

Vertical Farming as a Sustainable Alternative for Agriculture: The Italian Consumer Point of View [†]

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[†] Presented at the 4th International Electronic Conference on Foods, 15–30 October 2023; Available online: <https://foods2023.sciforum.net/>.

Abstract: Despite innovative approaches to urban food production, skepticism towards vertical crops remains widespread, posing profitability risks for agricultural enterprises. To overcome these challenges and develop successful business models, identifying consumer acceptance barriers is crucial for engaging stakeholders, investors, and farmers in local food production. When introducing innovative food production methods, like vertical farming, it is essential to gain public approval. However, recent technological advancements, such as genetically modified crops and artificial radiation, have been met with doubt, leaving overall consumer opinions about vertical farming uncertain. In this context, the purpose of this paper is to analyze Italian consumers’ acceptance of vertical farming systems and products, aiming to understand the main drivers that influence their desire to purchase such products. The research, conducted in Italy from April to May 2023, gathered qualitative and quantitative data through an anonymous online questionnaire that was completed by potential consumers. A total of 258 respondents were eligible for data analysis. The survey assessed participants’ knowledge, attitudes towards agriculture and food, and perceptions of vertical farming using Likert scale evaluations. The findings showed that, although a large proportion of respondents expressed interest in purchasing vertical farming products, concerns related to cost, authenticity, and environmental sustainability pose challenges. The evidence that emerged provides a series of indications for understanding consumer preferences more in-depth and useful suggestions for companies that need to expand the vertical farming products market.

Keywords: vertical farming; consumer perception; urban agriculture; survey analysis



Citation: Celestre, A.; Mina, G.; Bollani, L.; Peira, G.; Bonadonna, A. Vertical Farming as a Sustainable Alternative for Agriculture: The Italian Consumer Point of View. *Biol. Life Sci. Forum* **2023**, *26*, 35. <https://doi.org/10.3390/Foods2023-15088>

Academic Editor: Koushik Adhikari

Published: 14 October 2023



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1. Introduction

The enormous growth in the world’s population over the past century has been accompanied by an exponential increase in the demand for food, which has led, in turn, to the exploitation of 80% of the global arable land with disastrous consequences for the natural environment [1]. This trend is not likely to stop in the short term, and it is estimated that by 2050 there will be 9 billion individuals on earth [2]. For this reason, it will be necessary to exploit more and more arable land and intensify agricultural efforts, with likely repercussions at the global level [3]. One of the possible solutions to meet this growing demand is vertical farming, a technique that consists of large-scale indoor food production that allows for the rapid growth of crops, placed on overlapping layers, employing artificial lighting systems, climate control, automation, and hydroponic, aquaponic, and aeroponic growing techniques to provide plants with ideal growing conditions [4]. This approach, therefore, allows more plants to be grown year-round in less space than traditional soil-based agriculture, making production more efficient by cutting down on water and nutrient wastage, fertilizer and pesticide use, and production losses due to weather and seasonal influences [3,5,6]. Nevertheless, vertical agriculture is constantly evolving, and several

challenges need to be addressed to fully express its potential in terms of environmental, economic, and social sustainability [7,8]. However, success in solving these problems does not guarantee the spread of vertical farming in the mass market as it could be subject to consumer mistrust.

To this end, the purpose of this study is to explore the main causes driving the acceptance of VF systems and their products, as well as the purchase intentions of consumers. Recent technological innovations in agriculture have often been met with skepticism and distrust. This is also the case for vertical farming [9]. As a result, the general opinion of consumers on vertical farming and its products is still uncertain. Distrust of this new technology could threaten farm profitability and increase the risk of bankruptcy. Identifying barriers to consumer acceptance of vertical farming could provide an essential foundation for overcoming existing challenges and developing a successful business model for local food production by engaging stakeholders, investors, and farmers.

2. Materials and Methods

The research was conducted in Italy between April and May 2023, consisting of a collection of data through the completion of an anonymous online questionnaire by prospective consumers. The final total sample size was 258 respondents. The survey design was obtained following some previous works [10–12]. The survey began with a question about previous knowledge of vertical farming. Then, the questionnaire tested the respondents' general knowledge and attitudes toward agriculture and food through a five-point Likert scale. In the next section, the respondents' level of liking toward several characteristics of vertical agriculture was analyzed. At this point, the "climax" question was introduced by which the respondent was asked whether they are interested in purchasing vertically grown products. Three possible answers ("Yes", "No", "Don't know") were provided for this question, based on which respondents moved to three different sections: "Yes" respondents were asked to rate a series of statements about their perceptions of VF and to choose from a list the type of agricultural products they like best. "No" and "Don't Know" respondents were asked to rate a few possible reasons why they are uncertain or unwilling to purchase VF products. The questionnaire concluded with socio-demographic questions about the respondents.

3. Results

The sample consisted of 258 consumers from Italy. The percentage distribution of different socio-demographic profiles related to gender, age, and education can be seen in Table 1. The gender distribution was almost homogeneous, with a slight majority of female participation. As far as age was concerned, there appeared to be proportionately more people in their 20s and 30s, probably due to the university context in which the survey was conducted, followed by those over-50. Half of the participants held a bachelor's degree, while 12% held a postgraduate or doctoral degree.

The data obtained indicated that 59.3% of the respondents had prior knowledge about vertical farming, while 40.7% of them were unfamiliar with the topic.

A large majority of the participants (89%) considered sustainability in food production an important aspect. The same attitude was found regarding the absence of pesticides to protect the environment (78%) and the fact that there is a high waste of water in conventional agriculture (68%). This was in line with the perception of the environmental unsustainability of conventional agriculture shared by nearly 54% of people.

Table 1. Sample characteristics.

		Sample	Sample in %
Gender	Female	135	52.33
	Male	123	47.67
Age	<20	7	2.71%
	20–30	117	45.35%
	31–40	26	10.08%
	41–50	20	7.75%
	>50	88	34.11%
Education	Other	2	0.78%
	Elementary school	2	0.78%
	Secondary school	10	3.88%
	High school	84	32.56%
	Bachelor’s degree	129	50.00%
	Postgraduate master’s degree	31	12.02%

The next section consisted of seven statements describing certain characteristics of vertical farming for which respondents were asked to rate their agreement (Table 2). The feature that was most successful was the reduced environmental impact of this technology, with an average score of 4.29, followed by the freshness of food sold (M = 4.03), production capacity (M = 3.98), and controlled growing conditions (M = 3.93). As might be expected, the aspects least liked by respondents were high prices, which 64.7% of respondents rated negatively, and the high energy use required by this production system, which received an average score of 2.47. The statement on the use of artificial intelligence systems and robotic automation received positive opinions overall, with an average response of 3.47, but in this case many individuals expressed a neutral opinion.

Table 2. Descriptive statistics of general approval toward features of vertical farming.

Statements	(1)	(2)	(3)	(4)	(5)	M
Growing fruits and vegetables in vertical farming can help reduce carbon emissions	6 2.3%	10 3.9%	21 8.1%	87 33.7%	134 51.9%	4.29
Energy requirements of vertical farming systems are often high due to heating, cooling and lighting needs	45 17.4%	114 44.2%	48 18.6%	36 14.0%	15 5.8%	2.47
Supermarkets are stocked daily with freshly harvested fruits and vegetables	14 5.4%	27 10.5%	17 6.6%	79 30.6%	121 46.9%	4.03
Indoor vertical farming can produce up to five times more than traditional outdoor farming methods	11 4.3%	24 9.3%	31 12.0%	84 32.6%	108 41.9%	3.98
Fruits and vegetables produced through vertical farming systems are likely to be sold at high prices	54 20.9%	113 43.8%	36 14.0%	46 17.8%	9 3.5%	2.39
Vertical farming often relies on automation, robotics and advanced artificial intelligence systems	14 5.4%	51 19.8%	46 17.8%	94 36.4%	53 20.5%	3.47
Plants grow inside buildings under fully controlled conditions	8 3.1%	27 10.5%	36 14.0%	90 34.9%	97 37.6%	3.93

Note: (1) I do not like it at all, (2) I do not like it much, (3) it is indifferent to me, (4) I like it enough, (5) I like it a lot; M, Average.

The main question of the survey, on the attitude toward purchasing products created by vertical farming techniques, included three different responses (Yes, No, and Don’t know) leading to three different ramifications of the questionnaire. The three groups consisted of n = 154 people for the Yes answer, n = 76 for the Don’t know answer, and n = 28 for the No answer, respectively.

The first group accounted for 60% of the entire sample. Respondents then had to rate three statements through a five-level Likert scale (Table 3). The results showed that price was a strong discriminant for prospective buyers, who were generally unwilling to spend more on vertically grown produce (M = 2.69). In addition, the statement “Vertically grown produce is healthier than conventionally grown produce” had an average of 3.12 with more than 50% of the responses “Neither agree nor disagree” underscoring the fact that vegetables grown with this technology, at least for the time being, were not perceived to be healthier and superior in quality to classic ones; this could therefore influence people’s refusal to pay more for them. The third statement, on vertical farming as a possible evolution of traditional agriculture, collected average positive responses (M = 3.55); again, however, many people appeared to be undecided about this (42.2% of responses). The last question in this section of the questionnaire required respondents to make a choice in terms of preference among several possible types of food production. Vertical farming products were far from being the most popular choice, obtaining only 8% of responses in favor. The main option was local and organic products chosen by 48% of people, while a large segment of participants did not have a specific preference (17%).

Table 3. Descriptive statistics of the comparison between VF and traditional products.

Statements	(1)	(2)	(3)	(4)	(5)	M
I would be willing to pay more for vertically grown produce than conventionally grown produce.	20 13%	48 31.2%	51 33.1%	30 19.5%	5 3.2%	2.69
Vertically grown produce is healthier than conventionally grown produce	6 3.9%	25 16.2%	79 51.3%	32 20.8%	12 7.8%	3.12
I believe Vertical Farming is the future of agriculture	3 1.9%	7 4.5%	65 42.2%	61 39.6%	18 11.7%	3.55

Note: (1) Completely disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, (5) completely agree; M, average.

The second most populous group consisted of the Don’t Know respondents to the question “would you buy vertically grown products”, representing 29% of the total sample. In this case, the questionnaire proposed a range of possible reasons to explain uncertainty about buying VF products (Table 4). Studying the response averages, the cause that most reflected the perplexity of this group of people was the lack of knowledge about this cultivation technique (M = 3.75). Responses to the last question in this section, which asked respondents to express an opinion on the possible future evolution of vertical farming as the main cultivation technique, again showed strong doubt and indecision with a clear majority of people choosing “Neither agree nor disagree” as their answer (n = 42 out of a total of 76 responses).

Finally, the last group consisted of the No respondents representing 11% of the sample. The survey, in this case, included a range of possible reasons to explain the aversion to buying vertically grown produce (Table 5). The main and most shared cause deterring this group of possible consumers from purchasing was the perception of vertical farming products as too artificial (M = 3.54). This was followed by high means for the statements “I prefer conventionally grown foods” with M = 3.46 and “I have doubts about the quality of the products” with a mean of 3.39. Again, the last question in the section asked respondents to rate vertical farming as a possible future of agriculture, obtaining a generally negative average response of 2.18.

Table 4. Descriptive statistics of the causes of uncertainty toward the purchase of VF products.

Statements	(1)	(2)	(3)	(4)	(5)	M
I have doubts about the quality of the products	6 8%	17 22%	33 43%	18 24%	2 3%	2.91
High prices	8 11%	14 18%	24 32%	27 36%	3 4%	3.04
I do not consider it a sustainable project	9 12%	21 28%	38 50%	5 7%	3 4%	2.63
I am skeptical about this technology	7 9%	14 18%	42 55%	12 16%	1 1%	2.82
I perceive the production as too artificial	6 8%	15 20%	32 42%	21 28%	2 3%	2.97
I prefer food grown by the traditional method	5 7%	10 13%	31 41%	20 26%	10 13%	3.26
I do not feel that I have enough information to make a choice	7 9%	2 3%	18 24%	25 33%	24 32%	3.75

Note: (1) Completely disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, (5) completely agree; M, average.

Table 5. Descriptive statistics of the causes of rejection toward the purchase of VF products.

Statements	(1)	(2)	(3)	(4)	(5)	M
I have doubts about the quality of the products	3 11%	3 11%	7 25%	10 36%	5 18%	3.39
High prices	6 21%	4 14%	6 21%	5 18%	7 25%	3.11
I do not consider it a sustainable project	4 14%	3 11%	10 36%	10 36%	1 4%	3.04
I am skeptical about this technology	3 11%	4 14%	12 43%	4 14%	5 18%	3.14
I perceive the production as too artificial	3 11%	1 4%	8 29%	10 36%	6 21%	3.54
I prefer food grown by the traditional method	3 11%	3 11%	6 21%	10 36%	6 21%	3.46
I am not interested in these products	3 11%	5 18%	10 36%	7 25%	3 11%	3.07

Note: (1) Completely disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, (5) completely agree; M, average.

4. Discussion and Conclusions

The objective of the present study was to analyze Italian consumers’ perceptions of vertical farming techniques by examining their knowledge about them, behavioral attitudes, and purchasing preferences, with the aim of providing useful information and insights to companies operating in the country.

Italian consumers are showing a growing awareness of the negative impact of conventional agriculture on the environment and the intensive use of water and pesticides, believing that sustainability in food production is important. In addition, survey participants, appreciated several benefits associated with vertical farming, such as reduced CO₂ emissions, the freshness of vegetables supplied to supermarkets due to reduced supply chains, and increased production capacities. Another aspect relevant to consumers was food safety, and vertical farming offers optimal control of growing conditions, reducing the risk of contamination and plant diseases.

The results of this study are in line with previous studies found in the literature [10–13], showing that Italian consumers have similar preferences and concerns related to these technologies. Although a significant portion of the sample was interested in purchasing vertically grown products (60% of the total sample), there was still a considerable percentage of people who have shown no interest or were uncertain. A large proportion of the respondents had no knowledge of the topic or did not possess enough notions to have a definite opinion about it. The perception of cost and genuineness seems to influence the propensity to purchase, as potential buyers are not willing to pay a higher price for vertical products and do not perceive a clear superiority in terms of quality over traditional products. Although significantly more people were predisposed than those who gave negative or uncertain responses, data analysis showed that only 8% of respondents listed VF vegetables as their main purchase preference. The most popular choice among the proposed food options was local and organic produce, elected by 48% of individuals. A significant percentage of participants (17%), however, did not express a specific preference.

These results suggest that to capture a wider market share, it may be necessary for companies in the industry to focus on improving the quality–price perception in potential consumers. In addition, the fact that a significant percentage of respondents did not express a specific preference could indicate a potential opportunity to attract new buyers through innovative and attractive product offerings. For the group of respondents that were undecided about buying vertically grown products, the main concerns were food quality, high prices, and lack of knowledge on the subject. This indicates the need for more information and awareness about the benefits of vertical farming to win over this category of customers. On the other hand, the group that responded negatively to the survey expressed broader concerns. In addition to product quality and high prices, they cited the unsustainability of the project, skepticism toward the technology used, and the perceived artificiality of the food. These critical points could be addressed through education about the sustainable practices of vertical farming, transparency regarding the technologies used, and a stronger and more widespread information campaign that would help dispel doubts and encourage a more favorable attitude toward this innovative technique.

Therefore, what emerges from the survey is the need to make this cultivation technique known by transmitting the values and advantages that underlie vertical farming. In a country with a strong and deeply rooted culinary culture like Italy, it is certainly more complicated to get consumers to accept new food technologies if they are seen as discordant with what the traditions are, but succeeding in this challenge would make local players very competitive on the market.

Author Contributions: Conceptualization, A.C., A.B. and G.M.; methodology, A.C., G.M., A.B. and L.B.; validation, L.B., A.B. and G.M.; formal analysis, A.C.; data curation, A.C.; writing—original draft preparation, A.C.; writing—review and editing, A.C., G.M., A.B. and G.P.; visualization, A.C.; supervision, A.B., G.P. and L.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon request from the corresponding authors.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ellingsen, E.; Despommier, D. The Vertical Farm—The origin of a 21st century Architectural Typology. *CTBUH J.* **2008**, *3*, 26–34.
2. Despommier, D. Farming up the city: The rise of urban vertical farms. *Trends Biotechnol.* **2013**, *31*, 388–389. [[CrossRef](#)] [[PubMed](#)]
3. Kalantari, F.; Tahir, O.M.; Joni, R.A.; Fatemi, E. Opportunities and challenges in sustainability of Vertical Farming: A Review. *J. Landsc. Ecol.* **2018**, *11*, 35–60. [[CrossRef](#)]

4. Despommier, D. *The Vertical Farm: Feeding the World in the 21st Century*; Macmillan: Basingstoke, UK, 2010.
5. Gómez, C.; Currey, C.J.; Dickson, R.W.; Kim, H.-J.; Hernández, R.; Sabeh, N.C.; Raudales, R.E.; Brumfield, R.G.; Laury-Shaw, A.; Wilke, A.K.; et al. Controlled environment food production for urban agriculture. *HortScience* **2019**, *54*, 1448–1458. [[CrossRef](#)]
6. Martin, M.; Weidner, T.; Gullström, C. Estimating the Potential of Building Integration and Regional Synergies to Improve the Environmental Performance of Urban Vertical Farming. *Front. Sustain. Food Syst.* **2022**, *6*, 849304. [[CrossRef](#)]
7. van Delden, S.H.; SharathKumar, M.; Butturini, M.; Graamans, L.J.A.; Heuvelink, E.; Kacira, M.; Kaiser, E.; Klamer, R.S.; Klerkx, L.; Kootstra, G.; et al. Current status and future challenges in implementing and upscaling vertical farming systems. *Nat. Food* **2021**, *2*, 944–956. [[CrossRef](#)] [[PubMed](#)]
8. Benke, K.; Tomkins, B. Future food-production systems: Vertical farming and controlled- environment agriculture. *Sustain. Sci. Pract. Policy* **2017**, *13*, 13–26. [[CrossRef](#)]
9. Csordás, A.; Füzesi, I. The Impact of Technophobia on Vertical Farms. *Sustainability* **2023**, *15*, 7476. [[CrossRef](#)]
10. Ares, G.; Ha, B.; Jaeger, S.R. Consumer attitudes to vertical farming (indoor plant factory with artificial lighting) in China, Singapore, UK, and USA: A multi-method study. *Food Res. Int.* **2021**, *150*, 110811. [[CrossRef](#)] [[PubMed](#)]
11. Jürkenbeck, K.; Heumann, A.; Spiller, A. Sustainability Matters: Consumer acceptance of different vertical farming systems. *Sustainability* **2019**, *11*, 4052. [[CrossRef](#)]
12. Perambalam, L.; Avgoustaki, D.D.; Efthimiadou, A.; Liu, Y.; Wang, Y.; Ren, M.; Petridis, A.; Xydis, G. How young consumers perceive vertical farming in the Nordics. Is the market ready for the coming boom? *Agronomy* **2021**, *11*, 2128. [[CrossRef](#)]
13. Mina, G.; Peira, G.; Bonadonna, A. Public perception and social sustainability of indoor farming technologies: A systematic review. *Technol. Soc.* **2023**, *75*, 102363. [[CrossRef](#)]

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