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SHORT COMMUNICATION

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Buying vertically farmed produce: Comparison of people with lower and higher stated purchase likelihood

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Abstract

The study explored attitudinal and socio-demographic differences between potential buyers and non-buyers of lettuce grown in a vertical farming (VF) system. Data were collected from people ($n = 2193$) in four countries—United States, Germany, Singapore, and Australia. Survey results demonstrated a clear link between positive VF attitude and intention to buy, and similarly for negative attitude and intention to not buy. A key difference between people with "lower" and "higher" purchase likelihood (more or less than 50% probability) was that the former were consistently less positive about the benefits of VF. The consumer groups largely perceived the disadvantages of VF similarly. Socio-economic differences between the consumer groups related to country of living and having children below the age of 18 living at home. The latter significantly increased the likelihood that consumers would classify a having "higher" purchase likelihood for VF-grown lettuce. German participants were less likely to have a "higher" purchase likelihood.

Practical applications

Major food system transformations are needed to feed growing global populations and ensure access to heathy diets. Proposed solutions include high-technology production systems that disentangle food production from natural ecosystems. VF is among these; it is an indoor and fully controlled method for crop production. If most consumers are positive towards VF, as past research suggests, it is paramount that they also purchase VF foods. By comparing consumers who are positively and negatively inclined towards purchasing lettuce from VF, the present research identifies children below the age of 18 living in participants' households as a significant predictor of higher intention to purchase. This may be linked to parental concern for their offspring's future lives in a world likely to be impacted by ecological challenges. A likely positive consequence for VF uptake is that children carry forward some of their food-related habits and behaviors into adulthood.

1 | INTRODUCTION

Major food system transformations are needed to ensure access to heathy diets for all (FAO et al., 2021). Technological solutions are paramount to achieving this objective without increasing pressure on natural resources in the context of limited agricultural land and climate change (FAO, 2022).

High-technology production systems focused on disentangling food production from natural ecosystems, such as vertical farming (VF), are among the solutions proposed to expand agricultural

production (Muller et al., 2017). VF is an indoor method for crop production, where temperature, lighting, and nutrients are carefully controlled (Yuan et al., 2022). This technology enables food production in a climate-resilient manner, independently from local weather conditions (Coughlan et al., 2022). VF is efficient in natural-resource use and can reduce land and water requirements, as well as the use of pesticides compared to conventional agriculture (Rufí-Salís et al., 2020; Shamshiri et al., 2018; Van Delden et al., 2021). Adoption of VF by agro-enterprises relies on profitability and governmental incentives to encourage change (De Oliveira et al., 2021), as well as uptake of produce from VF by consumers, especially those living in urban regions. Therefore, understanding consumer attitudes and beliefs about VF is essential.

Heterogeneity in consumer perception food production technologies is expected given large differences in consumer preferences, attitudes and values (Hassoun et al., 2022). Although consumers are often positive about technological progress, a considerable proportion are often hesitant to accept novel food technologies (Siegrist & Hartmann, 2020). Regarding VF, research shows that most consumers have a positive attitude and are willing to accept produce from VF (e.g., Ares et al., 2022; Ha et al., 2021). Higher yield, freshness, less pesticide and herbicide use, reduced carbon emissions, and securing access to food have been identified as the key VF characteristics underlying consumer positive attitudes (e.g., Ares et al., 2022; Ha et al., 2021; Jaeger et al., 2023). Despite the general positive attitude, a segment of consumers skeptical or negative about VF has also been identified in studies conducted in different countries across the globe (Ares et al., 2022; Yano et al., 2021).

Socio-demographic and psychographic characteristics can underlie differences in attitudes towards novel food technologies (Siegrist & Hartmann, 2020). However, a deeper understanding of the individual determinants of attitudes towards VF and the characteristics of prospective buyers of produce from VF is lacking. The present study is situated in this knowledge gap, and it explores attitudinal and socio-demographic differences between potential buyers and non-buyers of VF-grown produce. Specifically, it is based on a re-analysis of data from an online study conducted in four countries: United States of America (US), Federal Republic of Germany (DE), Republic of Singapore (SG), and Commonwealth of Australia (AU). Significant growth for the VF sector towards 2030 is projected for these countries as part of the outlook for the, respectively, North American, European and Asian-Pacific markets (Vertical Farming Market, 2022).

2 | MATERIALS AND METHODS

2.1 | Participants

Participants ($n = 2193$) registered on data bases maintained by ISO-certified commercial market research providers took part. Regular involvement in household grocery shopping and food preparation (both at least weekly) was required. Excluded were people with self-declared red-green color blindness which could interfere with ability to perform the text highlighting task (see below). Only people with self-declared language proficiency in German (DE) or English (AU, SG, US) could take part. For Singapore, it was appropriate to use English, which is the lingua franca.

Full data were obtained from 537 to 556 people per country. In each country, interlocking quota for men (50%) and women (50%) across two age groups (25–39 years old (50%), 40–54 years old (50%)) were recruited. Participants lived in urban regions and samples were diverse across household income, household members, and education.

2.2 | Purchase likelihood for VF-grown lettuce

Written product concepts for lettuce were used as stimuli. Lettuce is one of the most accessible and regularly consumed vegetables (Kim et al., 2016) and one of the most important VF crops (Avgoustaki & Xydis, 2020). The response scale for stated purchase likelihood was: 1 = "Definitely will not buy (0%–9% chance)," 2 = "Probably will not buy (10%–29% chance)," 3 = "Possibly will not buy (30%–49% chance)," 4 = "Possibly will buy (50%–69% chance)," 5 = "Probably will buy (70%–89% chance)," and 6 = "Definitely will buy (90%–100% chance)."

To obtain independence from specific wordings, four product concepts were used, which comprised three statements in addition to "Lettuce from indoor farming" (Table 1). The statements pertained to characteristics of the VF system or properties of the lettuce itself and were based, directly or indirectly on information from the text about VF (see below). According to a between-subjects experimental design, each participant evaluated one of the four concepts.

2.3 | Text highlighting task

Before measuring purchase likelihood for VF-grown lettuce, participants received written information about VF. This described what VF is and covered some of the pros and cons of this technology (Figure 1), supplemented by two VF images (Supplementary Material S1). Jaeger et al. (2023) has further details on the text development.

While reading the information about VF, participants performed a text highlighting task (Jaeger et al., 2022) in which they used electronic highlighter tools to select text that they liked/felt positive about (hereafter, "like" highlighting) and content that they disliked/felt negative about (hereafter, "dislike" highlighting) (Supplementary Material S1).

2.4 | Data collection

The online survey was completed using a desktop or laptop computer. Demographic and socio-economic questions were asked at the end of the survey. The overall survey included sections linked to other projects that were unrelated to this research (not considered further).

TABLE 1 Product concepts for vertical farming (VF)-grown lettuce used in the research. Each participant evaluated a single concept on a 6-point scale of purchase likelihood (0%–100%).

ID	Description	"Higher" purchase likelihood (%)	"Lower" purchase likelihood (%)
1	Lettuce from indoor farming 100% pesticide-free Grown in hydroponic conditions Same nutrition content as lettuce grown outdoors	76.4[a] (14.0)	29.1[a] (14.0)
2	Lettuce from indoor farming Indoor farm located in 10-storey high building Available in supermarkets <24 h after harvest Farmland corresponding to 5000 football fields returned to nature	75.7[ab] (14.6)	27.7[a] (14.9)
3	Lettuce from indoor farming Grown under purple lighting Same taste score as lettuce grown outdoors Industrial robots used during planting and harvesting	73.6[b] (13.8)	29.5[a] (13.6)
4	Lettuce from indoor farming 100% energy from sun and wind Clearly labeled on front of pack as "indoor grown" Indoor farm located in the urban region where you live	76.7[a] (13.7)	27.9[a] (13.8)

Note: Values shown for groups of participants with "higher" and "lower" purchase likelihood. Averages (and standard deviations, SD) based on data from all four countries are shown. Post hoc tests performed by Tukey's method, and concepts which share a letter are not significantly different at the 5% level.

2.5 | Data analysis

2.5.1 | Classification of participants according to their purchase likelihood

Purchase likelihood data were transformed into an interval scale considering the average purchase likelihood (%) of each scale points: 1: 4.5%, 2: 19.5%, 3: 39.5%, 4: 59.5%, 5: 79.5%, and 6: 95%. Average purchase likelihood scores were calculated for each of the four product concepts. Participants reporting a likelihood of purchasing VF-grown lettuce lower than 50% (i.e., response options 1–3) were classified as having "lower" purchase likelihood, whereas those reporting a likelihood equal to or higher than 50% (i.e., response options 4–6) were classified as having a "higher" purchase likelihood. Analysis of variance was used to determine if stated purchase likelihood differed between the four lettuce concepts for the two groups of consumers. Tukey's test was used for post-hoc comparisons.

2.5.2 | Text highlighting

Responses to the text highlighting task were analyzed using categorical coding for individual words: +1 if highlighted as "like", −1 if highlighted as "dislike", and 0 if not highlighted (Jaeger et al., 2022). Then, the same coding was applied to each of the 37 sentences of the text to record their sentiment, that is, whether each participant only selected words as "like" (+1), "dislike" (−1) or did not highlight any word or highlighted words both as "like" and "dislike" (0). Scores were averaged across participants for each of the sentences. Positive values indicate an overall positive attitude towards the content of the sentence, negative values indicate an overall negative attitude, and values close to 0 indicate an overall neutral or ambivalent attitude. Statistically significant differences in sentiment between the two consumer groups ("higher" and "lower" purchase likelihood for VF-grown lettuce) were evaluated using Kruskal-Wallis test.

2.5.3 | Comparison of the characteristics of participants with different purchase likelihood

Logistic regressions were used to explore the influence of participant characteristics on stated purchase intention. Group membership ("higher" vs. "lower" purchase likelihood, 1 and 0, respectively) was considered as the dependent variable. The independent variables were country, gender, age group, annual household income, household size, children aged under 18 living in the household, and education level. First, univariate regressions were run separately for each independent variable. Then, a multivariate regression was run considering only the variables that were found to be significant in the univariate regressions to account for potential correlations between variables. Results were expressed as odd ratios with 95% confidence intervals.

Indoor farming is a name for vegetable production that takes place inside buildings[1]. To grow indoors, the plants – for example, salad greens, cucumbers, zucchini, and eggplant – need artificial lighting[2]. Purple lighting helps the plants to grow and is often used[3]. Hydroponics, where plants grow in nutrient-rich water instead of soil, are common in indoor farms[4]. Using IT systems, water and nutrient supplies to the plants can be recycled and fully used[5]. When growing outdoors, plants are at risk from unwanted insects, weeds, and plant diseases[6]. Buildings protect against these, and indoor farmers rarely need to control such biological threats with pesticides and other chemicals[7]. The name "plant factories" is sometimes used for indoor farms[8]. This relates to the production efficiency of indoor farming[9]. When temperature and lighting are controlled, vegetables can be grown and harvested all year round[10]. Output can be several times higher than when the same plants grow outdoors[11]. Crop losses caused by droughts, frosts and excessive rain are avoided too[12]. The reference to "plant factories" can also relate to the use of automation[13]. Industrial robots are used in some indoor farms, to limit repetitive manual labor tasks during planting and harvesting[14]. The use of automation and advanced IT systems means that indoor farms can be at risk from evil-minded hacking and cyber-attacks[15].

Indoor farming makes it possible to grow plants in vertically stacked layers, and indoor farming is also called "vertical farming."[16] Vertically stacking reduces the land required for vegetable production compared with production outdoors or in glasshouses[17]. Where farmland for food production is limited, this matters[18]. Elsewhere, unused farmland can be given back to nature for wildlife and biodiversity recovery[19]. The significant cost of building and operating indoor farms can lead to higher shop prices for indoor-farmed vegetables[20]. A particular issue is that energy use in indoor farms is high[21]. Electricity is needed to replace natural sunlight with artificial lighting; and to replace open-air environments with climate-controlled ones[22]. Indoor farming is environmentally friendly only when the necessary electricity comes from renewable energy sources, like sun and wind[23]. By making use of the ability to create and maintain different climate conditions, it becomes possible to grow many different types of vegetables in indoor farms[24]. This way, "exotic" products, which would normally grow only in countries with a certain type of climate can be produced anywhere in the world with indoor farming[25]. Expansion of indoor farming will lead to new jobs, particularly in engineering and information technology[26]. But rural towns may suffer and disappear as people working in outdoor farming lose their jobs and livelihoods[27].

With indoor farming, the vegetables people need to eat can be produced in the area where they live[28]. On a bigger scale, indoor farming can aid global food security[29]. Indoor farms are often located in or near cities, and for this reason the name "urban farming" is sometimes used[30]. Producing food close to where people live reduces CO_2 emissions from long-distance transportation[31]. Producing food close to the consumers also means daily access to fresh products[32]. Vegetables from indoor farms are typically on sale in shops less than 24 hours after they were harvested[33]. Growers and shops differ in how much attention they draw to the fact that vegetables for sale are indoor-grown[34]. Sometimes this is clearly stated on the front of product packaging, other times it is not[35]. Food safety regulations apply to indoor-farmed vegetables in the same way that they apply to other commercially produced and sold foods[36]. Scientific studies of nutrient content and product quality show that vegetables grown indoors match those grown outdoors[37].

FIGURE 1 Information about vertical farming (VF) provided to participants. Sentences are numbered from 1 to 37 using superscript.

3 | RESULTS

Most consumers ($n = 1931$, 88.1%) were in the group of "higher" purchase likelihood for VF-grown lettuce (Table 1). The four concepts had average likelihood values between 73.6% and 76.7%, which aligned with the verbal anchor "probably will buy." Conversely, the average purchase intent for the 262 consumers (11.9%) who comprised the "lower" purchase likelihood group ranged between 27.7% and 29.5% ("probably will not buy"). The four lettuce concepts were significantly differentiated in the "high" purchase likelihood group ($F_{3,1927} = 4.81$, $p = .002$), with the concept describing the use of purple lighting and industrial robots (Concept 3) showing significantly lower purchase likelihood than concepts highlighting health and sustainability benefits of VF-grown produce (Concepts 1 and 4) (Table 1). For the "lower" purchase likelihood group, no significant differences among product concepts were found ($F_{3,258} = 0.05$, $p = .83$).

The two groups of consumers differed in their attitudinal responses to VF as established in the text highlighting task. Significant differences were found in the sentiment scores of 29 of the 37 sentences (Figure 2). Participants in the "higher" purchase likelihood group showed a significantly higher sentiment score than those in the "lower" purchase likelihood group for all sentences with positive sentiment. Conversely, no significant differences between the two groups were found for sentences with negative sentiment (Sentences 15, 21, 22, 27, 34, and 35) or neutral sentiment (Sentences 6 and 8). The only exceptions were Sentences 13, 14, and 20. For Sentences 13 and 14, which described the use of automation and robots, participants in the "lower" purchase likelihood group showed a negative sentiment whereas those in the "higher" purchase likelihood group showed a neutral sentiment (Figure 2). In the case of Sentence 20, which described higher shop prices of VF-grown foods, participants in the "higher" purchase likelihood group showed a more negative sentiment than those in the "lower" purchase likelihood group (−38.8 vs. −29.4).

Differences in the characteristics of participants with "higher" and "lower" purchase likelihood for VF-grown lettuce were

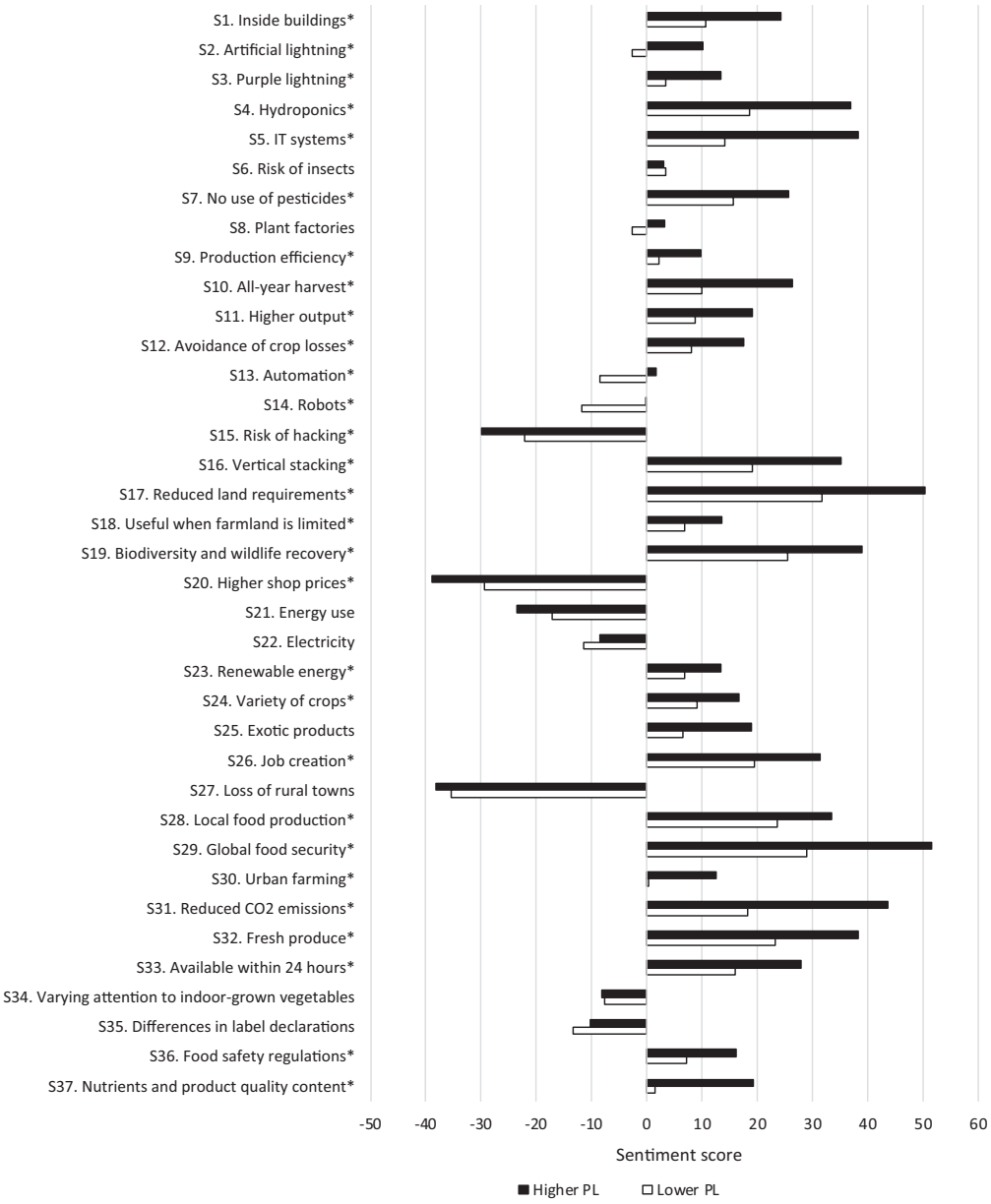

FIGURE 2 Sentiment scores (−100 to +100) by sentence (S1–S37) following the text highlighting task (Figure 1 has full sentence wordings). Values shown for pan-national groups of consumers with "lower" (unfiled bars) and "higher" (filled bars) purchase likelihood (PL) for vertical farming (VF)-grown lettuce. The marker "*" is used to indicate that sentiment scores differ significantly between countries at the 5% level according to Kruskal-Wallis test.

summarized (Table 2). Univariate logistic regressions showed that five variables had a significant effect on the likelihood of reporting "higher" (vs. "lower") purchase intention: country, household income, household size, presence of children under 18 in the household and education level (Supplementary Material S1). These variables were included in a multivariate logistic regression model to take account of potential correlations. Only two of the variables had a significant effect on the likelihood of reporting "higher" (vs. "lower") purchase likelihood: country and presence of children under 18 in the household. Participants from Germany were 5.1% less likely to classify in the "higher" purchase intention group than those from Australia, whereas those from Singapore were 5.4% more likely. Meanwhile, participants who lived in households with children under 18 were 5.1% more likely to report "higher" likelihood of purchase than those who lived in households without children.

4 | DISCUSSION AND CONCLUSIONS

In line with the VF-positive attitude that many consumers are reported to hold (Ares et al., 2022; Ha et al., 2021; Jaeger et al., 2023), the present research found that 88.1% of participants ("higher" purchase likelihood group) were positively inclined towards buying ("probably will buy") VF-grown lettuce (Table 1). These consumers also held a more VF-positive attitude than people who were negatively inclined towards purchase ("lower" purchase likelihood group) (Figure 2). In terms of attitude to VF, the more versus less positive attitude to VF differentiated the two groups of consumers rather than a (on average) negative attitude to VF in the "lower" purchase likelihood group. This shows that strength of positive attitude matter for purchase likelihood whereby stronger positive attitude is more likely to result in strong behavioral intention (and, in turn, actual

TABLE 2 Summary of participant characteristics by consumer groups defined as having, respectively, "higher" and "lower" purchase likelihood for lettuce from vertical farming.

Participant characteristic	"Higher" purchase likelihood ($N = 1931$)	"Lower" purchase likelihood ($N = 262$)
Gender		
Male	49.8	47.7
Female	50.2	52.3
Age group		
25–39 years old	50.6	46.6
40–54 years old	49.4	53.4
Country		
Australia	25.2	26.3
Germany	22.7	37.4
Singapore	26.3	15.3
United States	25.8	21.0
Annual household income, before tax[a]		
Below average	57.9	67.9
Average or above	40.0	29.4
Prefer not to say	2.1	2.7
Household size		
1 person	17.2	25.6
2 people	23.9	24.8
3 people	22.7	26.0
4 people	24.4	18.7
5 or more people	11.5	4.6
Prefer not to answer	0.3	0.4
Education		
High school/college certificate or lower	13.3	17.9
Polytechnic or vocational training	26.7	29.0
University degree (bachelor or higher)	58.8	51.1
Other or prefer not to answer	1.2	1.9

Note: Values are shown as percentages (% [some percentages values do not add up to 100 due to rounding]) of total sample size (n) unless otherwise stated.
[a]Average income defined as AUD$100,000 for Australia, SG$100,000 for Singapore, USD$80,000 for United States and €40,000 for Germany.

TABLE 3 Results of the multivariate logistic regression exploring the effect of participant characteristics on the likelihood of reporting "higher" (vs. "lower") purchase likelihood of VF-grown lettuce. Only variables with a significant effect in univariate logistic regressions were included in the model.

	Odd ratios (95% confidence interval)
Country	
Germany	**0.950 (0.911–0.990)**
Singapore	**1.053 (1.011–1.096)**
United States	1.016 (0.978–1.056)
Household income	
Average or above	0.988 (0.958–1.019)
Household size	
2 people	1.024 (0.980–1.070)
3 people	0.976 (0.927–1.027)
4 people	0.999 (0.946–1.056)
5 or more people	1.039 (0.976–1.107)
Children under 18 in the household	
Yes	**1.057 (1.018–1.099)**
Education	
Polytechnic or vocational training	1.026 (0.980–1.074)
University degree (bachelor or higher)	1.019 (0.975–1.064)

Note: The reference level for the independent variables were the following: Age group (25–29 years), country (Australia), household size (1 person), children under 18 in the household (No), education (high school/college certificate or lower). Odd rations highlighted with bold characters are significantly different from 1 for a significance level of 0.05.

behavior). Theories of consumer behavior such as Theory of Planned Behavior (Ajzen, 1991) predict this. Interestingly, the groups mostly differed in their attitude towards positive aspects of VF, suggesting that strategies to promote purchase of VF-grown vegetables should emphasize the advantages of the technology.

The multivariate logistic regression exploring the effect of participant characteristics on the likelihood of reporting "higher" (vs. "lower") purchase likelihood of VF-grown lettuce identified odds ratios significantly greater than one for participants living in Singapore and participants with children below the age of 18 living at home (Table 3). In the case of Singapore, Ares et al. (2022) found a similar result, and the high acceptance of VF seems a likely reflection of a positive attitude to technology in general. Adoption of technology has brought economic benefits to the country (Vu, 2013), and is accompanied by a vision of its contribution to improved quality of life (Mahizhnan, 1999).

The positive effect of living with children on purchase likelihood of VF-grown lettuce intuitively makes sense in the context of parental concern for their offspring's future lives in a world likely to be impacted by environmental and associated challenges. Since a more sustainable world will increase the change for children to have access to enough resources, parents should logically engage in pro-environmental behaviors. Migheli (2020) finds empirical support for this in the case of purchasing green goods, but only among mothers. Ritch and Brownlie (2016) reach a similar conclusion and further

stress the importance of social dynamics and educating children about sustainability. Both studies note that financial obstacles hinder these altruistic behaviors. A similar concern has been expressed for produce from VF, that is, that high prices prevent consumers from regular purchases (e.g., Coyle & Ellison, 2017; Jaeger et al., 2023).

With a view to greater acceptance of VF and integration of VF produce in daily diets, the positive effect on purchase likelihood in households with children under the age of 18 years was further encouraging because there is evidence to suggest that children when they start to live independent lives will carry forward some of the purchasing and consumption habits from their childhood (e.g., Branen & Fletcher, 1999). This includes fruits and vegetables (e.g., Arcan et al., 2007) which is a secondary benefit considering the importance of these categories for healthy and balanced diets.

The findings are contingent on the text about VF that participants and may, thus, change if other information is provided. The same goes for the specific product concepts, and the use of lettuce as a case study. Because the four countries included in the research represent societies of the type "Educated, Industrialized, Rich and Democratic" the findings may not generalize to other types of societies. However, since VF can be used anywhere to advance sustainable food production and supply (e.g., Kalantari et al., 2018), there is merit in extending the present research more countries. Extension to older participants is also appropriate, given global aging (Lutz et al., 2008). Since younger age is associated with a more VF-positive attitude (Perambalam et al., 2021; Robinson et al., 2022; Yano et al., 2021), inclusion of older participants will likely increase the size of the consumer group with "lower" purchase likelihood for VF-grown lettuce. Therefore, it is important to find ways to mitigate age bias.

We note in closing that when significant effects for participant characteristics on purchase likelihood were observed, the associated odds ratios were close to 1, meaning that the observed effects were small. Thus, care needs to be taken in not overinterpreting the findings. Changes in the order of 5% in likelihood of purchasing VF-grown lettuce are not expected to lead to a large impact in the marketplace and on food supply and provisioning becoming more sustainable overall. However, we subscribe to the point of view that "little strokes fell great oaks."

AUTHOR CONTRIBUTIONS

Sara R. Jaeger: Conceptualization, methodology, writing–original draft, writing–review & editing. Sok L. Chheang: Implementation, data curation. Gastón Ares: Conceptualization, formal analysis, writing–original draft, writing–review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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