Agriculture and Human Values
https://doi.org/10.1007/s10460-021-10261-7

Perceptions of high-tech controlled environment agriculture among local food consumers: using interviews to explore sense-making and connections to good food

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Accepted: 12 August 2021

Abstract

In recent years, new forms of high-tech controlled environment agriculture (CEA) have received increased attention and investment. These systems integrate a suite of technologies – including automation, LED lighting, vertical plant stacking, and hydroponic fertilization – to allow for greater control of temperature, humidity, carbon dioxide, oxygen, and light in an enclosed growing environment. Proponents insist that CEA can produce sustainable, nutritious, and tasty local food, particularly for the cities of the future. At the same time, a variety of critics raise concerns about its environmental impacts and energy use, high startup costs, and consumer accessibility challenges, among other issues. At this stage, however, relatively little research has explored actual consumer knowledge and attitudes related to CEA processes and products. Guided by theories of sense-making, this article draws from structured interviews with local food consumers in New York City to examine what people know and think about high-tech CEA. From there, it explores the extent to which CEA fits into consumer conceptualizations of what makes for "good food." Key findings emphasize that significant gaps in public understanding of CEA remain, that CEA products' success will depend on the ability of the industry to deliver on its environmental promises, and that concerns about "unnatural" aspects of CEA will need to be allayed. Given the price premium at which high-tech CEA products are currently sold, the industry's expansion will depend in large part on its ability to convince value-oriented food consumers that the products meet the triple-bottom-line of economic, social, and environmental sustainability goals.

Keywords Controlled environment agriculture · Hydroponics · Urban agriculture · Consumer perceptions · Sense-making · Local food

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Abbreviations

CEA	Controlled environment agriculture
GM	Genetically modified
GMO	Genetically modified organism
LED	Light emmiting diode

Introduction

Pointing to a host of potential agricultural, environmental, economic, and social benefits, proponents of high-tech forms of controlled environment agriculture (CEA) argue that such systems will play an important role in the future of food production (Despommier 2010; Kozai et al. 2015; Benke and Tomkins 2017). Various forms of "protected agriculture" that extend the growing season and insulate crops from external pressures have been practiced for thousands of years, with accounts of such practices dating back to ancient Greece, Rome, and Japan, among

Published online: 25 August 2021

other regions. Greenhouses, which allow sunlight to enter through a transparent roof, have been used in commercial crop production since at least the mid-twentieth century (Jensen 1999). Today, new forms of CEA integrate a suite of novel technologies and growing approaches – including digital automation tools, LED lighting, vertical plant stacking, and hydroponic fertilization—as a way to allow for total control of the temperature, humidity, carbon dioxide, oxygen, nutrients, and light in an enclosed growing environment (Rorabaugh 2015).

Despite an increase in attention and investment directed at high-tech CEA, relatively little research has explored consumer knowledge and attitudes related to this form of production (Ercilla-Montserrat et al. 2019; Jürkenbeck et al. 2019). Elsewhere, however, a significant body of recent scholarship has identified increased consumer interest in "good food," that which is not only affordable, nutritious, and tasty, but also promotes values of sustainability and local economic development (Feldmann and Hamm 2015). Additional research has shown that many consumers express concern about food production practices that are deemed overly technological or "unnatural" (Ronteltap et al. 2007; Lusk et al. 2014). Interestingly, proponents of high-tech CEA seem to attempt to thread this needle: they promote their methods as both high-tech and capable of generating "good food" for people and the planet, pitching a type of "techno-local food" as central to their imagined urban and peri-urban food system futures (Specht et al. 2014; Rangarajan and Riordan 2019; Broad 2020).

Guided by theories of sense-making (Dervin 1998; Woodside 2001; Golob 2018), this article draws from structured interviews with local food consumers in New York City to examine what people know and think about high-tech CEA. From there, it explores the extent to which CEA fits into consumer conceptualizations of what makes for "good food." Key research questions assess existing consumer attitudes about CEA systems and products, as well as explore what value judgments respondents offer when presented with both supportive and critical information about the enterprise. The research contributes to a growing body of social science literature that explores the implications of digitalization in agriculture, particularly high-tech farming within the urban and peri-urban context (Klerkx et al. 2019; Carolan 2020). In addition, this article builds upon recent scholarship that raises important questions about the factors that might promote or constrain consumer acceptance of new food technologies (Specht et al. 2019). It offers insights for scholars and market actors interested in CEA's role in the future of food production and consumption, identifying both opportunities and potential barriers for expansion.

On CEA as a technology and industry

Consumers already purchase a variety of agricultural products cultivated via different forms of protected agriculture, with greenhouses being the most common. According to data from the Cuesta Roble consulting firm, in 1980, global greenhouse vegetable cultivation covered 150,000 ha. (371,000 acres), increasing to 496,800 ha. (1,228,000 acres) by 2019. Tomatoes and cucumbers are the most common vegetables grown in greenhouses, while lettuce, herbs, bell peppers, eggplant, and strawberries are also popular crops (Walker and Joukhadar 2019). In 2012, the global market for greenhouse vegetable production was estimated at nearly $350 billion (Kopf 2017). CEA systems use a variety of growing media, including soil and soil-less alternatives. In soil-less hydroponic systems, plants are grown in nutrient solutions (water and fertilizers) with or without the use of a soil-less medium (such as perlite or peat moss) to provide mechanical support (Jensen 1999). Approximately two-thirds of the US sales of agricultural products grown via protected agriculture currently come from hydroponic systems, while the global hydroponic system market is projected to grow from $8.1 billion in 2019 to $16 billion by 2025 (Lensing 2018; Markets and Markets 2019).

Generally speaking, hydroponic CEA systems are touted as offering a variety of advantages to traditional field agriculture, which include, "high-density maximum crop yield, crop production where no suitable soil exists, a virtual indifference to ambient temperature and seasonality, more efficient use of water and fertilizers, minimal use of land area, and suitability for mechanization and disease control" (Jensen 1999, p.7). Recent years have also seen the advancement of other related forms of plant cultivation – including aeroponics (which is similar to hydroponics, but feeds nutrients to the roots of plants via a mist rather than submersion), as well as aquaponics (in which fish and plants are grown in a coupled or decoupled system, and the fish waste is used to fertilize the plants) (Kagan and Riemenschneider 2018). Indoor vertical farms represent a novel high-tech form of CEA: here, plants are grown inside a building and stacked across multiple levels; programmable LED lights provide illumination; air temperature and humidity can be controlled; and recycled water systems connect to hydroponic plant-feeding systems. Advocates argue that high-tech CEA offers the opportunity for the efficient production of sustainable, nutritious, and accessible local foods, even in areas that were previously unsuitable for growing these foods.

Many predict that urban residents, in particular, will come to embrace high-tech CEA products and systems in the decades ahead. The argument follows that CEA

production could make productive use of urban and peri-urban spaces – such as former industrial facilities, basements, and rooftops – while meeting growing urban consumer demand for fresh, local produce (Despommier 2010; Specht et al. 2014; Kozai et al. 2015; Benke and Tomkins 2017). As one example of this link, research into social media posts about vertical farming shows that public discussion and consumer marketing on the topic co-occurs most often with posts about urban farming (Waller and Gugganig 2021). Further, CEA entrepreneurs themselves often describe their technological solutions in terms of urban agriculture (Broad 2020). The New York-based firm Agritecture Consulting, for example, calls its team "global leaders in urban agriculture" while touting a portfolio of CEA projects and co-authoring an annual Global CEA Census (Agritecture n.d.).

Hundreds of millions of dollars have been invested into CEA technology and urban-based CEA companies around the world in just the last few years (Burwood-Taylor 2019). Meanwhile, a variety of people with interests in food, technology, and entrepreneurship have rushed to get involved. The 2020 Global CEA Census, conducted annually by the agricultural technology company Autogrow and Agritecture Consulting, showed that much of this involvement has come from young founders with little to no agricultural experience. Many of the new companies are focused on growing vegetable greens and herbs inside vertical farms and high-tech greenhouses in urban and peri-urban areas; census respondents point to the need to raise capital funds, scale business to maximize profits, and integrate automation to reduce labor costs as key industry challenges (Autogrow and Agritecture 2020).

At the same time, a variety of CEA critics have emerged, raising concerns about its environmental impacts and energy use, high startup costs, and unforeseen pest control issues. Related critiques have called into question the nutritional value of CEA produce, its price point and related accessibility concerns, the opportunity costs of expanding CEA at the expense of promoting soil health or community-based urban farming, its potential role as a force for urban gentrification, and problems of consumer acceptance, among other issues (Specht et al. 2014; Mattson et al. 2015; Goodman and Minner 2019; Carolan 2020; Nicholson et al. 2020). In this current study, we do not endorse either the most optimistic or pessimistic perspectives on the potential of CEA, but instead focus on what consumers perceive it to be.

To date, a relatively limited body of research has examined public perceptions of foods grown via CEA, particularly in the United States, where the industry is experiencing significant growth. Several studies have assessed how key food system stakeholders – including food system researchers, activists and practitioners, and designers and policymakers – evaluate the risks and benefits of rooftop gardens, rooftop greenhouses, and indoor farms in urban areas. Specht and Siebert et al. (2016a) found that perceived benefits among German stakeholders included education, consumer awareness, resource savings, and the repurposing of abandoned or blighted buildings; potential risks included concerns that the growing techniques are "unnatural," too expensive, or overly complex. Sanyé-Mengual et al. (2016), as well as Specht and Sanyé-Mengual (2017), added Spanish stakeholders to their sample and found similar concerns. There, respondents argued that urban CEA could conflict with existing images of "natural" agriculture and modern urban life, promote gentrification, create health and environmental risks, and provide little economic benefit. Soilless techniques for increasing crop yields were received with particular skepticism. Several stakeholders criticized these as unnatural, detached from the land, overly dependent on expensive technology, and providing low-quality products. Sanyé-Mengual et al. (2020) also surveyed a mix of urban agriculture project leaders, key stakeholders, and the general public in Italy to assess their perceptions of the ecosystem services performed by different types of urban agriculture. Compared to high-tech greenhouses, peri-urban farms, community-supported agriculture projects, community rooftop gardens, and urban co-ops, indoor farms were found to have the lowest perceived ecosystem-service contributions across the categories of socio-cultural benefits, food provisioning, climate and environmental regulation, and habitat.

A few studies have focused primarily on consumer perceptions of vertical CEA products and systems. Coyle and Ellison (2017) conducted a willingness-to-pay experiment in which respondents in the United States were asked to rate lettuce grown through field farming, greenhouse farming, and vertical farming. In terms of willingness to pay, perceived safety, and expected quality of produce, all three systems were ranked similarly. Vertical farming was the least likely to be purchased by consumers, and it was also perceived as the least natural, particularly when respondents were given additional information about how vertical farming works. Knowledge of vertical farming was also significantly lower than greenhouse and field farming.

Elsewhere, Jürkenbeck et al. (2019) conducted an online survey with German consumers, the vast majority of whom reported minimal knowledge of vertical farming. The analysis found that, among consumers who expressed support for vertical farming, perceived sustainability benefits were the primary driver of acceptance. In that sample, a slight majority rejected the contention that vertical farming systems were "too artificial." Specht and Weith et al. (2016b) recruited survey participants from public spaces across Berlin to explore their perceptions of different forms of urban agriculture. They found that consumers were less accepting of urban farming as a use of public space when it was associated with intensive

or high-tech forms of agriculture (including agroparks, aquaponics, and vertical farming) as compared with systems considered more low-tech or consistent with traditional images of horticultural production.

Ercilla-Montserrat et al. (2019) surveyed consumers' perceptions of tomatoes grown in urban rooftop gardens using soil-less systems in Barcelona, varying the level of information provided to participants regarding how the tomatoes were produced. The results showed generally positive responses for both the quality of the product and the growing system across the experimental conditions. Given the opportunity to offer open-ended feedback, some respondents did raise questions about food safety, potential heavy metal contamination, the use of organic practices in soil-less production, as well as the broader social and environmental impacts of these growing practices.

Several other studies have explored consumer perceptions of aquaponics systems, specifically, finding that a majority of respondents were not familiar with aquaponics, and that additional information about the system had mostly neutral impacts on their attitudes and willingness to pay more for the products (Short et al. 2017, 2018). A survey across 16 European countries found that awareness of aquaponics was well below that of hydroponics, and while attitudes toward aquaponics were generally positive, willingness to pay was primarily based on price, as well as whether the products were free of antibiotics, pesticides, and herbicides. That research also concluded that the most likely consumers of aquaponics products are consumers who already value organic and local produce (Miličić et al. 2017).

In general, prior research has argued that urban agricultural projects with less novel products, production practices, and design are viewed more favorably by stakeholders (Specht and Weith et al. 2016b). In order to court consumer acceptance, the scholarship suggests, the environmental sustainability of high-tech CEA farming practices needs to be improved and verified (Sanyé-Mengual et al. 2020), the products should not be solely targeted to elite consumers (Specht and Siebert et al. 2016a), and concerns about land use and development implications should be taken into consideration (Carolan 2020). In addition, countries and regions whose populations have higher technology appreciation and more urgent problems related to land and water scarcity might prove particularly amenable to CEA (Specht et al. 2019). Despite this growing body of scholarship, it is clear that more research is needed to understand how potential consumers make sense of new innovations in CEA, particularly in the United States, and to situate that understanding within broader scholarship on consumer attitudes, food preferences, and values.

On "good food"

Consumers' food choices are motivated by a set of intersecting factors – including the physiological need to satiate hunger, pleasure and other emotional states, external food cues such as smell and appearance, social dynamics, price, convenience, health, and other value-related motives (Renner et al. 2012). The priorities of safety, nutrition, taste, and price have been found to be among the most important to consumers on average, but responses vary widely. Other factors, such as perceived naturalness, convenience, appearance, environmental impacts, fair labor practices, tradition, and food origin also play a role for some consumers (Lusk and Briggeman 2009). When it comes to the acceptance of technology-based food innovations, specifically, Ronteltap et al. (2007) argue that distal factors (characteristics of the innovation, the consumer, and the social system in which they are embedded) influence the proximal factors (perceived costs and benefits, risks and uncertainties, social norms, and perceived behavioral control) that determine consumer intentions and decisions. They add that communication serves an important means for linking innovation features to consumer perceptions, and that communication may need to be tailored depending on the food-oriented priorities and perceptions of the consumer segment toward which the innovation is targeted.

Recent years have seen increased public discussion about the very nature of what makes for good food. The dominant industrial food system has been criticized by a variety of scholars, practitioners, activists, and consumers for a number of perceived environmental, economic, ethical, and nutritional deficiencies. Collectively, these critics have often self-identified as part of an "alternative food movement" or, in other instances, the "good food movement" (Broad 2016; Alkon and Guthman 2017). Across a diverse range of producers, consumers, and advocates of good food, common values articulated include a focus on supporting local economies, healthy nutrition, fair labor practices, environmental sustainability, and animal welfare (Center for Good Food Purchasing n.d.; Porter et al. 2017). Notably, there is significant debate as to whether such a diffuse set of initiatives could qualify as a legitimate social movement, whether it might be better classified as a "lifestyle movement," or whether it is simply a consumer trend (Alkon and Guthman 2017; Haenfler et al. 2012).

Regardless, it is clear that advocacy and market action in support of these "good food" principles – often understood to incorporate local, organic, sustainable, "clean," and "real" foods, among other official and unofficial labels – has pushed many consumers to take into account additional value-oriented considerations when deciding what foods are good to eat (Feldmann and Hamm 2015; Asioli et al. 2017; Porter et al. 2017). Most research describes the typical good food

consumer as a highly educated, financially comfortable, and politically active "green" shopper (Schoolman 2020). Generally speaking, many of the same values motivate consumer preferences for organic and local foods, although some distinctions can be identified (Ditlevsen et al. 2020). As the key reasons for purchasing organic foods, specifically, consumers are likely to cite environmental and health benefits that come with the avoidance of pesticides and hormones, while they also express concerns about the environmental and health impacts of genetically modified (GM) foods (Zepeda and Deal 2009; Funk and Kennedy 2016). Among local food consumers, food quality, food safety, and health benefits are cited as primary values. There is significant evidence, as well, that local food consumers of varied economic status aim to promote civic values associated with supporting local farmers and economies, as well as maintaining local farmland (DeLind 2002; Onozaka et al. 2010; Lyson 2012; Schoolman 2020).

Among those who seek out "clean" food labels, intrinsic properties such as nutrition, health promotion, and sensory attributes are combined with extrinsic qualities such as product sustainability, labels, and certification to influence purchasing decisions (Asioli et al. 2017). A focus on natural foods, and concern about foods deemed unnatural and overly technological, plays a significant role across this and other categories (Lusk et al. 2014). The increased interest in these food qualities and values can be seen in recent purchasing data: organic food sales in the United States reached a record high of $47.9 billion in 2018, up from $21.3 billion in 2009 (Organic Trade Association 2019), while the local food market in the US went from approximately $5 billion in 2008 to $12 billion in 2014, with the total US market value estimated to be well over $20 billion as of 2020 (Stone 2018).

The good food movement has not been without its critics, coming from multiple angles. A number of scholars have argued that the mainstream of the movement has been too consumer-oriented, politically limited, elitist, and racially exclusive (Guthman 2008; Broad 2016; Garth and Reese 2020). Others have criticized the approach for being "retrogressive" in its, "call to eat slower, more natural, organic, and local food," ignoring the value of technological innovation for both producers and consumers (Lusk 2016, p.8). Within this context, the question of whether consumers will consider the process and products of high-tech CEA to be aligned with "good food," as many of the industry's proponents hope and expect they will, becomes particularly relevant.

On sense-making and CEA as good food

As outlined above, boosters of new, high-tech forms of CEA argue that their products represent the sustainable, nutritious, and tasty local food of the future (Despommier 2010; Benke and Tomkins 2017; Broad 2020). In this respect, they are banking on the idea that a consumer market increasingly interested in eating products that exhibit intrinsic and extrinsic good food qualities will come to incorporate CEA's "techno-local food" into that conceptualization. However, there are a number of reasons why this may not be the case. As several recent studies have outlined, some of the big promises of commercial CEA have not yet come to fruition (Goodman and Minner 2019; Nicholson et al. 2020). Indeed, since low-biomass and relatively high-priced produce (on a per calorie basis) such as leafy greens and herbs are the most economically feasible to grow at this stage, CEA has done little to improve nutritional outcomes or food security. While the systems do present some potential environmental benefits – including reductions in water use, pesticides, and transport-related greenhouse gas emissions, as well as the ability to grow a wide range of greens and herbs from heirloom seeds – there remain high energy costs associated with the enterprise, limited reductions in global warming potential, as well as significant debate about its other purported environmental merits. Perhaps not surprisingly, these points of contestation are often left out of the rhetoric of many high-tech CEA advocates (Broad 2020; Waller and Gugganig 2021).

Further, the high-tech nature of CEA appears to contrast many of the low-tech and perceived "natural" solutions that have come to characterize the good food consumer movement. Innovative technologies in the food and agricultural sectors are often met with skepticism among the public. Several of the new digital farming technologies developed in recent years – for instance, sensors, automation, and robots in production systems – have been met with ambivalence, as consumers may appreciate their potential contributions to efficiency and sustainability, but worry about how these technologies may contribute to a loss of agrarian values, traditions, and naturalness (Pfeiffer et al. 2020). It is no surprise, then, that the November 2017 decision by the National Organic Standards Board to allow soil-less hydroponic produce to be certified as USDA Organic was met with significant resistance from those who believe organics should necessarily be soil-based and work to actively build healthy soil (Kagan and Riemenschneider 2018).

The question of how potential consumers understand the nature, benefits, and risks of CEA, as well as how that understanding connects to existing notions of good food, is the primary aim of this paper. In order to explore these dynamics, we are guided by interdisciplinary scholarship on the concept of sense-making. Sense-making relates to the processes by which humans attempt to understand ambiguous and puzzling issues and events, as well how they bridge the gaps between conflicting realities (Dervin 1998; Golob 2018). Early sense-making research emphasized the human capacity to accurately perceive what is

transmitted via the senses, but more contemporary scholarship has aimed to expand the concept beyond this focus on cognition and accuracy. As Dervin and Naumer (2009) explain, this research focuses on, "how sensing can be assumed to involve processes of communicative engagement – intrapersonal, interpersonal, group organization, and societal," such that it moves beyond a focus on individual perceptual processes to, "redefine sense-making not merely as interpretation, but as dialogue, both internal and external" (p. 877). Or, as Woodside (2001) defines it, sense-making is, "meaning creation based on current and prior interpretations of thoughts generated from three sources: external stimuli, focused retrieval from internal memory, and seemingly random foci in working memory," adding that, "such sense making is constructed on cultural pilings held unconsciously in long-term memory" (p. 415).

Methodologically, then, the goal in sense-making research is to use qualitative or quantitative methods to examine the varied frameworks, schemas, representations, and/or mental maps upon which sense-making is built (Dervin and Naumer 2009). The approach has been put to use previously by scholars interested in food systems and the values of food consumers. Hilverda et al. (2017) noted that sense-making takes place when people receive information about the risks and benefits of particular foods. Those researchers ran an online interaction experiment to explore how message-framing about organic foods catalyzed sense-making and influenced perceptions. Several recent studies have used sense-making as a framework to investigate how people come to understand novel food technologies, including cell-based/cultured meat (Marcu et al. 2015; Stephens et al. 2019). In these studies, sense-making concepts were used to explore the constellation of factors that shape or assert how the new food products should be understood, as well as to identify the analogies, metaphors, and other conceptual connections that lay respondents make when asked to engage with the topic. Elsewhere, the concept of sense-making has been integrated into other qualitative explorations of dietary lifestyles and knowledge construction related to food. For instance, researchers have examined sense-making in the context of vegan identity (Costa et al. 2019), as well as investigated the construction of "common sense" related to "natural foods" (Kooijmans and Flores-Palacios 2014). Pfeiffer et al. (2020) showed pictures of digital farming technologies to gather spontaneous associations from respondents, arguing that qualitative approaches in this vein offer valuable contributions to measuring and understanding consumer acceptance in food and agriculture. This paper follows from such previous work, using interviews with a local food consumer demographic to examine how they make sense of the emerging methods and products of high-tech CEA.

Material and methods

Recruitment, sample, and interview protocol

Based on conversations with entrepreneurs in the CEA industry, as well as analysis of CEA industry marketing materials, the research team determined that the target market for CEA products includes consumers interested in local, sustainable, and healthy fresh produce. With this in mind, interview participants were recruited at multiple locations in the New York City area where such consumers would be present. These included local farmers' markets/greenmarkets, restaurants and food halls that feature local foods, and events related to urban agriculture and sustainable foods. This targeted recruitment strategy builds upon the insight that, when examining consumer acceptance of novel foods, researchers should grant greater analytical attention to early adopters and potential early adopters as opposed to only focusing on the general population as a whole (House 2016). All aspects of the research process were approved by research team members' respective Institutional Review Boards.

In total, 45 semi-structured interviews were conducted, and a brief demographic survey was also completed by interview participants. Detailed demographic data is presented in Table 1 below. While not a random selection and clearly not representative of the US population as a whole, these demographic characteristics do align with the nation's local and organic food consumer market as identified in previous research, which has been shown to overrepresent white, young, middle-to-upper-class, educated consumers (Hauman 2015; Schoolman 2020).

Each interview followed a semi-structured protocol (see Appendix), which was collaboratively created by the research team based on the stated goals and research questions of the study, grounded in an understanding of key CEA industry debates, scholarly literature on the topic, as well as feedback from industry informants. The semi-structured interview format allows researchers to gather rich socio-cultural data about a topic by eliciting many respondents' understandings of that topic (Charmaz 2006). In this case, our respondents were primarily at events or out shopping and gave us limited time, so we focused on a narrow set of questions that asked them to consider several aspects of and claims about CEA, and we also probed for a general sense of their understanding of CEA as positive or negative. A semi-structured approach was preferred over longer unstructured interviews or participant observation approaches, as the latter would have been inconvenient for our sample and location. Likewise, a more rigidly structured approach such as a survey would have been less

Table 1 Sample demographic characteristics as self-reported by respondents

Demographic characteristics	Approximate proportion of respondents
Gender self-identification	
Female	56%
Male	42%
Non-binary identification or No answer	2%
Age	
18–29 years	33%
30–49 years	38%
50 years or older	22%
No answer	7%
Ethnic/Cultural identity	
Asian, South Asian or Pacific Islander	4%
Black or African American	2%
Hispanic or Latino	13%
White (non-Hispanic)	69%
Other or No answer	6%
Highest level of education completed	
Associate's degree, Two-year degree, or Some college	16%
Bachelor's degree	42%
Graduate or Professional degree	36%
No answer	7%
Household annual income before taxes	
Less than $25,000	7%
$25,000–$74,999	27%
$75,000–$149,000	33%
$150,000 or more	29%
No answer	13%

effective for elucidating sense-making insights that could later be compared and analyzed thematically.

The interviews lasted approximately 10–20 min and were audio recorded for subsequent transcription. Guided by the sense-making perspective, two overarching research questions asked (1) how respondents understood key terms and arguments used by CEA producers about their systems and products, and (2) what value judgments respondents made about CEA systems and products when given both supportive and critical information. Respondents were screened to ensure that they were over the age of 18 and did not work directly in the CEA industry. From there, respondents were first asked about their priorities when purchasing fresh produce. The next set of questions assessed respondents' knowledge of CEA, hydroponics, and related concepts. Key definitions and arguments in favor of CEA – related to agricultural productivity, environmental sustainability, and the value of local foods – were then offered, with respondents asked to interpret and assess these topics. Next, several critiques of CEA were offered – related to energy use, naturalness, soil health, and USDA Organic certification – with respondents asked to interpret and assess those concerns. The interview concluded by asking respondents for their overall impressions and any questions that they might have.

Analysis

Analysis of the transcribed interviews followed an adapted grounded theory approach (Charmaz 2006). First, all three members of the research team conducted a process of initial line-by-line coding with an aim to separate the data into categories and make visible respondents' processes of thinking and understanding. While the first round of coding was open-ended, it remained in conversation with the theoretical and empirical frameworks—related to understandings of good food, the CEA industry, and the process of sense-making—that the team brought with them to the analytical endeavor (Charmaz 2000). From there, the research team engaged in collaborative discussion to identify salient codes, isolate discrepancies in interpretation, and develop an in-progress codebook that could be used in the next stage of analysis. There, the team members engaged in focused coding of the transcripts, a more directed and conceptual approach in which the adequacy of existing codes was tested, and related codes were either consolidated or constructed as sub-categories. Another round of collaborative discussion followed, with the codebook updated to reflect further refinement. A final round of coding was then conducted, with two research team members responsible for coding and then reconciling their codes for each interview transcript.

At this stage, a descriptive count of identified codes was conducted as a way to use basic quantitative insights to help ground the qualitative inquiry, support pattern recognition, and promote "internal generalizability" (Maxwell 2010). These counts indicate the total number of times a code was identified across the entirety of interviews, with some codes identified multiple times within a single interview. At the end of this process, the primary codes most prominent in the data on the basis of frequency included the following, in descending order: valorizing CEA, expressing unfamiliarity with CEA, expressing ambivalence, seeking more information, evaluating evidence, valorizing local food, expressing familiarity with CEA, and valorizing food quality. In addition to these primary codes, a set of modifying category codes were also compiled, and those most prominent in the data included the following, in descending order: chemical use, freshness, hyperlocal, hydroponics, organic, aquaponics, aeroponics, naturalness, food miles, environmental impacts, and price. A visual display of the top primary codes and a full list of all primary codes can be found in Fig. 1 and Table 2 below, respectively. From there, the team engaged in collaborative concept mapping and memo-writing based on

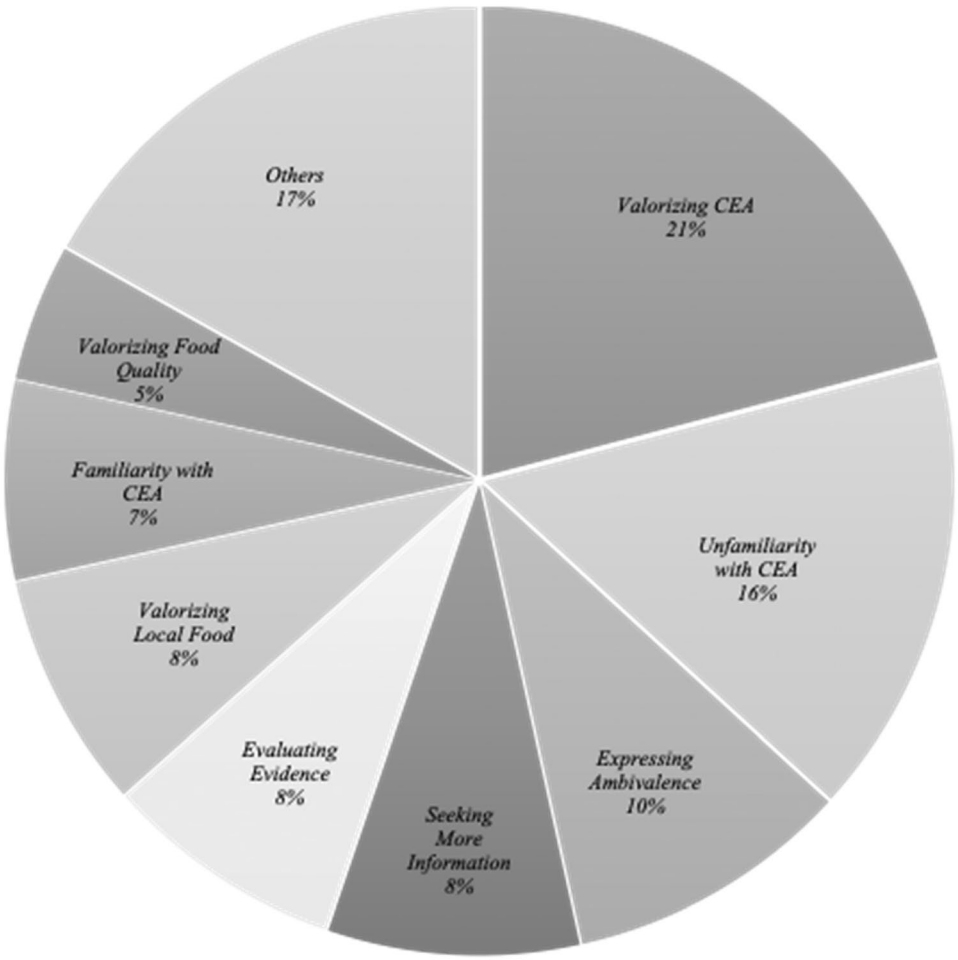

Fig. 1 Occurrences of top codes in interview transcripts as a proportion of all codes

Table 2 Occurrences of all codes in interview transcripts as number of occurrences and proportion of all codes

Code	Count	%
Valorizing CEA	165	21%
Unfamiliarity with CEA	125	16%
Expressing ambivalence	77	10%
Seeking more information	68	9%
Evaluating evidence	65	8%
Valorizing local food	64	8%
Familiarity with CEA	54	7%
Valorizing food quality	37	5%
Expressing criticism	27	3%
Valorizing organic food	27	3%
Valorizing outdoor Ag	24	3%
Conflating production practices	14	2%
Making food system connections	13	2%
Comparing regions	11	1%
Expressing disinterest	11	1%
Connecting to cannabis	6	1%
Total count: 788		

these final sets of codes and modifying categories, expanding upon their meanings and drawing analytical connections between categories and sub-categories, in conversation with relevant theory. These memos served as the foundation for the results.

Results

Following the analysis, two primary conceptual categories emerged, each of which are described in detail below: (1) Good food sense-making and (2) CEA sense-making.

Good food sense-making

The interviews revealed a range of opinions regarding what makes food "good." The analytical coding process pointed to valorizing local food, valorizing food quality, and expressing ambivalence as primary codes most frequently cited in the discussion. The top modifying category codes included references to chemical use, freshness, organics, naturalness, environmental impacts, and price. From a thematic analysis

perspective, interview respondents generally expressed a supportive sentiment regarding the core good food movement tenants of local, organic, and "real." Many respondents did initially point to freshness, convenience, and price as the primary determinants of their produce purchasing decisions. From there, they underscored their support for what they perceived to be value-driven modes of agricultural production. At the same time, respondents expressed divergent and at times ambivalent views about the role of novel technologies in food production. Many respondents considered foods grown using methods they perceived as more natural to be more nutritious and sustainable, while others subordinated concerns about naturalness below other determinations of goodness.

A common understanding of the goodness of food for respondents was simply high quality. Respondents discussed their desire for fresh, good-tasting, nutritious food. Typical quality-focused responses often listed organoleptic properties (taste, smell, and texture) together as a collective criterion by which to judge the goodness of food:

> To me, I always have a good eye for food. Food is a passion of mine, so you kind of just tell by the freshness, by feeling it, by touching it… Also the color as well. (Interview 38)

A different but often related sense of food's goodness was its overlap with local food and/or organic food, which were seen by many to be fresher and better tasting than "conventional" or "industrial" alternatives. Indeed, many respondents expressed some immediate valorization of locally grown food as superior across a variety of categories. At the same time, this valorization of the local revealed conceptual slippages that linked locally grown to other related but distinct qualities, including the level of transparency regarding who grew the food, concerns about food miles and greenhouse gas emissions, and regional variance in the quality of specific foods, as evidenced by the responses below:

> [What] I look for when I'm purchasing is, who's kind of getting that produce together for me. So that is definitely important to me, so if I could know down the block in Gowanus, because I live in Brooklyn, someone is growing basil, I would love to purchase that. (Interview 36)
>
> First thing of importance is obviously where is it grown? Like what kind of soil is it sitting in, where is it? I care a good amount about that. But I also care about obviously how long has it been sitting around, how fresh is it, and then anything interesting about it. (Interview 18)

Respondents also linked the goodness of foods to broader social and environmental topics that they perceived to be important building blocks of a good food system. Here, much of the rhetoric of the good food movement appeared to be implicitly embedded within the respondents' minds. Specifically, some respondents evaluated food as good if it was produced in a way that met the triple-bottom-line of sustainability: "good food," for these respondents, was environmentally responsible (by reducing chemical use, improving soil quality, limiting food miles and greenhouse gas emissions, and eliminating waste), economically positive (particularly in terms of providing local jobs and being accessible to all residents), and socio-culturally productive (particularly in terms of community-building, as well as educating people about food and agriculture through gardening):

> I look for seasonal as much as possible, because that's the way you are supposed to eat. I try to support small farms because I believe in it. I believe it's a much better way of living, for the environment, for everybody, just for everybody in general. (Interview 15)

Despite this interest in sustainability and locality, respondents also expressed ambivalence throughout the conversations, signaling that their food choices had multiple layers of complexity:

> It's hard because it goes between, "Is it local?" and, if local's available, I'll do that. But it's really like, "I need an eggplant, therefore here's an eggplant," I'm gonna grab it. (Interview 13)

This lack of clarity was particularly present when respondents deployed "naturalness" in the context of good food. Good imagined food system futures were often articulated as more natural than the present, meaning less industrial, less centralized, and less corporate, as well as more local, pesticide-free, and otherwise environmentally sound. The term organic was often used interchangeably with natural, while for some, naturalness was further grounded by an ethos in which growing food was tied not only to commodity production, but also to broader spiritual conceptions of the living world:

> I prefer to use organic, natural soil, no artificial things whatsoever. In today's food, people want the crop to grow very fast, so what they do is never organic anymore. (Interview 4)
>
> I do like the idea of dirt, you know what I mean? Just the way it was from the beginning and everything, I like doing it that way. I think the dirt is very important because that's where it began, that was God's idea, you know what I mean? (Interview 44)

With that said, topics like organic food brought more ambivalence to the fore, as in the case of a few who expressed skepticism about the validity of USDA Organic certification:

> Organic is a name. I can call myself organic and use pesticides for everything, so I don't trust when I see organic…A lot of people say organic and that's like their name, but they use pesticides and herbicides and everything else. So I'm a little sketchy about some organics. But I am about natural, clean, organic. (Interview 40).

Notably, this skepticism was not reserved for organic certification labels alone, but rather a part of a general mistrust of product labeling, a concern that was reported by a number of respondents.

Taken together, respondents' sense-making related to the concept of good food brought forth several key themes that align with existing literature on the topic (Renner et al. 2012; Feldmann and Hamm 2015; Porter et al. 2017). They asserted that primary determinants of food choice focused on considerations of freshness and basic accessibility. More value-driven attachments also played significant roles in their stated perceptions, including support for local foods on account of their assumed environmental, economic, and social sustainability advantages. For many, the notion of naturalness was also a highly prized, if contested and multidimensional, characteristic of "good food."

CEA sense-making

While respondents came into the discussion of good food with a variety of existing opinions and attitudes, when it came to sense-making related to controlled environment agriculture (CEA), few participants began with fully-formed perspectives. The analytical coding process identified the most salient codes in this portion of the interviews to be focused on valorizing CEA, valorizing local foods, expressing unfamiliarity with CEA, expressing ambivalence, seeking more information, evaluating evidence, and expressing familiarity with CEA. The top modifying category codes included references to hyperlocal foods, hydroponics, aquaponics, aeroponics, naturalness, chemical use, food miles, and environmental impacts.

Importantly, the information provided by the interviewers to participants about CEA spurred a mix of sometimes competing and often contingent conclusions, both within and across respondents. For some, these conversations represented the first time they had considered CEA at all, while others expressed a vague familiarity with some of the terminology but expressed few set conclusions. As sense-making ensued, respondents offered a wide range of opinions on the merits and drawbacks of CEA production and its products. Those who expressed support were impressed by claims about CEA's ability to increase water and yield efficiency, reduce food miles, and promote access to fresh and local foods in urban communities, all while reducing agriculture's reliance on chemical inputs like pesticides and fertilizers. Some were particularly excited by the use of novel technologies, seeing CEA as the way of the future. Other respondents, however, came away with negative impressions, as they saw CEA as unnatural and disconnected from soil, leading them to be highly skeptical of the sustainability claims made by its proponents. Across these varied opinions, many aimed to situate CEA within their existing conceptualization of good food, attempting to reconcile whether or not it could align with their desires to advance sustainability, provide nutritious food, and support local farmers and businesses. Overall, there was an overwhelming request for more information about CEA, including specific life-cycle assessment data that would allow for direct comparisons with other food production methods.

Within the sample that was interviewed for this project, direct experience with and knowledge about agricultural technology, in general, and CEA, in particular, was fairly limited. Therefore, in initial conversations about CEA, respondents aimed to filter the information they received through their own existing ideological and knowledge-based frameworks regarding food systems and technology. For some, this led to generally positive initial reactions:

> I'm always interested in, like, new technology and new development in certain areas, especially when it comes to food… I think it's good to see that innovation is happening. And I definitely would be interested in learning more about it. (Interview 16)

For others, however, the ambivalence displayed elsewhere in discussions of natural foods was quickly brought into relief, leading them to express skepticism on a spectrum from concern to outright rejection:

> You know, there's a fine line between, like, food and tech. Like food needs tech, and tech needs food, but you know, I guess it's in the whole, like, GMO kind of category. (Interview 17)
>
> There's a place for it in my mind. But if I had to choose between the two, I would prefer natural-grown. (Interview 9)

Since much of the CEA-related terminology used by the interviewer was relatively unfamiliar or completely new to most respondents, they attempted to ground that new information in their own direct experiences or knowledge gained from media coverage. The term hydroponics did have a marginal level of recognition as a general food production practice, while it also brought to mind cannabis production for some participants. Others expressed vague knowledge of urban agricultural projects in the New York City area that they believed employed the method. Less familiar were terms such as aeroponics, aquaponics, and controlled environment agriculture, and it was rare for respondents to make

clear and accurate delineations between these approaches. Instead, the introduction of these terms often led respondents to simply break down the meanings of the words; they intuited, for instance, that CEA entailed the use of environmental controls, suggested that aeroponics had something to do with air, and assumed that aquaponics incorporated water into food production in some respect. In a few instances, respondents did correctly assert that fish were used in some way within aquaponics systems, but their knowledge rarely went beyond that basic observation.

Ultimately, as the interviewers offered more detailed definitions, most respondents offered up more questions than direct answers. They wanted to know, for instance, about the technological and financial feasibility of CEA, what the cost of production as well as price for consumers would be, what CEA products tasted like, and so on. More information on these topics would allow them to provide a clearer evaluation as to whether CEA could meet their standards for good food:

> I'm interested in how easy this is to maintain, how cost effective it is, and if it is offset by lower transport costs because it's capable of being grown in an urban environment. But there's always a tradeoff, and I'm wondering what that is. (Interview 1)

Considerations of the triple-bottom-line of sustainability also played a major role in shaping how respondents made sense of the overall value of CEA. Building upon the prompts of the interview, respondents critically considered key environmental implications (including greenhouse gas emissions, land use, water use, energy use, soil health, and the use of plastic packaging), economic impacts (including questions related to the impacts on local economies, food access, and consumer price), and the socio-cultural contours of the enterprise (including the meanings of hyperlocal, the place of new technology in food cultures, and changes to the characters of urban communities). Respondents evaluated the competing arguments and evidence offered to them in real time, with some using that evidence to valorize the sustainability possibilities of CEA, others to express skepticism, and others to express feelings of ambivalence and long-term uncertainty:

> The biggest critique is, like, the energy consumption in these farms. Like, hydroponics, and I think in that way, they aren't sustainable…But I think there are ways to make these new, like, hydroponic systems – say you use, like, renewable energy – then I think it would be a sustainable system. (Interview 34)
>
> If there are implications environmentally with, like, these artificial lights, for example, then in, like, 10, 20 years from now, I'd hate to think it was something that, like, seemed like a good idea, and actually we find out it was a horrible idea. But I do remember when organic stuff was coming out at first, I remember my parents being like, but don't we need those chemicals? So I feel like I'd want to see 15 years down the line if it's still a good idea. (Interview 27)

Regardless of respondents' confidence in their knowledge about sustainability, many voiced that they were suspicious of hyperbolic claims from the CEA industry. Flashy marketing appeals regarding the benefits of high-tech agriculture clashed with some of their existing conceptions of good food. Specifically, some respondents felt that claims such as the products' "hyperlocal" origins rightly aligned CEA with the principles of the good food movement, but others were suspicious of this language:

> It's kind of like just trying to throw buzzwords on food to make it sound, like, cooler and healthier. (Interview 6)

Throughout the interviews, concerns about CEA's sustainability intersected with concerns about the naturalness of its suite of agricultural technologies. Many respondents used this heuristic as a determining factor of CEA's value alongside sustainability. Most saw naturalness as good and tried to make sense of the extent to which CEA could meet their definition of natural:

> I like the idea of nutrient-enriched water. I feel like something about the no sunlight thing is for me is like an interesting one…I'm interested, but I'm trepidatious…It just feels very unnatural, it just feels kind of warehouse-y (sic). I just picture something a little bit more industrial. (Interview 27)
>
> I'm very positive for anything that doesn't have any chemicals in, so that's why I prefer the natural, the things that grow naturally. Even if you maybe help it a little, but not with chemicals, but just by the natural control of the environment. (Interview 26)

Once again, naturalness was often conflated with organic agriculture. When the interviewer presented respondents with the question as to whether CEA-grown produce should be allowed to be certified as such, the tensions between those concepts were made evident. Some dismissed the idea outright, arguing that the unnatural nature of CEA production and its disconnection from outdoor soil-based growing should disqualify it from being considered organic. Others endorsed the possibility, seeing CEA-grown produce as "natural" because it was free of conventional fertilizers and pesticides:

> You would have to specify (in) what environment it's certified organic. Because it's different in a soil-certified organic. When you think of something organic,

> you don't think of something that way. That way you just think of something more natural. (Interview 15)
> That's a very complicated question. It really is. There's many farmers now who are sustainable and are just as organic, but they're not certified. There are endless debates about what constitutes [organic], what does "organic" mean? (Interview 23)

Ultimately, the biggest takeaway of the CEA portion of the interview was that most respondents knew little about the dynamics of CEA food production, and in particular knew little about the distinctions between different types of CEA modalities. After being provided with both positive and negative arguments related to the approach, a majority of respondents did express a tentative acceptance of CEA as a production method, albeit with many lingering questions and a good deal of ambivalence. They made sense of CEA by reference to other food and agricultural technologies, evaluated it in terms of sustainability and naturalness, often had to reconcile novelty with naturalness, and expressed a strong desire for more information.

CEA as a topic did seem to challenge some respondents' opinions about food systems. On the one hand, they valorized the idea of a pesticide-free growing method that can be kept away from many environmental contaminants. On the other hand, some respondents struggled to support CEA due to the perception that soil is natural and soil-less techniques are therefore not natural. Of the many respondents who found the researchers' positive characterization of CEA to be convincing, a subset simultaneously struggled to reconcile CEA's novel technologies with their existing commitments to "good food," given that food's goodness was often closely tied to the notion of naturalness. Some of these pro-CEA respondents valorized CEA as ultimately natural, after a fashion, while many concluded by asking for more information, highlighting the categories about which they hoped to learn more, or drawing analogies between CEA and other aspects of the food system.

Discussion

These findings carry implications for the nascent CEA industry from both scholarly and practical perspectives. As noted previously, a growing body of literature has begun to examine public perceptions of CEA, as well as to critically interrogate the overall value proposition offered by the industry. Many of this study's descriptive findings align with public opinion research conducted in European contexts, including those related to the perceived risks and benefits of the enterprise (Sanyé-Mengual et al. 2016; Specht and Siebert et al. 2016a; Miličić et al. 2017; Specht and Sanyé-Mengual 2017; Ercilla-Montserrat et. al., 2019; Sanyé-Mengual et al. 2020). Previous research has largely coalesced around the conclusion that high-tech CEA is viewed less favorably than urban agricultural approaches that are pitched as more natural and are integrated into traditional agricultural land-use practices. Research has also pointed out the disconnect that exists, at times, between optimistic rhetoric from advocates and the actual performance of CEA systems in terms of producing fresh, nutrient-dense, and affordable produce with a low carbon footprint (Goodman and Minner 2019; Broad 2020; Waller and Gugganig 2021). Here, we see significant overlap in our study, especially insofar as many target consumers in an urban setting in the United States maintain a skeptical stance toward high-tech food production and seek additional assurances about its sustainability performance. Yet, this remains a deeply muddled landscape, as other potential consumers are attracted by the inherent novelty of the technology and are encouraged by the possibilities of new pathways for local food production. In some instances, potential consumers even reevaluate their definition of "natural" to map onto the practices of CEA.

In addition, the nearly universal positive assessment of local and natural foods in our study reinforces the idea that there is a high level of valorization of small-scale, presumably more natural ways of producing food among certain segments of good food consumers in the United States (Lusk et al. 2014). In this sense, promises about the ability to scale-up high-tech CEA to industrial levels may prove advantageous in some areas while creating suspicion elsewhere, with variations taking shape both between and within different national contexts (Specht et al. 2019). Researchers should continue to be mindful of international, regional, and other demographic differences in how consumers and other key stakeholders evaluate high-tech CEA and other novel agricultural technologies.

The work also raises some important points for scholars interested in the "good food movement," as well as equitable and sustainable food systems more generally. One relevant finding in this context is that, contrary to concerns raised by scholars about high-tech urban agriculture's potential role as a force for gentrification (Carolan 2020), neither this specific issue nor urban development concerns in general were salient among the respondents in our study. This is not to say that the gentrification topic would not raise concerns among other local residents or food activists, but rather that among those we conceptualized as a likely target market, other nutritional and environmental considerations were given primacy. This raises the possibility that, if high-tech CEA is able to overcome consumers' association as an unnatural form of food production and become integrated into good food movement consumer practices, it may end up further reinforcing some of the exclusionary and elitist practices for which the consumer movement has previously been criticized (Guthman, 2008; Alkon and Guthman 2017).

On the other hand, an outright rejection of high-tech CEA by these consumers might play into previous critiques of the good food movement as "retrogressive" and technologically misinformed (Lusk 2016). Once again, this further demonstrates the somewhat precarious position in which the high-tech CEA industry has positioned itself, straddling the line between being on the cutting edge of innovation while also insisting its "techno-local food" can be a key force for providing local, sustainable, "good food" for all (Specht et al. 2014; Broad, 2020).

Building on this discussion, from a more practical perspective, the findings of the research suggest that consumers are not a priori against CEA, but that both skepticism and support for novel agricultural techniques come from fairly narrow bases of agricultural knowledge, and that consumer attitudes demonstrate significant ambivalence (Pfeiffer et al. 2020). Thus, in determining their strategy for positioning their products, CEA producers may assume a general lack of knowledge about CEA among most consumers, including those who self-identify as shopping according to good food movement values. This knowledge gap is very noticeable regarding the diverse forms of CEA, as consumer awareness of the differences and similarities of hydroponics, aeroponics, and aquaponics is extremely limited.

Given the identification of local food consumers as a target market in the United States, CEA producers must find ways to convincingly describe their growing process in terms that are amenable to that audience. CEA market success will therefore depend in part on the industry's ability to become credible good food movement actors themselves, making the case that their products are truly local, sustainable, and, to a certain extent, also natural. Reinforcing Ronteltap et al.'s (2007) argument that tailored communication plays a key role in linking food innovations to consumer perceptions, this situation implies a discursive challenge for the CEA industry moving forward. Notably, this challenge is not only about basic information provision, but given the highly value-laden and cultural contextual nature of food preferences, raises more complex communicative questions. Who will successfully reach consumers and provide them more information regarding CEA? Will consumers trust CEA producers or look to extant good food movement proponents for informed opinions regarding CEA?

This is not simply a marketing issue, however. The best way for the CEA industry to make this case is to actually deliver on its promises, providing high-quality produce that competes with existing options on price and organoleptic properties such as taste and freshness, as well as demonstrably meets the triple-bottom line of sustainability. This is currently and will likely continue to be a significant challenge for a host of economic and technological reasons (Goodman and Minner 2019). The industry also needs to think critically about whether it seeks to appeal to a broader, non-value driven consumer base, in which case classic food choice considerations may become even more paramount. Although many CEA products currently command a price premium, if the industry hopes to expand its reach more widely, it may need to give up the opportunity to charge higher rates and compete more directly with conventional growers.

Importantly, this research comes with some limitations, even as it offers several fruitful directions for future scholarship. Demographically, our pool of interview respondents was not statistically representative of New York City or the United States. Psychographically, this research was limited by its focus on self-identified local food consumers. While there is value in focusing on this subset of potential early adopters (House 2016), other studies could examine larger and more diverse consumer cohorts, including consumers who do not self-identify as sharing good food movement values. Due to the small-size and localized sample of the present study, follow-up studies could also examine different regions in the U.S., including rural counties where the average agricultural knowledge is likely greater, as well as make comparisons between U.S. consumers and those in other nations.

Methodologically, the descriptive statistics applied to the coding process were used as a tool to support what Maxwell (2010) refers to as "internal generalizability" in the qualitative analysis process, but they do not allow for clear causal claims with external generalizability to be made. Follow-up studies could complement findings derived from structured interviews with consumer surveys and willingness-to-pay behavioral experiments. Larger sample sizes and quantitative analysis could generate more robust findings, using qualitative studies as helpful tools in designing surveys. Members of the research team are currently engaged in such research, including a study of New York City residents' willingness to pay for lettuce if it is indoor-grown, field-grown, organic, pesticide-free, conventional, and/or locally grown.

Studying sense-making in the context of a novel technology meant having to offer interview respondents working definitions and potted arguments in order to start conversations. The evolving opinion formation that was on display throughout the interview process helped to validate the sense-making orientation that guided this project, reinforcing the work of others who put the approach to use in studies of food choice and the values of food consumers (Woodside, 2001; Dervin and Naumer 2009; Hilverda et al. 2017; Pfeiffer et al. 2020). With that said, although we attempted to formulate these functional statements as neutrally as possible, it is possible that respondents were unduly influenced by the nature of the information provided to them and the sequence of the questions asked. Since this study aimed to gather initial sense-making impressions and did not attempt to create experimental conditions, we cannot come to clear conclusions about the impacts of the messages we provided.

With that said, since responses indicated a general lack of knowledge about CEA and agriculture in general, and since most respondents were ultimately ambivalent about CEA's promises at the conclusion of the interview, we hypothesize that reordering questions would likely have not changed responses in a substantive way. Follow-up studies could try different approaches, providing more or less information, and more negative or more positive information, in different sequences. Online surveys could allow for not only randomized but respondent-directed sequences of questions that allow for experimental conclusions to be derived. In addition, even in the physical context of local food hubs, the nature of the structured interview created a somewhat artificial environment wherein the researchers dictated consumers' engagement with information about CEA products. Studies could be conducted in more naturalistic settings (such as a grocery store) in order to examine how consumers evaluate CEA products when faced with multiple options.

Finally, another limitation of this study was simply the young nature of the CEA industry. Studying consumer perceptions in the absence of widely available sales and environmental data from the industry means studying opinions about claims (sense-making) without being able to tie these opinions to sociotechnical facts (i.e., how CEA compares to other production techniques in terms of environmental impacts). Further life-cycle analysis studies of CEA will complement consumer perception studies and offer a more holistic portrait of an industry that is expanding in the United States and around the world. As the industry matures, researchers will be better able to assess what most matters to consumers and how they assess CEA products according to multiple food choice values and preferences.

Conclusion

This study used semi-structured interviews with a demographic of local food consumers in New York City to explore their perceptions of new forms of high-tech controlled environment agriculture (CEA), as well as to understand how those perceptions were situated within broader understandings of "good food." The results demonstrated that public understanding of CEA remains very limited, and that upon learning more information about CEA, respondents expressed significant ambivalence about its overall value. While the promise of delivering fresh, local food through CEA technology was appealing to many, optimism was offset by concerns about the true sustainability implications of the enterprise, lingering concerns about its naturalness, and the straightforward question of its affordability and taste.

At a moment when significant investment and attention is being paid to the high-tech CEA industry, and when industry spokespersons advocate for the approach as key to the future of local and urban food systems, it is important to investigate how consumers actually make sense of the systems and their products. This research demonstrates that the CEA industry still has significant discursive and technological work to do if their products are to achieve appeal within the subset of value-oriented "good food" purchasers, let alone the broader consuming public. In order to have more widespread acceptance, the high-tech CEA industry will need to engage in more substantive consumer education. CEA industry members will have to position their methods for growing food as consonant with good food values – in part by overcoming some consumers' rejection of novel food production methods as "unnatural" – while simultaneously making their products affordable for larger segments of the population. Ultimately, the success of the industry will depend in large part on its ability to convince consumers that its practices meet the triple bottom line of environmental, economic, and social sustainability, while also competing on traditional determinants of food choice.

Appendix

Interview guide

1. When you are looking to purchase vegetables, what is most important to you? Why?
2. Have you ever heard of the term "controlled environment agriculture" or CEA?

    a. What does that term mean to you?
    b. I may refer to it as CEA moving forward.

3. Have you ever heard of the terms "hydroponics?" What does this term mean to you?

    a. Have you ever heard of the term "aeroponics?" What does this term mean to you?
    b. Have you ever heard of the term "aquaponics?" What does this term mean to you?

4. I'm going to tell you a little bit more about controlled environment agriculture, or CEA. I'm interested to hear your thoughts.
5. Controlled environment agriculture is a method of cultivating plants in an enclosed environment, using technology to ensure optimal growing conditions. For many years, people have grown food in greenhouses, which is a type of controlled environment agriculture that uses natural sunlight. In recent years, new types of CEA allow people to grow food indoors without soil or

sunlight. They use artificial lights like LEDs and grow the plants in nutrient-enriched water. In hydroponics, the roots are placed in that water; in aeroponics, the roots are sprayed with the water; and in aquaponics, the nutrients actually come from fish. Hearing about CEA practices such as hydroponic, aeroponic, and aquaponic agriculture, what is your general reaction?

6. Supporters of controlled environment agriculture argue that their products are good because they use less water than outdoor agriculture, can grow more food per square foot, and don't use pesticides or GMOs. They also say they can reduce greenhouse gas emissions by limiting fertilizer inputs and transportation, since they can be grown anywhere year-round, including right in the city.

   a. What do you think of these arguments?
   b. Are any of these specific claims important or convincing to you?

7. Let's focus a bit more on the idea of local food. Do you generally seek out local food? Why or why not?
8. Some supporters say CEA represents a new opportunity to grow food "hyperlocally" within urban areas, so that produce can be consumed very close to where it was grown and soon after harvesting to retain its freshness, flavor, and nutrients.

   a. What do you think about CEA producers' claims about being "hyperlocal?" Does this sound appealing or not? Why?

9. Some people are critical of controlled environment agriculture. They argue that the systems are expensive and use lots of energy due to their artificial lights, which can lead to a large greenhouse gas footprint. Some also argue that locally grown and organic foods grown in soil are superior, since they consider outdoor agriculture a more natural approach which also helps build soil health.

   a. What do you think of these arguments?
   b. Are any of these specific claims important or convincing to you?

10. Right now, there is a debate about whether controlled environment agriculture products should be allowed to be certified as organic. If you had to take a stance on this issue, what would you say?
11. After this conversation, how would you describe your overall feeling toward controlled environment agriculture products? What other questions do you have?

Acknowledgements This research was supported by a Fordham University Social Innovation Fellowship grant. Special thanks to Sophie Ambro, Lindsey Register, and Randy Mueller for their work as undergraduate research assistants. Additional thanks to Dr. Anu Rangarajan, Dr. Neil Mattson, and the Cornell CEA NSF INFEWS team for their support, as well as Ricky Stephens and other members of the CEA industry for their feedback. The authors also thank the research participants for sharing their perspectives, as well as the editor and anonymous peer reviewers for their constructive commentary.

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