Figure 1a); similarly, most of the respondents, 74%, perceived the environmental benefits of the recirculation of nutrient solution, which allows the conservation of water and nutrients and the reduction of emissions (Figure 1b). Regarding the use of LED lighting, the sample expressed a more heterogeneous perception: 42% negative (scores of 1, 2 and 3) and 40% positive (scores of 7, 6 and 5), probably due to the perception of artificial lighting as unnatural (Figure 1c).

Characteristics	Criteria	Frequency (no.)	Percentage (%)
Age	20–34	122	41.8
	35–49	70	24.0
	50–64	88	30.1
	>65	12	4.1
Gender	Female	190	65.1
	Male	97	33.2
Education	Elementary school	1	0.3
	Junior high school	10	3.4
	High school degree	94	32.2
	Degree	187	64.0
Household (the number of family member)	1	39	13.4
	2	59	20.2
	3	71	24.3
	4	92	31.5
	>4	31	10.6
Income	Low	68	23.3
	Middle	75	25.7
	High	149	51.0
Purchase frequency	Monthly	31	10.6
	Once a fortnight	88	30.1
	Once a week	135	46.2
	More than once a week	38	13.1
Familiarity with soilless technique	No	170	58.2
	A little	73	25.0
	Yes	49	16.8

**Table 1.**  
Summary of  
descriptive statistical  
analysis

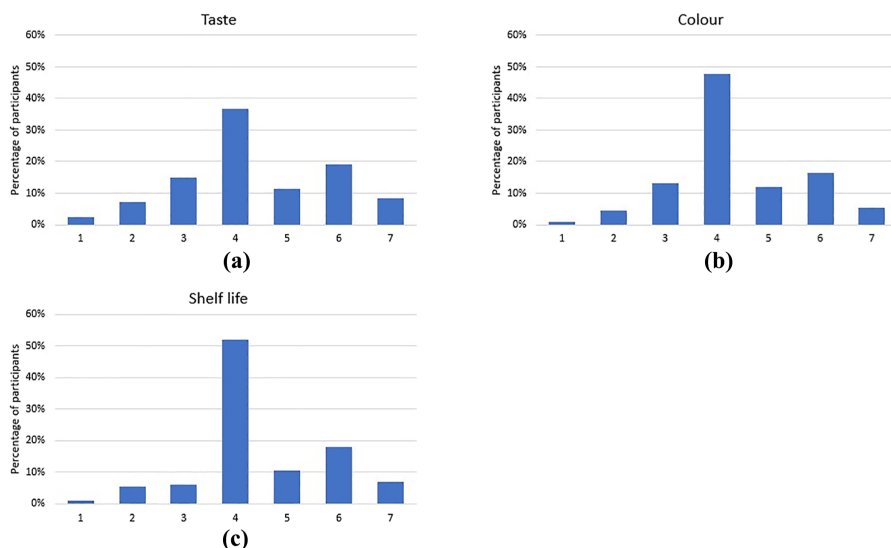
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**Figure 1.**  
Seven-point Likert  
scale responses on the  
perceived effects on  
environmental impact  
of soilless techniques

**Source(s):** Authors' own creation





Source(s): Authors' own creation

**Figure 2.** Seven-point Likert scale responses on the perceived effects on tomatoes characteristics of soilless techniques

With regard to the intrinsic characteristics of tomatoes, the largest percentage of respondents answered that they did not perceive any beneficial effect on any of the three characteristics: taste, colour and shelf life (Figure 2). The majority of the sample gave a score of 4 (irrelevant).

A correlation analysis was performed on the data matrix, which showed a low Pearson coefficient for all pairs of considered variables (Dufera *et al.*, 2023). Consequently, all variables were incorporated into the regression procedure using the backward stepwise method. A *p*-value of less than 0.05 was used to indicate the statistical significance of the analysis. The results of the multiple linear regression analysis are presented in Table 2.

The independent variables that showed statistical significance were frequency of purchase, familiarity with soilless technology, water and fertiliser saving, income and education. Based on the results of the regression analysis, the regression equation analysing the dependence of WTP on sample characteristics is as follows:

$$WTP = 0.05 - 0.01 * \text{FREQ} + 0.01 * \text{FAM} + 0.01 * \text{WFS} + 0.03 * \text{INC} - 0.02 * \text{EDU} \quad (2)$$

The survey results showed that most respondents (85%) would be willing to pay a premium for hydroponic tomatoes with “zero-residue” and “nickel-free” certifications, on top of the

Variable	Coef	Std. Err	<i>t</i> -value	<i>p</i> -value
Constant	0.05	0.0135	3.90	0.000
FREQ	-0.01	0.0028	-2.37	0.019
FAM	0.05	0.0034	1.62	0.008
WFS	0.01	0.0016	5.64	0.000
INC	0.03	0.0040	6.63	0.000
EDU	-0.02	0.0049	-4.77	0.000

Note(s): \*Statistical significance was considered for values of *p* < 0.05

Source(s): Authors' own creation

**Table 2.** Results of the regression analysis

average price paid for conventional tomatoes. Most participants (64%) were willing to pay a premium between 5 and 10%. Only a minority of participants (15%) indicated that they would not pay a higher price (Figure 3).

Our results show that WTP increases as familiarity with production techniques and perceived environmental benefits increase. Frequency of purchase has a negative influence. Among the socioeconomic variables, income level is a clear indicator of an increase in WTP. This suggests that WTP for a premium price is negatively influenced by the amount of product consumed and positively influenced by a higher income level of the buyers. However, the negative effect of education level suggests that a higher level of education does not necessarily lead to greater acceptance of technological innovations.

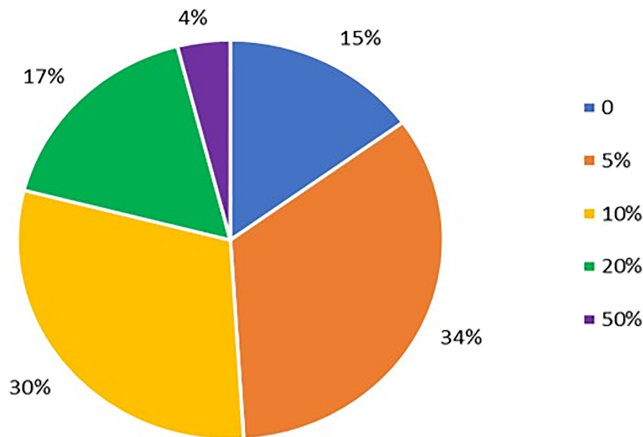
The level of knowledge about soilless technology (FAM) positively influences WTP. This suggests that respondents who are familiar with the technique are more likely to perceive the benefits and be willing to pay additional amounts. Furthermore, the environmental benefits associated with water and fertiliser savings (WFS) were found to positively influence consumer perception and WTP for a premium price.

Notably, respondents with higher levels of education (EDU) are comparatively less willing to pay premium prices. The negative influence, to some extent, may be due to their limited knowledge of soilless technologies. The model yields an R-squared of 0.69, signifying that 69% of the model is explained by the above variables and that these variables are statistically significant.

#### 4. Discussion

The aim of this study was to investigate consumers' perceptions of hydroponics and their WTP for hydroponically grown tomatoes with "nickel-free" and "zero-residue" certifications.

The findings of this study indicate that consumers are generally willing to pay a premium for hydroponic tomatoes, as they are perceived to be more environmentally sustainable and safer for human health. The results of a survey conducted in Trinidad similarly indicated a high willingness to pay for hydroponically grown tomatoes compared to those cultivated in open fields (Narine *et al.*, 2014). Consistent with our findings, Narine *et al.* (2014) showed that there was a positive relationship between consumer knowledge, perception of health benefits of hydroponically grown tomatoes and WTP. The results of the present work were also



**Figure 3.**  
Pie chart showing distribution of respondents by percentage of premium price they would be willing to pay

Source(s): Authors' own creation

consistent with the findings of [Miličić \*et al.\* \(2017\)](#), who investigated attitudes towards aquaponic products. The survey showed that 45% of respondents purchased pesticide and herbicide free vegetables. Additionally, 52% of respondents indicated a WTP as a premium price for pesticide- and antibiotic-free tomatoes, while only 15% expressed a similar preference for aquaponic tomatoes. On average, these respondents would be willing to pay 37.6% more for aquaponic than for conventionally grown tomatoes.

This study has demonstrated that consumers who buy tomatoes on a weekly basis are less willing to pay a premium price. As expected, the WTP data is strongly correlated with frequency of purchase. This finding is consistent with the research conducted by [Ezni Balqiah \*et al.\* \(2020\)](#), which indicates that WTP decreases with the frequency of consumption. These results suggest that the selling price may be a crucial factor in purchase decisions. Socioeconomic status affects the behaviour when purchasing safe food, that is, food with safety certification ([Wang \*et al.\*, 2018](#)). Interestingly, [Miličić \*et al.\* \(2017\)](#) observed that the consumers most likely to purchase aquaponic products are those who have previously shown an appreciation for organic and locally sourced products. These consumers are not differentiated by specific demographic characteristics, such as gender, age or monthly income.

Regarding the education variable, the results of the current study showed that consumers with a lower level of education were willing to pay more than those with an education at the university level. These findings contrast with previous results reported in the literature. [Narine \*et al.\* \(2014\)](#) found that WTP for hydroponic tomatoes increases with education and income levels; similarly, [Chen \*et al.\* \(2013\)](#) found that purchase intention for new food increased with education level. [Balogh \*et al.\* \(2016\)](#) showed that consumers with a university education tend to place a higher value on quality certification due to their enhanced ability to understand and interpret supplementary information. Therefore, a viable option to ensure understanding of quality certifications (“nickel-free” and “zero-residue”) would be to formulate their main message as simple as possible. It is recommended that commercial policy and communication strategies leverage certification to make the added value of the production method perceived by final consumers.

The current study starts from the shared assumption that hydroponic cultivation can save water and fertiliser and that hydroponic agriculture can offer greater environmental sustainability than conventional soil-based agriculture. The findings of this study showed that consumers were willing to pay a premium price for hydroponically grown tomatoes, as they were perceived as a more environmentally friendly option. However, [Ezni Balqiah \*et al.\* \(2020\)](#) reported otherwise. Willingness to purchase hydroponic products was not significantly influenced by environmental concern, which is an altruistic motive, but was positively impacted by health concern, which is an egoistic motive. This may be due to the fact that hydroponic farming is still in its early stages of development, resulting in a lack of expertise. This suggests that the dissemination of reliable information is a key factor in encouraging consumers to purchase hydroponic products. The findings on consumer attitudes towards aquaponic products reported by [Miličić \*et al.\* \(2017\)](#) are consistent with those of the present study. A majority of respondents (more than 45%) indicated that they believe aquaponics will be a key contributor to more sustainable food production in the future. The positive associations were mainly related to the innovative and sustainable aspects of aquaponics. Notably, the researchers suggest that positive attitudes have been shaped by the positive portrayals of aquaponics, as conveyed through marketing materials and communication channels. However, the results of the analysis showed that more than half of the respondents had no prior knowledge of aquaponics. This highlights the need for effective communication and marketing strategies. This is particularly relevant in the context of hydroponics products, which constitute a “newcomer” to the marketplace and are not widely understood by consumers. According to [Ezni Balqiah \*et al.\* \(2020\)](#) and

Gilmour *et al.* (2019), a better understanding of hydroponics, particularly in relation to environmental and quality enhancements, may foster more favourable attitudes. Technologically advanced practices can help achieve a higher level of sustainability in food production systems. Consumers can contribute to this by demanding quality and sustainable food. Policymakers and producers of soilless products can develop strategies based on the factors that influence consumers' WTP. The results of regression analysis indicate that increased sensitivity to the environmental sustainability of production processes plays a significant role in consumers' WTP. Therefore, an eco-label could incentivise sustainable resource management by producers and ensure fair remuneration for products. The importance of helping consumers recognise the wholesomeness of soilless products is confirmed by the fact that the WTP includes a premium for "zero-residue" and "nickel-free" certifications. This ensures that producers are fairly rewarded. The additional WTP for "zero-residue" and "nickel-free" certifications shows that the respondents to the present survey are interested in safer produce that does not contain pesticides or heavy metals. Chen *et al.* (2020) found that a higher level of consumer health concern increases the intention to purchase hydroponic products. Studies have also confirmed that consumers are willing to pay a premium for pesticide-residue-free certified products due to their perceived health benefits (Bernard and Bernard, 2010; Zheng *et al.*, 2022). These findings suggest that the market for hydroponic products could be strengthened by the growing demand for pesticide-free fruits and vegetables. At the same time, however, these studies have shown that consumers are concerned about the presence of pesticides but are unable to distinguish them due to a lack of information or confidence in the claims, resulting in a low declared premium price. Our results show that the higher the level of knowledge, the more positive the perception of benefits and the more people are willing to pay a premium price. Overall, consumer confusion about the effects of soilless cultivation on the tomato quality could have a significant impact on the market. It is therefore. It is important to provide adequate information and report certifications on products. Special attention must be paid to the packaging, which needs to explain the meaning of the certifications to the consumer in a clear and simple way. A literature review (Plasek *et al.*, 2020) showed that providing information about the nutritional value or health effects of products on their packaging has a positive impact on consumers' perceived healthiness. Based on our findings, it is very important that consumers have useful information to understand the added value of soilless products.

Respondents had negative perceptions of the use of LED lighting. Consistent with our findings, previous studies have shown that consumers perceive these systems as unnatural and artificial (Yano *et al.*, 2023). The use of soilless cultivation techniques that are unfamiliar to consumers may have a negative impact on perception and acceptance; Yano *et al.* (2023) showed that providing information on the scientific basis and benefits of using supplemental LED lighting (Sena *et al.*, 2024) could improve consumer confidence. In terms of premium price, most of the respondents were willing to pay a moderate premium not exceeding the 5% or 10%. This may be due to the unfamiliarity of respondents (83% of the sample) with the soilless cultivation system. Similar findings have been reported in Sweden, with 50% of unfamiliarity (Spendrup *et al.*, 2024), and the US, with 49% (Gilmour *et al.*, 2019). Given the low level of knowledge, it is necessary to pay more attention to the issue of communication and provide consumers with direct and understandable information on the value of soilless cultivation techniques. Gilmour *et al.* (2019) showed that consumers willing to pay a premium are those who formed a positive quality perception after receiving information on the environmental and quality benefits of hydroponic techniques. A similar survey conducted in China showed that individuals with a greater familiarity with hydroponics exhibited more favourable attitudes towards the adoption of hydroponic agriculture (Al Mamun *et al.*, 2023). On the other hand, the

lack of adequate knowledge about hydroponics is also a significant obstacle to the adoption of hydroponic technology by farms (Gumisiriza *et al.*, 2022). According to Widodo *et al.* (2022), promotion has a positive effect on the decision to purchase hydroponic vegetables.

The extant literature and the findings of the current study indicate that knowledge is the most important variable that positively influences attitudes towards hydroponic agriculture. The results suggest that consumers may appreciate the value of the production process and products if they are adequately informed about sustainable hydroponic practices. Current consumer opinions may be influenced by marketing messages about the improved environmental and organoleptic aspects that can be achieved by soilless cultivation and the nature and benefits of hydroponics. Focusing on the influence of knowledge about hydroponic farming, Al Mamun *et al.* (2023) highlighted that it would be beneficial for industry players to consider implementing training courses and promotional activities with the objective of increasing awareness of hydroponic technology. The findings suggest that consumer education is a crucial step in raising awareness of this innovative food production technology. This can be achieved through training programmes, promotional campaigns, or visits to hydroponic farms.

The main findings are consistent with those of previous authors confirming the importance of variables such as familiarity with hydroponics, income and education level in statements of purchasing behaviour.

## 5. Conclusions

In the field of greenhouse horticulture, soilless cultivation is a revolutionary, cutting-edge cropping system that combines efficiency and sustainability (Kumar *et al.*, 2023). The adoption of soilless technologies will help to build a more equitable, resilient and sustainable future, fostering environmental sustainability in agriculture and contributing to progress towards the SDGs. However, it is still unclear how consumers perceive hydroponic vegetables and how to increase their willingness to buy.

The analysis of the online survey data collected from 292 respondents in Italy revealed the significant influence of knowledge of the hydroponic system, interest in certifications related to safety and concern for environmental sustainability on WTP for hydroponic tomatoes.

The study showed that consumers were willing to pay a premium for “nickel-free” and “zero-residue” certifications, given the health benefits associated with consumption. Based on these results, marketing and promotion strategies should highlight the significant benefits of hydroponic agriculture, including food security, the potential for year-round local produce and the possibility of reducing the environmental impact of greenhouse cultivation. The factors influencing WTP can be used by governments, research organisations or agricultural entrepreneurs to promote technology adoption and develop marketing strategies. In order to enable consumers to actively contribute to the development of sustainable food production processes, it is first necessary to provide them with general information that enables them to become aware of the impact their consumption choices can have in terms of sustainability. Marketing strategies play a key role in this context, and the findings of this study may have practical implications for the development of marketing strategies based on the key factors that influence consumers’ purchasing decisions. Understanding the importance that consumers attach to quality certification provides an insight into the benefits that farmers could gain by adopting environmentally friendly practices. According to the results of this study, farmers can receive an estimated 10% premium for hydroponic tomatoes compared to conventional ones. These findings could be useful in encouraging farmers to adopt sustainable soilless practices in order to differentiate their products. The “nickel-free” and “zero-residue” certifications add value by satisfying the

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demands of health and environmentally conscious consumers as well as those with food intolerances.

The study may contribute to the dissemination of knowledge regarding the significance of sustainable agricultural practices and facilitate the adoption of such practices among producers and consumers. The study may have an impact on the quality of life of consumers in terms of access to healthier, safer and more sustainable products and the promotion of healthier and more environmentally friendly lifestyles. This may be achieved by disseminating information on the advantages of tomatoes grown in soilless systems, and by establishing production chains and distribution channels that ensure the quality and safety of the products, in addition to the transparency and social responsibility of the companies that produce and distribute them. Moreover, hydroponic cultivation can also be advantageous in rural areas where soil cultivation is not a viable option due to unfavourable soil conditions or climatic limitations. Consequently, the implementation of these systems could result in the creation of new employment and income opportunities for rural communities, thereby providing a potential solution to the problem of unemployment. The implementation of sustainable farming technologies in soilless greenhouse production has the potential to improve the profitability, efficiency and environmental performance of agricultural enterprises. Nevertheless, there are significant challenges that need to be addressed. At present, there are no regulations or EU standards in place governing the economic activities associated with the hydroponic production method. Furthermore, it is not feasible to integrate hydroponics into organic cultivation, as European organic legislation explicitly links soil cultivation to the definition of organic. It is therefore technically impossible to apply an organic label to hydroponics. Two main policy implications can be drawn. Governments can play a pivotal role in facilitating the transition towards an innovation-based agriculture by introducing a regulation that supports and promotes soilless cultivation practices. Furthermore, the results of the WTP analysis indicate the potential for a certification system to facilitate the attainment of a premium price, thereby increasing the profitability of farming operations. Therefore, hydroponic practice has the potential to improve agricultural production through the recognition of specific certifications. Additionally, these techniques require considerable investment, so government subsidies could be considered.

From a methodological perspective, the findings illustrate the potential to extend this analytical approach to other hydroponic products, thereby facilitating the generation of insights into consumer purchasing behaviour and WTP. The delineation of the factors influencing the WTP can assist producers and marketers in the development of effective marketing strategies by providing a basis for decision-making. Researchers have the opportunity to play an active role in the advancement of hydroponics by enhancing the production process and disseminating their knowledge in a way that allows companies to adopt and implement it.

### *5.1 Limitations and future research*

The study acknowledges certain uncertainties and limitations, such as the statistical non-representativeness of the sample and the potential discrepancies between stated and actual WTP. However, the survey provides valuable insights into the premium opportunities for hydroponic crops. The study demonstrates that certifications could encourage farmers to adopt sustainable soilless practices, creating an opportunity for differentiation. However, it needs to be integrated to better understand the dynamics that influence the market price and WTP for hydroponic products. Therefore, future research should analyse the consistency with real market data. A hedonic analysis can complement the WTP methodology to understand the characteristics that influence the real market price of hydroponic products.

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