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Consumer attitudes towards hydroponic cultivation of vegetables – Specifically exploring the impact of the fertilisation strategy (using mineral origin or food waste as fertilisers)

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ABSTRACT

This study explores consumer attitudes and beliefs towards hydroponics (growing without soil), as well as the willingness to eat vegetables grown using two different fertilisation strategies (mineral and food waste). The impact of food neophobia, connectedness to nature and awareness of ongoing climate change is also explored. Data were collected through a survey (October 2021) with 1,000 Swedish respondents. Less than half of the respondents were aware of hydroponics, with no differences due to gender or age. Nonetheless, education turned out to be a predictor. No differences were seen in attitude due to gender or level of education, yet a slightly more positive attitude was found among older respondents and a more positive attitude among those who had not heard about hydroponic systems before. Food neophobia and higher age only (negatively) predicted the willingness to eat food with input from food waste, whereas connectedness to nature did not predict willingness to eat vegetables from any of the two fertilising systems. A belief in climate change had a positive impact on the willingness to eat vegetables from both systems. The results revealed significant differences between the two systems, with the circular perceived as significantly more natural, environmentally friendly, more exciting, representing the future, more energy efficient, more innovative as well as more positive overall, compared to the mineral. These qualities could be used by stakeholders when communicating these new systems. The results support the understanding that hydroponics is a food technology to which consumers express positive attitudes and beliefs.

1. Introduction

Ongoing climate change, loss in biodiversity and an increasing population (Willett et al., 2019, United Nations, 2019) increase the need to, not only rely on traditional cultivation systems but also develop and expand the use of innovative and technology-driven food production systems (Giacalone and Jaeger, 2023; Siegrist and Hartmann, 2020). One example of such a system is hydroponic cultivation, which builds on the rationale of growing plants without soil (Gilmour et al., 2019). Instead, nutrition is provided through the water, and at times sunlight is combined/replaced with artificial light. The fundamental technology that enables hydroponic cultivation is, however, not entirely new but has been in use in traditional commercial greenhouses for the last 40 years. The technological development underpinning hydroponics has though developed since then. Presently, there is, apart from the high-tech greenhouses, also a growing entry of new hydroponic firms with systems often referred to as plant factories and vertical farming. These more recent systems build on similar hydroponic technology as the one used in traditional greenhouses, but more often solely with the use of artificial light (Kozai, 2013). In the present study, we follow a broader definition of hydroponics, which applies to the technology used within both conventional greenhouses as well as more recent systems, such as vertical farming and plant factories.

By adopting the suggested definition of hydroponics, it can be concluded that almost all greenhouse produced vegetables sold in most European supermarkets today, e.g. tomatoes, herbs and lettuce, are produced by the use of hydroponic systems. Identified sustainable qualities and technological advantages with hydroponics are linked to the flexibility in location (rural and urban environment), independency of external climatic or environmental conditions (due to the possibility

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of using artificial light), closed system (water efficiency) and space efficiency (Savvas and Gruda, 2018). Apart from technical advantages, it should also be kept in mind that the food category produced in the system, vegetables, is regarded as key in transforming food consumption into a more sustainable direction due to its very low climate impact (Garnett, 2011; Willett et al., 2019). Following these arguments, hydroponics, thus, represents a sustainable technology producing sustainable food (vegetables).

Circularity and a better use of resource-rich by-products has also been pointed out as an important factor in creating a more sustainable food system (Santagata et al., 2021). A practical and feasible example of an application of circularity is using household food waste as a fertiliser in hydroponic systems. In several Swedish cities, household food waste is already sorted and collected; moreover, major industrial facilities are in operation and have the potential to process and distribute food waste in a state that can be used for hydroponic systems. In addition to this, guidelines and recommendations are available from authorities, and it is presently possible to use food waste digested for the extraction of biogas and organic fertilisers or soil improvers (Jordbruksverket, 2023). There are also examples of Swedish commercial producers who market nutrients made from food waste (Biond, 2023), which can be used in hydroponic systems. Necessary knowledge, technology and infrastructure are thus available; nonetheless, the use of food waste as a fertiliser in hydroponics only takes place on a smaller commercial scale. Cultivation-related technical issues that may arise in the event of a change in the fertiliser used may be one limiting factor. Yet concerns about consumer reaction have also been singled out as a limiting factor in taking the step and implementing a system including food waste. Hence, knowledge on consumer attitudes and beliefs towards these new circular systems (Vidal-Ayuso et al., 2023) as well as the willingness to eat vegetables grown by using food waste is lacking. Here, we explore consumer attitudes and beliefs towards hydroponics, as well as circular hydroponic cultivation systems with the use of food waste as a nutrient source and the willingness to eat vegetables produced using such a system. In addition, the impact of food neophobia, connectedness to nature and awareness of ongoing climate change are explored.

1.1. Implementing a circular fertilisation: why and how to replace mineral fertilisers with food waste?

As previously described, for hydroponics to work, nutrients must be added through the water. The dominant system for this is mineral fertilisers, which are mainly synthetically produced using fossil resources, with effects on the environment like emission of greenhouse gases (Litskas, 2023). By replacing industrially manufactured mineral (inorganic) nutrients, and instead using recycled nutrients (anaerobically digested organic waste with a high concentration of food waste) as a nutrient source, hydroponic systems have the potential to be even more sustainable through linking itself to a circular food system.

Historically, using food waste (and e.g. manure) as a nutrient source when growing fruit and vegetables was a natural part of ensuring fertilisation within the food production system. However, in the beginning of the 20th century, local nutrient sources (manure and food waste from the farm) were replaced by a new system, where necessary nutrients were industrially produced, mineral fertilisers, which since then has been the global dominant nutrient source within horticultural and agricultural production systems (KSLA, 2023).

There are, however, some concerns that still hinder the development and use of food waste as sources for plant nutrients. In recent studies, the issues related to production systems and risks when applying anaerobic digestate based on food waste as a nutrient source in hydroponics have been addressed (Pelayo Lind et al., 2021; Golovko et al., 2022; Södergren et al., 2022; Bergstrand et al., 2020). However, it can be stated that conventional operating systems for degradation of organic waste (such as food waste) through anaerobic digestion have developed into large-scale net energy (biogas) production technology. This technology is widely used for the treatment of different types of organic wastes, such as food waste. In addition to the biogas, the anaerobic digestion also generates a nutrient-rich, partly degraded semi-liquid digestate (de Groot and Bogdanski, 2013). This by-product has the potential for use in hydroponic production as an organic nutrient source (Pelayo Lind et al., 2021; Bergstrand et al., 2020). It is this by-product we refer to in this paper when stating that food waste can be used as a nutrient in hydroponic cultivation.

1.2. Consumer acceptance of hydroponics and the use of food waste or mineral origin as a fertiliser

Studies exploring consumers' perception and acceptance of different types of innovative food technologies illustrate a frequently recurring scepticism (Siegrist, 2008; Frewer et al., 2013). Often linked to e.g. a lack of trust (Costa-Font et al., 2008) and/or a preference for naturalness (Lusk and Briggeman, 2009). Several previous studies have also explained that women are more concerned, less positive and see fewer benefits of food technologies and technology in general (Lyndhurst, 2009; Gaskell et al., 2010; Aschemann-Witzel & Peschel, 2019; Spendrup et al., 2021). Age has also been identified as a factor, with older persons more likely to be concerned about novel food technology (Lyndhurst, 2009), as well as education, which has been shown as a predictor of acceptance towards novel sustainable food technologies. There are, however, also differences in the acceptance of different technologies; as shown by Giacalone and Jaeger (2023), hydroponics represents a food technology with higher consumer acceptance compared to e.g. gene editing and cell-cultured meat and fish.

Turning to food waste, this topic has gained a great interest in the context of industrial processes (Hellali and Korai, 2023) as well as food loss and waste in the supply chain. Still less is known about consumer acceptance and perception of food that is based on food or ingredients that have been wasted (Aschemann-Witzel & Peschel, 2019; Hamam et al., 2021; Hellali et al., 2023). Recent findings by Hellali et al. (2023), however, show that consumerś willingness to pay for circular food products is lower compared to the corresponding conventional methods. Similar findings have been found for upcycled foods (food made from ingredients that otherwise would be thrown away or unused), explaining that consumers are less willing to pay for upcycled food (Bhatt et al., 2020). Studies have also investigated the effect of food neophobia (consumer reluctance to try unfamiliar food (Ritchey et al., 2003)) in the context of circularity. The outcome shows a negative influence of food neophobia on consumers' willingness to buy waste-to-value food (food with ingredients otherwise wasted) (Coderoni and Perito, 2020) as well as on the intention to consume upcycled food products (food made from ingredients that otherwise would be thrown away or unused) (Hellali and Korai, 2023). The emotion of disgust has also proven to have a negative effect on both perceived usefulness and consumption intention of upcycled foods (Aschemann-Witzel et al., 2022; Grasso and Asioli, 2020; Hellali and Korai, 2023). Taken together, these findings point out an expected negative effect of food neophobia on the willingness to eat vegetables produced using food waste as a fertiliser. No studies were found exploring consumer attitudes towards mineral fertilisers.

Connectedness to nature (CtN) constitutes an individual's experiential and emotional connections to nature (Mayer and Frantz, 2004); previous findings explain that consumers experiencing higher CtN have proven to make more sustainable choices in daily life, e.g. green purchasing, recycling (Dong et al., 2020) as well as adopting a plant-based diet (Krizanova et al., 2021). In a study looking at consumer associations towards Value-Added Surplus Food, VASP (food made from ingredients obtained during the production of other food), it was shown that consumers associate this category to organic food (Bhatt et al., 2018), suggesting interconnections between consumer perceived sustainability and VASP food. Additional sustainability associations such as "reducing food waste" and "good for the environment" have also proven to be associated with upcycled food (Grasso et al., 2023). Studies have also shown that consumers who both express a strong awareness of ecological concerns and a commitment to sustainable practices are more likely to recognise that upcycled foods can function as a solution to reducing food waste (Hellali and Korai, 2023). It has also been shown that consumers who believe in a link between food and environmental benefits were more likely to be willing to buy waste-to-value food (WTV) (Coderoni and Perito, 2020). Taken together, these findings suggest that it is reasonable to believe that consumers expressing high levels of CtN express a higher willingness to eat vegetables produced in a food waste system compared to the mineral system. Furthermore, it could be assumed that consumers convinced of climate change express a greater willingness to eat vegetables grown in the food waste system, compared to the mineral system.

To reach success with a system that interlinks hydroponic vegetable production with food waste, it is of importance to understand what (dis-) advantages consumers see with such a system. The awareness of, and consumer attitudes towards, hydroponics per se are less researched in a Swedish context, pointing to a lack of knowledge regarding these matters, too. Consequently, the aim of this study was to gain an understanding of consumer attitudes and beliefs towards hydroponic systems per se and explore attitudes and beliefs towards the system as well as the willingness to eat vegetables produced with the input of two different fertilisers: a) industrially manufactured fertilisers and b) household food waste as a fertiliser. To achieve the aim, four research questions were formulated:

RQ1. How well known are hydroponic systems per se, and is there a difference in awareness depending on age, gender or education?

RQ2. How do attitudes towards hydroponic production systems differ depending on gender, age, education and awareness of the system?

RQ3. How do attitudes and beliefs towards mineral fertilisers and food waste as a fertiliser differ?

RQ4. What is the impact of food neophobia, connectedness to nature, awareness of climate change and the link between food and climate, on the willingness to eat vegetables produced by using a mineral fertiliser or food waste?

To our knowledge, this is the first study quantitatively exploring Swedish consumer awareness of hydroponic cultivation systems and the impact of using mineral fertilisers or food waste. The outcome of the study is expected to support policy makers and market actors in developing target group applied strategies in line with conditions and preferences that apply to different target groups. The goal is to support a transition to a circular food system.

2. Material and methods

2.1. Survey participants

Data were collected in October 2021 in Sweden by using an online questionnaire in Swedish, using a commercial panel provider, PFM Research in Sweden AB. Only participants who answered all the questions were included in the analysis. Implementation of the survey followed the Swedish University of Agricultural Sciences policy for processing of personal data (https://www.slu.se/en/about-slu/contact-slu/personal-data/). The data were collected by PFM Research in Sweden AB and coded prior to delivery, ensuring anonymity. The general international code and guidelines on market and social research used by the International Chamber of Commerce (ICC/ESOMAR, 2016) were followed.

In total, 1000 complete participant datasets were registered and used for the analysis; see Table 1 for overview. Due to the low number of participants in the gender category 'Other' (N = 5), results are only presented for men and women (N = 995). All statistical analyses were conducted using IBM (SPSS, ver. 27). Demographics (gender, age, level of education) are presented in Table 1. The participants ranged in age from 18 to 83 years, with a mean of 49.40 years (SD = 17.7). Comparing the study sample with the Swedish population at large (SCB, 2021), the age and gender groups were in line with the general trend, but education level deviated somewhat, with a slightly higher proportion of university graduates than in the general population. Due to the small number of respondents in the education category "elementary school" analysis and results for the impact of education is represented by two levels (1: A combination of Elementary and High school and 2: University).

Table 1
Demographic characteristics of the study sample (N = 1000) in relation to the Swedish population.

	Study sample		Swedish population[a]
	N = 1000	%	%
Gender			
Men	496	49.5	50
Women	499	49.9	50
Other	5	0.5	
Age group			
18–24 years	87	9	8
25–34 years	175	18	14
35–49 years	244	24	19
50–64 years	233	23	18
65 and older	261	26	20
Education			
Elementary school	51	5	11
High school	439	44	45
University	509	51	44

[a] SCB (2021).

2.2. Measures

2.2.1. Food neophobia

Initial questions covered gender, age and education. Thereafter, food neophobia was measured using the food neophobia scale, developed by Pliner and Hobden (1992). Eight items were included and rated, from strongly disagree (1) to strongly agree (7). The items were:

(i) I am constantly trying new and different food (r).
(ii) I am sceptical of new types of food.
(iii) If I do not know what is in a food, I will not eat it.
(iv) I Like food from different countries (r)
(v) At a dinner party, I like to try new food (r).
(vi) I am afraid of eating things I have never eaten before.
(vii) I am very picky about what food I eat.
(viii) I eat almost anything (r).

Since a large part of Swedish restaurants have a menu that is not traditionally Swedish, but often have an international character, two items were de-selected (Ethnic food looks weird to eat; I like to try new ethnic restaurants). Prior to calculating the total scale scores, negatively worded items (indicated by r) were reversed for analysis, and the Cronbach alpha coefficient (0.80) was calculated.

2.2.2. Connectedness to nature

Connectedness to nature was measured through the scale developed by Mayer and Frantz (2004), rated from 1 (strongly disagree) to 5 (strongly agree). Ten questions were included (r = items reversed for analyses):

1. I often feel a sense of oneness with the natural world around me.
2. I think of the natural world as a community to which I belong.
3. I recognise and appreciate the intelligence of other living organisms.
4. I often feel disconnected from nature (r).
5. When I think of my life, I imagine myself to be part of a larger cyclical process of living.
6. I often feel a kinship with animals and plants.

7. I feel as though I belong to the Earth as equally as it belongs to me.
8. I have a deep understanding of how my actions affect the natural world.
9. I often feel part of the web of life.
10. My personal welfare is independent of the welfare of the natural world (r).

Due to space limitations in the survey, questions 10, 11, 12 and 13 in the original scale were de-selected. Negatively worded items were reversed, and the Cronbach alpha coefficient (0.85) calculated.

2.2.3. Awareness of hydroponics

The production system hydroponics was illustrated by two pictures (see Fig. 1) and a text describing the system (formulated by the authors): 'The cultivation technique is based on the knowledge of how to cultivate without soil (the technique is also called hydroponics). Instead of the nutrients found in the soil, a nutrient solution is used, where the nutrients are mixed with water'.

Awareness of the cultivation technique hydroponics was measured through the question: Did you know of this cultivation technique before (commercial, highly productive greenhouse cultivation without soil (hydroponics)? Response alternatives were yes/no/unsure.

2.2.4. General attitudes towards hydroponics

General attitude towards hydroponic cultivation was measured by five statements:

1. I like to eat vegetables that have been grown using this technology.
2. I would choose vegetables that are grown like this, even if they were more expensive.
3. This cultivation technique is an important part of creating a more sustainable food production.
4. Buying vegetables grown using this system makes me feel satisfied.
5. I Think it is stupid to buy vegetables that are grown like this (r)

Statement 1 is based on own elaboration; statements 2 and 3 are in line with the implementation by Miličić et al. (2017); and statements 4 and 5 are in line with Dean et al. (2008). The items were rated from strongly disagree (1) to strongly agree (5) and Dońt know (6). Prior to calculating the total scale scores, negatively worded items were reversed (indicated by r), and the Cronbach alpha coefficient was calculated, (0.87). The items were rated from strongly disagree (1) to strongly agree (5) and Dońt know (6). Only respondents reporting 1–5 are included in the analysis, and those responding dońt know are excluded.

2.2.5. Attitudes towards using mineral origin or food waste as fertilisers

Participants were randomly assigned to either the mineral fertiliser or the food waste hydroponic system, illustrated in Figs. 2 and 3 and respective descriptive figure text.

Figure text for Fig. 2: The figure shows a number of parts of the chain that are part of commercial cultivation (hydroponic cultivation of e.g. tomatoes and cucumbers) before you can buy it and cook it at home. The nutrients added to the water used in cultivation are produced by industrial processes (N, nitrogen), or mined from the soil (P, phosphorus).

Figure text for Fig. 3: the image shows a future scenario for circular hydroponic cultivation and consumption of e.g. tomatoes and cucumber. Instead of using industrially produced, nutrients used in cultivation come from food residues. The food residues come from household food waste, and the digestion takes place at a biogas plant where renewable energy (biogas) is produced at the same time as the digestate residue, which contains the plant nutrients that are produced.

To explore and understand differences in beliefs and attitudes towards the two different hydroponic systems, connotative meaning was assessed using a semantic differential test (Funk et al., 2020; Hartmann et al., 2018; Michel et al., 2021). Thirty-eight adjectives were presented as 19 bipolar pairs: Natural | Artificial, Tasty | Untasty, Traditional | Modern, Healthy | Unhealthy, Safe | Unsafe, Environmentally friendly | Not environmentally friendly, Exciting | Boring, Cheap | Expensive, The future | The past, Hygienic | Unhygienic, Easy to understand | Difficult to understand, Nutritious products | Nutrient-poor products, Energy efficient system| Energy-intensive systems, Hard to think about| Obvious, Authentic | Fake, Old-fashioned | Innovative, Positive | Negative, Want to know the origin of nutrients | Do not want to know the origin of nutrients, Want to eat | Do not want to eat. The pairs were explored on a sliding scale, from 0 to 100, following the outline in Michel et al. (2021). Participants were requested to value the adjective pairs towards the word they thought best represented vegetables produced in the system that had been described.

The pair "Want to eat | Do not want to eat" is additionally used as dependent variable when exploring the impact of food neophobia, climate conviction, CtN and age on the impact of eating vegetables produced in the two systems.

2.2.6. Personal conviction of climate change and the link between food and climate change

Personal conviction about ongoing climate change was measured by two questions and rated from 1 = not at all convinced to 4 = totally convinced: Question (i) "How convinced are you that global warming (climate change) is taking place?" following the implementation by Zaval et al. (2014), based on Leiserowitz et al. (2008). Question (ii) "How convinced are you that it is better for the climate if you reduce your meat consumption and eat more vegetarian food?" was used to measure a link between food choice and climate change, in line with the implementation by Milford and Kildal (2019), and Leiserowitz et al. (2008). The mean value for the two questions was calculated.

Fig. 1. The pictures show two examples of growing tomatoes (Pexels, 2021) and lettuce (Pixabay, 2021) in highly productive commercial greenhouses (hydroponics).

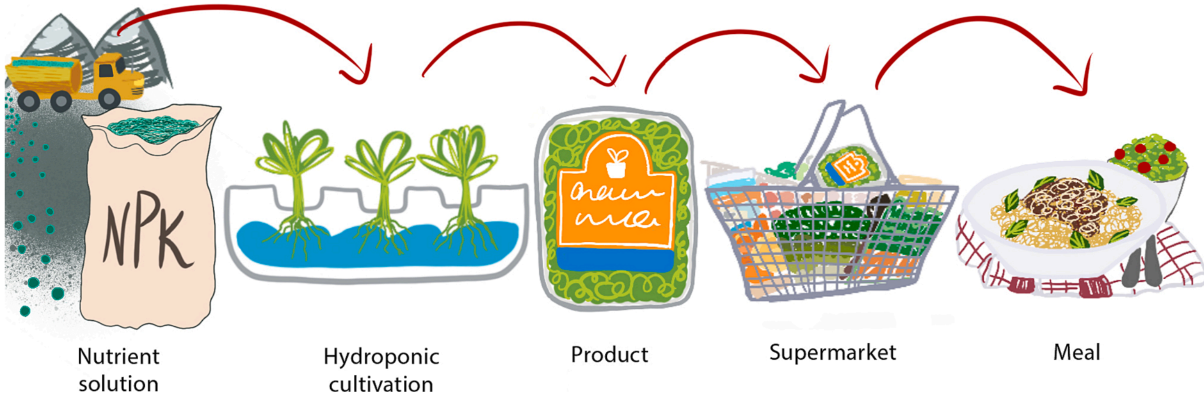

Fig. 2. Steps in conventional mineral fertiliser hydroponic cultivation. Illustration by Rebecca Thörning.

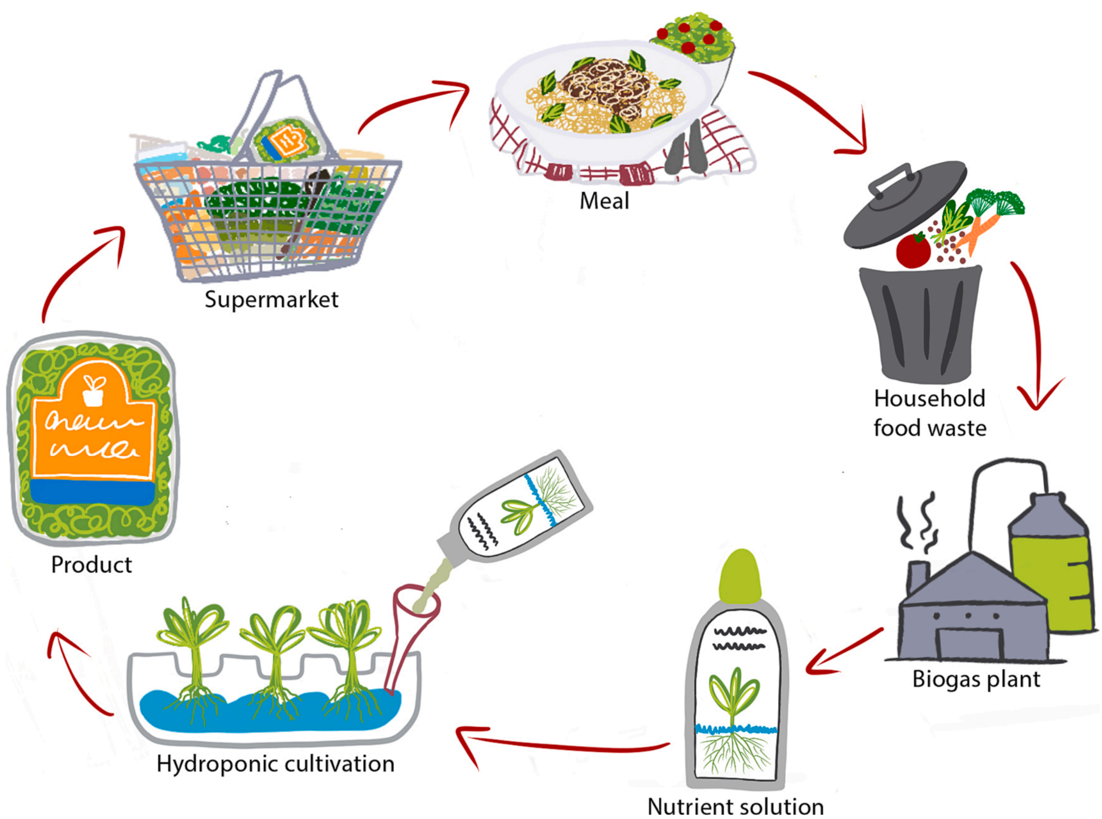

Fig. 3. Steps in a hydroponic cultivation with food waste as a nutrition source. Illustration by Rebecca Thörning.

3. Results

3.1. Consumer awareness of hydroponic systems and difference depending on gender, age and education

The results (see Table 2) show that a larger proportion of the male respondents (50.9 %) compared to female (45.4 %) knew about hydroponics before being provided with information. To explore whether awareness of hydroponics differed depending on gender, a Chi-Square test for independence (with Yates' continuity Correction) was conducted (the category unsure was de-selected for this calculation, $n=135$). The Chi-square test indicated no significant association between gender and (un-) awareness of hydroponic systems $x^2(1, n = 860) = 2.23$, $p = .14$, $phi = 0.05$. The proportion of those who knew about the system and did not know did not significantly differ between men and female. The result for age shows no correlation between age and an

Table 2
Awareness of hydroponics, presented by gender, mean age and level of education.

Total (N = 995)		Yes	No	Unsure
Total		(479) 48.1 %	(381) 38.3 %	(135) 13.6 %
Gender	Men	(252) 50.9 %	(180) 36.3 %	(64) 12.8 %
	Women	(227) 45.4 %	(201) 40.3 %	(71) 14.3 %
Mean age		50	49	50
Education	Elementary and high school	(213) 44.5 %	(211) 55.5 %	(62) 46.2 %
	University	(266) 55.5 %	(170) 44.5 %	(73) 53.8 %

awareness of the system, $r = -0.03$, n = 860, p =.46, suggesting that age is of less importance regarding whether a person is aware of the system or not. Regarding education, the results show that the level of education is higher among those who knew about the system. A Chi-Square test for independence was conducted, confirming a significant association between level of education and (un-) awareness of hydroponic systems $x^2(1, n = 860) = 9.70, p = .00, phi = -0.11$.

3.2. Differences in general attitudes towards hydroponic systems depending on gender, age education and awareness of the system

Results related to the impact of gender, education and awareness are presented in Table 3. To explore if men and women express differences in attitudes towards hydroponics, an independent-samples *t*-test was conducted. Calculations show that there was no significant difference in scores for men ($M = 2.76$, SD = 1.06) and women ($M = 2.76$, SD = 1.01; $t(505) = 0.13$, $p = .90$, two tailed).

The relationship between age and attitudes towards hydroponics was investigated using a Pearson product-moment correlation coefficient. There was a small correlation between the two variables, $r = 0.20$, $n = 455$, $p = < .001$. The results, thus, suggest that attitudes towards hydroponics increase with age.

To explore differences in attitudes depending on education, an independent-samples *t*-test was conducted. The results show no significant difference between elementary/ high school ($M = 2.80$, SD = 1.08) and university level ($M = 2.67$, SD = 1.03;$t(453) = 1.25$, $p = .21$. in attitudes towards hydroponics in general.

To determine if attitudes differ depending on awareness of hydroponic systems, an independent-samples *t*-test was conducted. The results show a significant difference between those who already knew about the system ($M = 2.52$, SD = 0.99) and those who did not ($M = 3.18$, SD = 1.07;$t(453) = -6.44$, $p = .000$. The results, thus, show that attitudes were more positive among consumers who had no previous knowledge about the system.

3.3. Differences in attitudes and beliefs towards the two fertilisation systems in hydroponics

To explore differences in attitudes and beliefs towards using a mineral fertiliser or food waste as a fertiliser, semantic differentials (mean values with 95 % confidence intervals) were calculated for the two systems, following calculations performed by Michel et al. (2021). Results are presented in Fig. 4. To identify significant differences in expressed attitudes and beliefs towards the two systems, independent t-tests were conducted for the two groups and the 19 adjective pairs. Significant differences were found for the food waste system, as being perceived as more natural, more environmentally friendly, exciting, the future, energy efficient, innovative, and positive. See Appendix for calculations.

The results, thus, also show that for 12 adjective pairs, no differences were found between the two fertilisers. For these pairs, the results show that consumers find hydroponic systems and both fertilisers to produce tasty, modern, healthy, safe, hygienic, nutritious, products in systems that are easy to understand, where the consumer wants to know the origin of the nutrients and produces vegetables that the consumer wants to eat. For three adjective pairs, the result is more neutral showing that the consumers find both systems producing vegetables that are neither cheap nor expensive, not hard to think about or obvious as well as not authentic or fake, but somewhere between these opposites.

Table 3
General attitudes towards hydroponic presented by gender, education, and awareness.

Total (N = 455)		N	Attitude
Total		507	2.76 ± 1.04
Gender	Men	297	2.76 ± 1.06
	Women	210	2.76 ± 1.01
Education	Elementary and high school	222	2.80 ± 1.08
	University	233	2.67 ± 1.03
Awareness*	Yes	309	2.52 ± 0.99
	No	146	3.18 ± 1.07

* Respondents who were unsure (n = 135) about awareness of the system are de-selected for these calculations, respondents who indicated unsure for questions in 2.2.4, general attitudes towards hydroponics are also de-selected (n = 353).

3.4. The impact of food neophobia, connectedness to nature, belief in climate change and age on the willingness to eat food produced in a hydroponic system by using mineral fertilisers or food waste as a fertiliser

To explore differences between a mineral fertiliser and a food waste system in relation to the willingness to eat (Want to eat | Do not want to eat) food produced in such a system, linear regression was calculated; the results are presented in Table 4. The willingness to eat food produced in a mineral fertiliser system was only significantly predicted by climate change. This suggests that the willingness to eat vegetables produced in the mineral fertiliser system is higher among consumers believing in climate change. The result for the food waste system illustrates a significant prediction, by both food neophobia and climate change, suggesting that a higher degree of food neophobia has a negative impact on the willingness to eat, and conviction of climate change has a positive impact in the food waste system. Age was additionally explored, mainly due to the finding in 3.2 explaining that attitudes towards hydroponics did increase with age. Interestingly the result for food waste did also show a significant prediction. However, here it was on the contrary shown that higher age had a negative impact on willingness to eat, when using food waste. Connectedness to nature did not predict either the mineral fertiliser or the food waste system.

4. Discussion

This study analysed Swedish consumers' awareness of hydroponic cultivation systems of vegetables as well as attitudes and beliefs towards two different fertilisation strategies, using mineral origin or food waste. A range of factors were explored, including socio-demographic variables, food neophobia, connectedness to nature and awareness of climate change. Findings are expected to provide input to the level of awareness of hydroponics among consumers and the understanding of what consumers see as positive and/or negative with eating vegetables from either the dominant fertilising system (mineral origin) or a more circular system, using food waste instead. This knowledge is important in adopting food waste as a fertiliser and thus accelerates a transformation of the dominant mineral use regime towards a sustainable circular food system, through linking cultivation to the household food waste system.

The findings of the study indicate that less than half of the respondents were aware of hydroponics, with no differences depending on gender or age. However, education turned out to be a predictor, suggesting that a higher education was linked to greater awareness. For attitudes, the results show no difference depending on gender or level of education; however, there was a slightly more positive attitude among older respondents and a more positive attitude among those who had not heard about hydroponic systems before. Turning to differences in attitudes and beliefs towards the two different fertilising strategies, food waste was regarded as significantly more natural, more environmentally friendly, exciting, the future, energy efficient, innovative, and positive overall. Food neophobia only (negatively) predicted the willingness to eat food with input from food waste, whereas connectedness to nature did not predict the willingness to eat vegetables from any of the two fertilising systems. Finally, the results show that a belief in climate change had a positive impact on the willingness to eat vegetables from both fertilising systems.

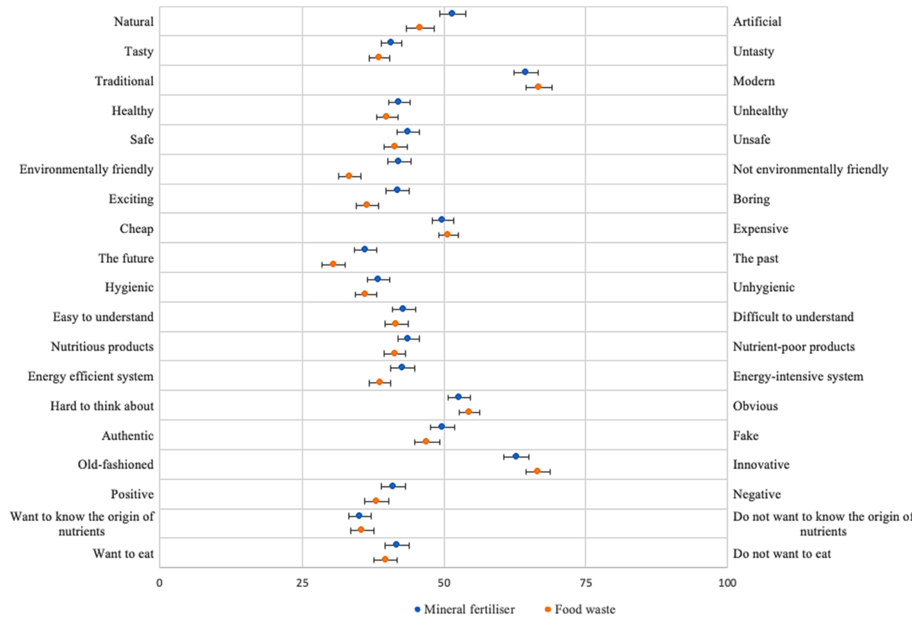

Fig. 4. Differences in attitudes and beliefs towards using a linear system (mineral fertilisers) and a circular system (using food waste). Semantic differentials (mean values with 95% confidence intervals) for the two different production systems are presented.

Table 4
Result of linear regression analysis for the willingness to eat food produced by using mineral fertilisers or food waste in relation to the impact of food neophobia, connectedness to nature, conviction of climate change and age.

	Mineral fertiliser					Food waste				
	B	SE	Beta	*t*	*p*	*B*	SE	Beta	*t*	*p*
(constant)	49.29	7.46		6.61	0.000	33.26	7.22		4.60	0.000
Food neophobia	1.34	1.03	0.06	1.30	0.19	4.00	0.99	0.18	4.04	0.000
Connectedness to nature	0.24	1.50	0.01	0.16	0.88	1.35	1.41	0.04	0.96	0.34
Climate conviction	−5.43	1.39	−0.19	−3.91	0.000	−5.30	1.32	−0.18	−4.03	0.000
Age	0.11	0.06	0.08	1.79	0.07	0.13	0.06	0.10	2.19	0.03

Since hydroponics is the dominating production system for almost all tomatoes, salads and herbs grown and/or sold in Swedish supermarkets, it may seem a bit surprising that more than 50 per cent of the respondents were unsure about or had no awareness of hydroponic systems. However, similar findings have been reported for Denmark, with 51 % familiarity (for vertical farming) (Perambalam et al., 2021) and the US, with 49 % (slightly or not at all familiar with hydroponics) (Gilmour et al., 2019). Taken together, the result presented for Sweden is presumably not unique; rather, it indicates a general state for consumer awareness of hydroponics in a broader sense. When searching for possible explanations, it could be argued that this finding corroborates the understanding that consumers, in general, have quite a restricted knowledge of nutrition and food production (Song et al., 2022). It should also be considered that the main drivers of why consumers buy vegetables are largely related to health, nutrition and taste (Song et al., 2022) and not the specific production system. It can also be assumed that the fairly low awareness of hydroponics is a result of the relative novelty of the system, compared to more traditional cultivation in soil. However, it is also clear that hydroponics is presently gaining quite a lot of media attention and interest among consumers as well as commercial actors. Which in turn is manifested through a rather rapid implementation of commercial vertical hydroponic systems in, e.g. Sweden and other European countries. This ongoing change could, by extension, mean that there is an increasing awareness of the technology. However, for the time being, the results of the study show that for more than half of the consumers, there appears to be a gap between how consumers believe that vegetables are grown and reality.

Looking at attitudes towards hydroponics, it was interesting to see that among those with previous knowledge, attitudes were more within the neutral spectra (2.52) compared to those with no previous awareness, expressing a significantly more positive attitude (3.18). The findings, thus, suggest that those who learned about the system during the survey expressed a significantly more positive attitude compared to those who knew about the system prior to the survey. One possible answer could be that among those who believed that they knew about the system the explanation given diverged from their understanding of the system, which lead to a less positive result. This finding is still difficult to explain, and it is suggested that interviews with consumers would probably be a relevant future path to take to get an understanding of underlying factors.

Taking into consideration that hydroponics is a cultivation system that builds on technology, the result that neither awareness nor attitudes towards hydroponics differ depending on gender contradicts findings by Lyndhurst (2009), Gaskell et al. (2010), Aschemann-Witzel and Peschel (2019) and Spendrup et al. (2021) who all identified a more positive attitude among men. Instead, the presented result suggests that hydroponics is a food technology where the expected attitude gender gap appears to be absent. The outcome also suggests that attitudes towards hydroponics did increase (positively) with age, which contradicts findings by Lyndhurst (2009) who, instead, found that older persons are more likely to be concerned about novel food technology. The finding that awareness was greater among those with a higher education corroborates findings by Giacalone and Jaeger (2023), but it was most unexpected that the result revealed no significant difference in attitude depending on education. Education, thus, seems to be of importance when it comes to awareness of hydroponics, yet not for attitudes.

When turning to the measurement of attitudes and beliefs structured through the pairs of adjectives (see Fig. 4), the result illustrate hydroponic systems (no differences between the two fertilisation strategies) to produce tasty, modern, healthy, safe, hygienic, nutritious, food in a system that is easy to understand, where they want to know the origin of the nutrients, and want to eat what is produced. This result points to a generally positive image among consumers and supports previous findings explaining that hydroponics represents technologies with high consumer acceptance (Giacalone & Jaeger, 2023).

When examining the result looking into differences between the two fertilising strategies, consumers attitudes and beliefs towards the food waste system are more associated with several qualities associated with sustainability and circularity: more natural, more environmentally friendly, exciting, the future, energy efficient, innovative and positive. The fact that younger consumers express a higher willingness to eat food from a food waste system is interesting and suggest that acceptance for such solutions may be higher among younger persons. The finding that food neophobia only (negatively) predicted the willingness to eat food with input from food waste is in line with previous findings (Coderoni & Perito, 2020; Hellali and Korai, 2023) and highlights the issue of further addressing these matters.

Surprisingly, the expected impact of connectedness to nature (CtN) on the willingness to eat food grown using the food waste fertilisation system was not evident. However, it was found that, among those believing in climate change, as well as the link between food and climate, consumers expressed a significantly higher willingness to eat food produced with the input of food waste. These two results for food waste may, thus, seem to contradict each other, but it could also be interpreted as a finding that even though one is convinced of climate change, this does not automatically mean that you also experience a high connectedness to nature. The absent link to CtN could be explained by findings presented by Cavaliere and Ventura (2018) who saw that consumers characterised by high sustainability concerns fail to recognise, in science and technology, a possible contribution to sustainability. Similar findings were also reported by Hellali and Korai (2023), who found a negative association between the level of innovation and perceived usefulness. Meaning that as the innovation increased, respondents were seen to be less likely to perceive the food technology to address the problem of food waste. Nonetheless, it is worth highlighting the result that a belief in climate change did, irrespective of fertilisation strategy, result in the finding that hydroponics did produce vegetables that consumers would like to eat. Ergo, among consumers who believe in climate change, hydroponics produces vegetables they would like to eat.

One limitation of the study is that we did not explore consumer willingness to eat actual products (vegetables grown in the two different fertilisation systems). It is highly recommended that future studies take on such an approach in combination with interviews, to get a deeper understanding of the underlying motives and arguments. The framing of the concept "food waste" should also be further explored to get an understanding of associations towards the concept, as well as alternative descriptions, e.g. upcycled and circular. It could also be argued that the design of our study should have included additional aspects such as e.g. naturalness and more explicit acceptance of new technology (Siegrist, 2008) to also grasp these matters. One future line of thought is, thus, to explore if it is the actual technology (hydroponics) that hinders consumers from experiencing a high CtN to express a positive attitude towards hydroponics. Arguing that such a technology is perceived as contradictory in relation to sustainability aspects. It is also suggested that future studies should explore how to frame food waste to increase acceptance within this specific food neophobic consumer group. In addition, it would also be of interest to pre-test the descriptions used in the study, to explore whether these descriptions are in line with how consumers believe that these systems function, or not.

Finally, food waste from households may decrease due to the new household behaviours as well as competition from other systems and technologies that want to use food waste as a resource. In a long-term perspective, the food waste collected from the households and used for biogas production will ideally mainly be composed of unavoidable parts such as peels, bones and coffee grounds. This could indicate a future scenario where food waste is less available and possibly also more expensive to use. However, from 2024 separation of food waste will be mandatory in the whole EU and the volumes can be expected to increase in the coming years (Regeringskansliet, 2023). If a lack of food waste becomes a reality in the longer perspective, questions about which future area of use is best suited, from a sustainability perspective, arise. The current scenario where food waste, combined with other organic wastes, are anaerobically digested to produce energy and plant nutrients is well adapted to the circular society and can be expected to be competitive also in the long-term perspective.

5. Conclusions

One could argue that the lack of awareness of hydroponics is not a problem; apparently, consumers still buy healthy and sustainable vegetables. Yet the problem may arise when climate change, increasing populations and urbanisation require increased technical solutions and transformation of the food system. A change that could imply an even more technology-dependent food system, relying on e.g. hydroponics as well as emerging plant factories and vertical farming. If these systems collide with how consumers believe that safe and sustainable greenhouse vegetables are grown, a situation may emerge with strong consumer non-acceptance. Nonetheless, the results of our study underline that there is, generally, a high consumer acceptance of hydroponics.

The newness, and at times unawareness, of the system, may also suggest good opportunities to have an influence on consumer opinions. Especially since the results of the study show that hydroponics is associated to a great variety of positive attitudes and beliefs, such as tasty, modern, healthy, safe, hygienic, nutritious, easy to understand, a system where you want to know the origin of the nutrients and that it produces vegetables that consumers want to eat. In addition, the result for the circular system (building on the use of food waste) is explained to be linked to qualities such as more natural, more environmentally friendly, exciting, the future, energy efficient and innovative. This study thus contributes with several findings that can be used to communicate positive qualities with not only hydroponics but also the use of food waste as a fertiliser, closely linked to environmental and health benefits. It is thus suggested that stakeholders within the horticultural and hydroponic sector investigate the opportunity of using these concepts in raising awareness of hydroponics and circular systems as well as when marketing the products.

CRediT authorship contribution statement

Sara Spendrup: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Karl-Johan Bergstrand:** Writing – review & editing. **Rebecca Thörning:** Visualization, Writing – review & editing. **Malin Hultberg:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Differences in attitudes and beliefs towards using a mineral fertiliser or food waste as a fertiliser, separated on the 12 semantic differentials (mean values with 95 % confidence intervals).

	Linear			Circular		
	Mean	Low	high	Mean	Low	High
Natural | Artificial	51.55	49.12	53.98	45.87	43.60	48.15
Tasty | Untasty	40.75	38.94	42.55	38.67	36.87	40.48
Traditional |Modern	64.45	62.18	66.71	66.72	64.60	68.85
Healthy | Unhealthy	42.10	40.22	43.98	39.98	38.09	41.88
Safe | Unsafe	43.66	41.61	45.71	41.41	39.48	43.35
Environmentally friendly | Not environmentally friendly	42.13	40.11	44.15	33.39	31.34	35.44
Exciting | Boring	41.83	39.84	43.81	36.52	34.47	38.57
Cheap | Expensive	49.80	48.06	51.54	50.78	48.92	52.65
The future | The past	36.18	34.15	38.21	30.53	28.55	32.50
Hygienic | Unhygienic	38.48	36.64	40.33	36.23	34.30	38.16
Easy to understand | Difficult to understand	42.94	40.88	45.00	41.64	39.53	43.75
Nutritious products | Nutrient-poor products	43.73	41.82	45.64	41.36	39.45	43.27
Energy efficient system| Energy-intensive systems	42.67	40.79	44.56	38.74	36.64	40.84
Hard to think about| Obvious	52.70	50.88	54.52	54.53	52.51	56.55
Authentic | Fake	49.72	47.51	51.94	47.01	44.83	49.20
Old-fashioned | Innovative	62.77	60.61	64.92	66.59	64.38	68.80
Positive | Negative	41.10	38.97	43.24	38.08	35.94	40.22
Want to know the origin of nutrients | Do not want to know the origin of nutrients	35.14	33.06	37.21	35.55	33.55	37.59
Want to eat | Do not want to eat	41.74	39.63	43.85	39.68	37.55	41.80

Independent t-tests for the two groups and the 19 pairs of adjectives.

	Linear Mean	Circular Mean
Natural | Artificial	51.55 ± 27.47	45.87 ± 25.93*0.001
Tasty | Untasty	40.75 ± 20.39	38.67 ± 20.58n
Traditional |Modern	64.45 ± 25.62	66.72 ± 24.23n
Healthy | Unhealthy	42.10 ± 21.27	39.98 ± 21.63n
Safe | Unsafe	43.66 ± 23.15	41.41 ± 22.10n
Environmentally friendly | Not environmentally friendly	42.13 ± 22.82	33.39 ± 23.39*.001
Exciting | Boring	41.83 ± 22.43	36.52 ± 23.38*.001
Cheap | Expensive	49.80 ± 19.63	50.78 ± 21.26n
The future | The past	36.18 ± 22.94	30.53 ± 22.52*.001
Hygienic | Unhygienic	38.48 ± 20.83	36.23 ± 22.01n
Easy to understand | Difficult to understand	42.94 ± 23.32	41.64 ± 24.07n
Nutritious products | Nutrient-poor products	43.73 ± 21.56	41.36 ± 21.77n
Energy efficient system| Energy-intensive systems	42.67 ± 21.32	38.74 ± 23.97*.006
Hard to think about| Obvious	52.70 ± 20.53	54.53 ± 23.05n
Authentic | Fake	49.72 ± 25.03	47.01 ± 24.96n
Old-fashioned | Innovative	62.77 ± 24.37	66.59 ± 25.21*.02
Positive | Negative	41.10 ± 24.16	38.08 ± 24.40*.05
Want to know the origin of nutrients | Do not want to know the origin of nutrients	35.14 ± 23.47	35.55 ± 23.25n
Want to eat | Do not want to eat	41.74 ± 23.86	39.68 ± 24.26n

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