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Will Consumers Find Vertically Farmed Produce "Out of Reach"?

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An Introduction to Vertical Farming

The global population is expected to increase to 9.7 billion people by 2050, approximately 2.4 billion more mouths to feed than we have today (United Nations, Department of Economic and Social Affairs, 2015). This likely means more food will need to be produced, yet there are concerns about the scarcity and quality of critical inputs for future food production. Lotze-Campen et al. (2008) note that land previously used for agricultural production will likely be converted for other purposes such as urbanization, infrastructure development, bioenergy production, or biodiversity protection. Others researchers caution that high-quality water and soil inputs may also be constrained (Tilman et al., 2002; Ehrlich, Ehrlich, and Daily, 1993). Climate change is also expected to be a major challenge for agricultural production in the coming years due to warming temperatures, increased carbon dioxide emissions, and more severe weather events (Howden et al., 2007). Climate change models predict that agricultural losses will be greatest in the developing world (Rosenzweig and Parry, 1994), especially in southern Asia and Africa (Parry, Rosenzweig, and Livermore, 2005).

One potential way to increase agricultural production (and ultimately the food supply) that is largely impervious to climate change is vertical farming, a type of controlled-environment agriculture that primarily uses artificial lighting and hydroponics to grow plants stacked in layers (Banerjee and Adenaueer, 2014). Because the climate in a vertical farm is controlled, plants can grow faster and be harvested year-round. By stacking layers of plants on top of each other, vertical farms can produce much higher yields per unit of land than traditional farms.

Vertical farms also have the benefit of being able to produce crops like lettuce in non-traditional areas (Despommier, 2010). Vertical farms currently produce crops like fresh lettuce in cities in the northern United States, Northern Europe, and East Asia—areas where production is uncommon. The presence of vertical farms allows consumers in those areas to buy locally produced food, an attribute that has been shown to be highly valued by consumers (e.g., Loureiro and Hine, 2002; Darby et al., 2008; Onozaka and Thilmany McFadden, 2011). Additionally, vertical farms may be a good means for increasing produce availability in highly urbanized areas and urban food deserts, which could improve community food security (Specht et al., 2014).

Critics contend that vertical farming presents more problems than it solves. Cox and Van Tassel (2010) argue that energy usage is high because vertical farming depends on artificial lights to grow plants and that the production of additional electricity for vertical farms will result in increased pollution and greenhouse gas emissions. Furthermore, the cost to purchase the LED lights used in vertical farming is prohibitively expensive for many small farmers. Critics also argue that crops that can both be grown vertically and be economically viable are limited to the extent that vertical farming will not be a meaningful solution to our agricultural problems.




While there are arguments for and against vertical farming, whether consumers are even willing to buy vertically farmed produce—an important consideration in the cost-benefit discussion—is rarely discussed. Recent agricultural technologies—such as genetically modified (GM) crops, food irradiation, and nanotechnology—have often been met with consumer skepticism (Frewer et al., 2011; Dannenberg, 2009; Siegrist et al., 2007; Ragaert et

al., 2004), so it is unclear how vertical farming will fare with consumers. The overall purpose of our research is to investigate consumers' perceptions of and willingness to pay (WTP) for produce—specifically, lettuce—grown in a vertical farm production system. Results from this study should provide insight on the potential for consumer acceptance of vertical farming as a new production technology relative to greenhouse and field production systems. This study will also examine the impact of information on perceptions of and WTP for vertically farmed lettuce.

Consumer Assessment

We conducted this study in January 2016. We recruited 117 participants from the University of Illinois campus and surrounding community. To be eligible for the study, participants had to be at least 18 years of age and consumers of lettuce. Participants were paid \$5 for attending a 20-minute session that included an experimental auction and accompanying survey. We held 20 sessions across the study period, with an average of almost six subjects per session. The final sample included 116 observations, as we removed one observation from the sample due to a participant misunderstanding auction procedures.

Figure 1: Information Treatment Handout

	Vertical Farm	Greenhouse	Field Farming
			
<i>Light Source</i>	Artificial lighting	Sunlight and/or artificial lighting	Sunlight
<i>Land Use</i>	365 days/year	365 days/year	About 275 days/year
<i>Soil use</i>	None. Plants grown hydroponically.*	None. Plants usually grown hydroponically.*	Yes. Plants grown in soil.
<i>Harvests per year</i>	8–12 for lettuce	6–7 for lettuce	Usually 2 for lettuce
<i>Water source</i>	Local water network	Local water network	Rainfall and irrigation
<i>Water use</i>	Low 0.3 gallons/head of lettuce	Low 0.3 gallons/head of lettuce	High 6.5 gallons/head of lettuce
<i>Electricity use</i>	High. Lights run for 12–16 hours per day and heating system must be run in the winter.	Medium. Lights run for a 2–4 hours per day and heating system must be run in the winter.	Low
<i>Pest control use</i>	Enclosed building	Enclosed building	EPA-approved herbicides, insecticides and fungicides as well as traditional methods such as weeding, mulching and plowing.
<i>Production</i>	5,000,000 heads of lettuce/acre/year	1,600,000 heads of lettuce/acre/year	50,000 heads of lettuce/acre/year

Notes: *The roots are immersed in water and soak up nutrients from a solution added to the water.

In each research session, participants participated in a practice candy bar auction to explain the experimental auction procedure. For this study, we used the Becker-DeGroot-Marschak auction to determine consumers' WTP (Becker, DeGroot, and Marschak, 1964). After the practice auction, sessions were randomized to either receive information about the three agricultural production systems of interest (referred to as the treatment group) or to receive no information (referred to as the control group). For the treatment sessions, a table with information

about vertical farms, greenhouses, and field farms was provided to all participants. The table contained a picture typical of each production system as well as nine pieces of information on water use, electricity use, and pest control use for each production system (Figure 1). The moderator discussed the information sheet, allowed participants to ask clarification questions, and then had participants answer comprehension questions at the start of their surveys to ensure that they understood the information presented. Participants in the control group did not receive any information about agricultural production systems and proceeded directly from the practice auction to the rest of the study.

In the lettuce auction, participants placed three bids for 5-ounce boxes of lettuce produced by a vertical farm, a greenhouse, and a field farm. The session moderator showed participants a sample box of lettuce in order to communicate the quantity of lettuce they were bidding on.

We also asked comparison questions about the three agricultural production systems. Participants rated their perceptions of lettuce grown using each production system with regard to safety, quality, and naturalness. Additionally, subjects were asked to indicate their knowledge level of each of the production systems, as well as if they thought the average consumer would be willing to buy lettuce grown in each of the production systems. Responses were indicated on a five-point scale (from 1 = very unsafe, low quality, unnatural, low knowledge, or very unwilling to buy to 5 = very safe, high quality, natural, high knowledge, or very willing to buy).

In addition to perceptions, participants were asked about their attitudes toward farming broadly and vertical farming specifically. The general farming statements corresponded to the information given to the treatment group, but both the control and treatment groups were asked about their attitudes to determine whether the information had impacted them. Sample statements included “Farmers use too much water,” “Farms should only use natural lighting,” and “Farmers should always maximize production per acre.” Similar statements were used to measure attitudes toward vertical farming, including “Vertical farming will improve the standard of living for future generations” and “Vertical farming will cause health risks in human beings.” For all attitude statements, subjects indicated their level of agreement on a five-point scale (1 = strongly agree to 5 = strongly disagree).

To learn more about how consumers expected vertically farmed lettuce to fit in to the market, subjects were questioned about where they expected this product to be sold. Since this survey was restricted to a single community, specific store names were used; however, several broad store types were represented, such as supercenters (Walmart, Target, Meijer), supermarkets (Schnucks, County Market), specialty stores (Common Ground Food Co-op, Strawberry Fields), and discount stores (Aldi).

How Does Vertically Farmed Lettuce Rate with Consumers?

Perceptions and Knowledge

Participants rated their perceptions of lettuce grown in three agricultural production systems—vertical farming, greenhouse farming, and field farming—with respect to naturalness, safety, quality, and willingness of the average consumer to buy (Table 1). Significant differences between production systems existed for each variable of interest. For safety and quality ratings, vertically farmed lettuce was rated lower than greenhouse grown but higher than field-grown lettuce; however, only the safety ratings significantly differed across the three production systems. Despite strong quality and safety ratings, vertically farmed lettuce was considered to be the least natural (average ratings were 3.1, 3.5, and 4.4 for vertical farm, greenhouse, and field farm, respectively) and the least likely to be purchased by the average consumer (vertical farm=3.0; greenhouse=3.6; field farm=4.3).

Table 1: Consumer Perceptions by Production System

<i>Production System</i>	<i>Knowledge of System</i>	<i>Naturalness Rating</i>	<i>Safety Rating</i>	<i>Quality Expectation</i>	<i>Willingness of Average Consumer to Buy</i>
Vertical Farm	2.3 ^a	3.1 ^a	3.7 ^a	3.8 ^{ab}	3.0 ^a
Greenhouse	3.1 ^b	3.5 ^b	4.0 ^b	4.1 ^a	3.6 ^b
Field Farming	3.4 ^b	4.4 ^c	3.4 ^c	3.6 ^b	4.3 ^c

NOTES: Averages in a column that share the same letter in the superscript are not significantly different at the 5% significance level. Participants were asked to rate their response on a five-point scale where 1=No Knowledge, Unnatural, Very Unsafe, Low, or Very Unwilling and 5=Very Knowledgeable, Natural, Very Safe, High, or Very Willing.

The information treatment had little impact on ratings within or across production systems, with the exception of the natural rating. Here, we observed that participants in the control group rated vertically farmed and greenhouse grown lettuce as equally natural; however, once information was provided, vertically farmed lettuce was perceived to be significantly less natural than both greenhouse and field-grown lettuce. Knowledge of the three production systems was also assessed. Not surprisingly, the average knowledge level of the vertical farm system was significantly lower than knowledge of greenhouse and field farm production systems, but the information treatment marginally improved consumers’ knowledge of vertical farming.

Will Consumers Pay?

On average, participants’ WTP was \$2.23 for a 5-ounce box of vertically farmed lettuce, \$2.28 for the greenhouse grown, and \$2.36 for the field-grown lettuce. Participants in the information treatment were not willing to pay as much for vertically farmed lettuce compared to those in the control treatment (average WTP for treatment: \$2.00; average WTP for control: \$2.47), but this difference was not statistically significant.

To better understand bidding behavior for an unfamiliar product, we asked participants to explain how they developed their bids for the vertically farmed lettuce. The most commonly cited factors participants listed for determining their bid were expectations about production costs. For participants who received the information treatment, the effect was even more pronounced, with participants focusing on the potential of vertical farms to produce large amounts of lettuce. These responses were likely referencing the part of the information sheet that listed production for a vertical farm at 5,000,000 heads of lettuce/acre/year (in comparison to field farming producing 50,000 heads of lettuce/acre/year).

The expectation that differences in production per acre between agricultural systems would result in lower cost expectations, and therefore lower WTP, may indicate a lack of consumer literacy among our participants. An underlying assumption of numerous qualitative responses seems to be that higher yield per acre is associated with lower-cost lettuce. However, we did not provide any information directly regarding costs of production. Further, the fact that participants seemed willing to base their WTP on what they perceived as costs of production does not fit neatly with neoclassical economic theory. It may be the case that participants considered other factors beyond their own costs and benefits when determining WTP.

Consumer Attitudes

When asked about production practices broadly, consumers tended to agree that year-round crop production is desirable, but they were not in favor of pesticide use. Participants in the information treatment group had

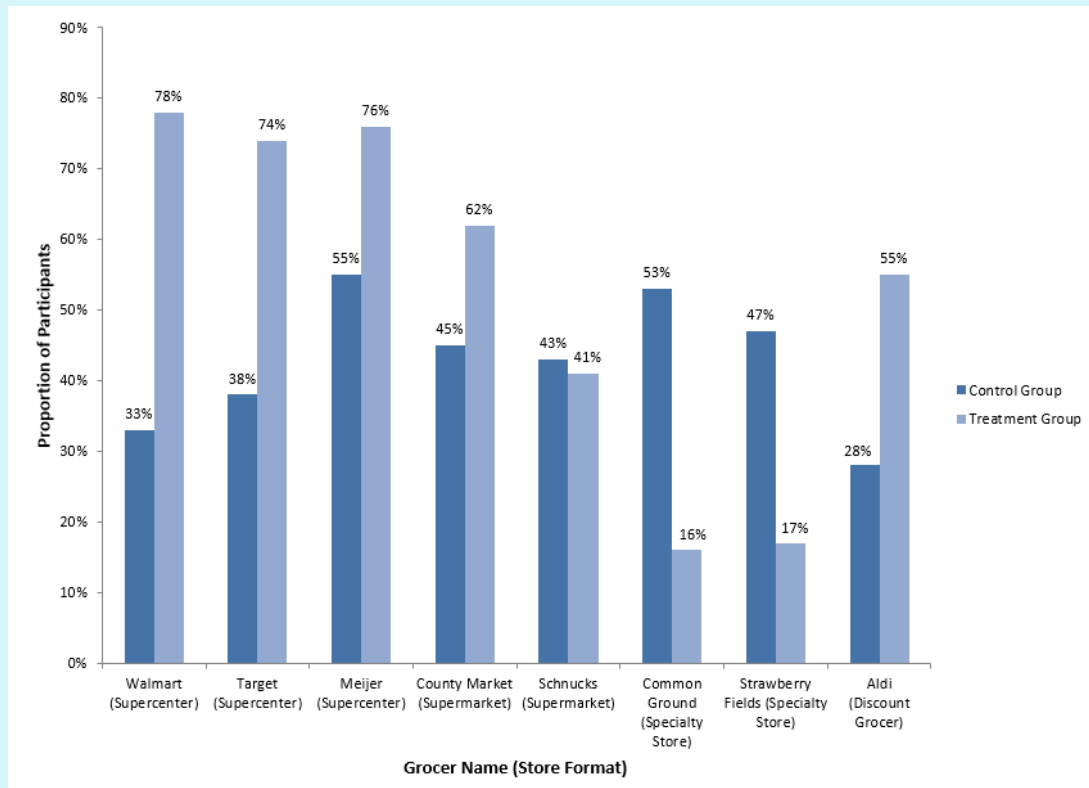
significantly higher levels of agreement with the statements “Growing crops at a faster rate is a good thing” and “Farmers should always maximize production per acre.” These attitudes suggest that participants are open to a type of agriculture, such as vertical farming, that uses land intensively to grow pesticide-free plants at an accelerated pace year-round.

More specific attitude statements indicated that consumers viewed vertical farming positively. Participants generally agreed that vertical farming could be used to solve environmental problems, reduce the price of lettuce, and improve the standard of living for future generations. They did not expect vertical farming to cause health risks but were less certain about how natural vertical farming is or whether vertical farming would produce healthier lettuce.

A Place for Vertically Farmed Produce in the Market?

As an indicator of market placement, we asked participants to identify which type(s) of stores they expected to sell vertically farmed lettuce. As shown in Figure 2, store expectations were quite different between the treatment and control groups. Participants in the control group envisioned vertically farmed lettuce being sold at a variety of stores; high-end, specialty food stores were two of the three retailers most frequently selected. For those participants who received information, however, the specialty food stores were the two least frequently selected as potential sellers of vertically farmed lettuce. Instead, supercenters such as Walmart, Meijer, and Target were most frequently selected as stores that would sell vertically farmed lettuce.

Figure 2: Proportion of Participants Who Expect a Grocery Store to Sell Vertically Farmed Lettuce



Additionally, the proportion of individuals selecting Aldi (a discount retailer) was significantly higher in the treatment group. These results indicate that consumers who are unfamiliar with the vertical farming production system view vertically farmed lettuce as a premium product that would be sold in premium stores. As consumers

learn more about the production efficiencies of vertical farming, though, their perceptions may adjust such that vertically farmed produce is a low-cost product that would be sold in supercenters and other discount grocers.

In Summary

Consumers' perceptions and WTP values suggest that many individuals see vertical farming as a comparable—and perhaps acceptable—form of agricultural production. WTP for vertically farmed lettuce was similar to that of greenhouse or field-grown lettuce. In addition, consumers rated the safety and expected quality of produce from all three production systems similarly. We see this as evidence that consumers largely fail to distinguish between these agricultural production methods when purchasing lettuce. That being said, it should be noted that study participants still rated vertically farmed lettuce as significantly less natural and significantly less likely to be purchased by the average consumer than other alternatives. Thus, while vertical farming may be one marketable solution to the problem of slowing yield growth and limited food supplies in the future, producers and retailers alike need to be prepared for hesitation on the part of consumers—a common occurrence with the introduction of many new food technologies (Bieberstein et al., 2013; Grunert, Bredahl, and Scholderer, 2003; Henson, 1995; Honkanen and Verplanken, 2004; O'Connor et al., 2006; Sparks, Shepherd, and Frewer, 1994).

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