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Consumer preferences for produce grown with reduced pesticides: a choice experiment in Missouri

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Research Article

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Abstract

There have been growing concerns about exposure to chemical pesticides in fresh fruits and vegetables, which are an important part of a healthy diet. This study investigates consumer preferences for reduced pesticide, organic, local, and Missouri Grown produce using a discrete choice experiment. An online survey of fresh tomato consumers was conducted in Missouri to collect choice data, demographic information, and the individual health and environmental attitudes of shoppers. Respondents were willing to pay a premium of 6% for tomatoes produced with 50% less pesticide than conventional tomatoes. The finding indicates there may be a demand for reduced pesticide produce as a compromise between conventional and organic products in terms of price and safety. Also, we found complementary effects between the reduced pesticide attribute and local or Missouri Grown labels, which means consumers in this segment would pay more for fruits and vegetables that were also locally produced. The results suggest important implications for local producers and policy makers in terms of the production and marketing of reduced pesticide produce, such as the need to develop a reduced pesticide label.

Introduction

Changes toward healthier and environmentally friendly food consumption have been highlighted in business practice and academic research (e.g., Li and Kallas 2021; Miller et al., 2021; Su et al., 2019). While eating fresh vegetables and fruits is considered as an important part of a healthy diet (e.g., Lee et al., 2022; Wallace et al., 2020; WHO, 2020), one concern is possible exposure to harmful pesticide residues (Roberts, 2020). According to the U.S. Food and Drug Administration (FDA), pesticides were found in 66.3% of fresh fruits and 55.2% of fresh vegetables (FDA, 2021). While the levels of these chemical residues are generally acceptable and compliant with food safety regulations[1], there has been increasing interest in food produced with reduced pesticide use (e.g., Marette, Messéan, and Millet 2012; Chen et al., 2018). The reduced pesticide in food production can mitigate health concerns (e.g., less pesticide residue risk) and environmental concerns (e.g., reducing pesticides' effects on soil, aquatic life, and pollinators) (Milford, Trandem, and Pires, 2021; Khachatryan, Wei, and Rihn, 2020).

With regard to pesticides, the differences between conventional, reduced pesticide, and organic produce are the amount and the types used in their production. In general, conventional production applies synthetic pesticides as needed, as long as the amounts and timing comply with EPA regulations. Reduced pesticide production applies a lower quantity than typically used amount in conventional production, e.g., 50% of the pesticides that a farmer would typically apply. Consequently, reduced pesticide practices would lead to less pesticide residue than conventional production. Organic farming uses only natural or non-synthetic pesticides approved by the USDA National Organic Standards, which were established in 2002. Organic products do not have any synthetic pesticide residue because they are not allowed. However, organic produce is more expensive than conventional products, and the higher price is a barrier for health-conscious consumers (Aschemann-Witzel and Zielke, 2017). Reduced pesticide use can thus be a compromise between conventional (lower cost, but higher health and environmental risk) and organic (higher cost, but lower risk) methods. However, the markets for vegetables or fruits grown with reduced or lower pesticides are vague and lack of clear terminology and definitions. Claims such as 'natural,' 'green,' 'eco-,' and 'environmentally friendly' generally imply zero or lower pesticide use without indicating a specific reduction of pesticides in production (Li and Kallas, 2021). Thus, the purpose of this research is to study consumers' preferences and willingness to pay for 50% reduced pesticide produce. By specifying half of the

[1]The U.S. Environmental Protection Agency (EPA) establishes tolerances for pesticide chemical residue in and on food. The tolerances indicate maximum residue levels (MRLs) of a specific pesticide permitted in the United States.

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amount of conventional pesticide use, we can communicate clearly with consumers as well as enabling survey results to be used by policy-makers to compare costs and benefits of a specific reduction.

Previous studies have shown that consumers have positive preferences for organic food (e.g., Denver and Jensen, 2014; Govindasamy, Decongelio, and Bhuyan, 2006; Kovacs and Keresztes, 2022; Skreli et al., 2017; Van Loo et al., 2015). Though several attempts have been made to address consumer preferences for reduced pesticide fruit and vegetables, these pesticide reductions were associated with integrated pesticide management (IPM) practices[2] (Govindasamy and Puduri, 2008; Moser, Raffaelli, and Notaro, 2010; Biguzzi et al., 2014). However, the IPM approach does not result in specific or consistent pesticide reductions (Alwang, Norton, and Larochelle, 2019; Durham and Mizik, 2021; Moser and Raffaelli, 2012). Overall, few studies have examined reduced pesticide use as a food attribute to compare it with preferences for organic and conventional production methods. This study helps to fill that gap.

This study examines consumer preferences and willingness-to-pay (WTP) for tomatoes with four different attributes: production method, origin, type of producer, and price, using a dataset of consumers in Missouri. The production methods include 50% reduced pesticide, organic, and conventional. The origins include local, Missouri Grown, and none of the above. Small/medium family farms, large family farms, and corporations are compared.

This study contributes to the literature in several ways. It adds to the scarce literature on reduced pesticide use from the consumer perspective, while previous research has mostly focused on pesticide use in production. The research offers empirical evidence of a potential premium for reduced pesticide use compared to conventional production, which would be meaningful for pest control practices such as IPM. An innovation of this research is that it examines the combined impacts of production methods and origin labels on WTP. It also explores the heterogeneity of preferences for production methods and other attributes. Last, the research provides valuable implications for farmers and policy makers regarding potential marketing strategies for reduced pesticide produce.

The rest of the paper is structured as follows. Section 'Background' presents background information on production methods related to pesticide use from the consumer perspective. Section 'Experimental design' describes the design of the choice experiment. Section 'Data and empirical model' summarizes survey procedures, data collection, and empirical models. Section 'Results' presents summary statistics and empirical results. Finally, we draw conclusions and implications of our findings in Section 'Conclusions'.

Background

Increasing attention has been paid to production methods and food purchasing behavior. After the Green Revolution, food crop production systems known as conventional agriculture (CA) became the norm. It is typically characterized by mechanization, improved varieties, and intensive input use, including synthetic fertilizers and pesticides, for improved output. However, it is recognized that conventional production may have potential negative impacts on human health and the environment (WHO-FAO, 2019). Compared to CA, organic agriculture (OA) considers potential environmental and social impacts and emphasizes the use of agronomic, biological, and mechanical methods as opposed to synthetic materials. Regarding pesticide use, OA is more likely to be associated with lower health and environmental risks but is more costly (Garcia and Teixeira, 2017). Reduced pesticide use would be intermediate.

There is a large body of literature on organic and sustainable farming from the consumer side (e.g., reviews of Li and Kallas, 2021; Katt and Meixner, 2020; Cecchini, Torquati, and Chiorri, 2018). Previous studies generally found that consumers are willing to pay a premium for organic and sustainable food attributes (e.g., Aryal et al., 2009; Ballen, Evans, and Parra-Acosta, 2021; Bazzani et al., 2017; Lin, Smith, and Huang, 2008). Based on 80 empirical studies implemented around the world from 2000–2020, Li and Kallas (2021) reported that the overall WTP for sustainable attributes is about 30% above the price of conventional food products. However, the premiums differ by food category, sustainable attribute, certification, region or country, and heterogeneity across consumers. For example, the estimated premium for organic tomatoes ranges from 10% for uncertified organic in Ghana (Owusu and Dadzie, 2021) to 100% for certified organic in Myanmar (Aye, Takahashi, and Yabe, 2019).

Several studies have examined consumer preferences for the reduced pesticide attribute of fresh produce and found consumers were willing to pay a premium for reduced pesticide products over conventional ones (Table 1). Moser, Raffaelli, and Notaro (2010) estimated WTP for apples produced by four methods: conventional, integrated (IPM), innovative (IPM with biological control), and organic production, and only found a significant WTP for organic apples. Marette, Messéan, and Millet (2012) developed a new label of 'few pesticides' for apples (50% reduction in pesticide use compared to conventional apples) and found these apples were preferable to conventional ones. Kiruthika and Selvaraj (2013) discovered that younger and higher-income consumers were more likely to buy IPM produce and willing to pay a 10% premium for IPM labels. Biguzzi et al. (2014) implemented a lab experiment on tomato purchases to investigate the role of IPM information on the food label. They found that WTP for IPM was significantly less than for organic tomatoes in the absence of any information, but consumers preferred IPM to organic when IPM information was provided and there was a large price difference ($0.30 per pound or more). Chen et al. (2018) found that WTP for fresh strawberries using less pesticides than the industry average was higher than other sustainable practices (less fertilizer, less negative impacts on water quality, less negative impacts on soil quality, less negative impacts on air quality). These studies suggest that reduced pesticide products are differentiated from both conventional and organic.

The 'certified organic' label in the U.S. indicates there is no synthetic pesticide residue on food and implies a wide range of health and environmental benefits. However, the 'reduced pesticide' outcomes obtained by IPM and other sustainable practices may not be similarly informative. IPM systems generally have no clear commitments about how much pesticide reduction would occur nor the effects of the reduction on health and environmental outcomes (e.g., Alwang, Norton, and Larochelle, 2019). Previous studies have shown a majority of consumers do not know what IPM is (Biguzzi et al., 2014), and therefore, labeling

[2]IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. The IPM approach takes advantage of all appropriate pest solutions, including judicious use of synthetic pesticides (EPA, 2022).

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Table 1. Studies on willingness-to-pay (WTP) for produce with reduced pesticide use

No.	Study	Country	Food products	Reduced pesticide use	WTP[a]
1	Moser, Raffaelli, and Notaro (2010)	Italy	Apple	IPM and biocontrol agent	0.28 Euro/kg
2	Marette, Messéan, and Millet (2012)	France	Apple	50% less pesticides than conventional method	0.06 Euro/one apple
3	Kiruthika and Selvaraj (2013)	India	Fresh produce	IPM	At least 10%
4	Biguzzi et al. (2014)	Italy	Tomato	IPM	−0.45 Euro/kg[b]
5	Chen et al. (2018)	USA	Strawberry	Less pesticides than the industry average	$0.31/lb.

[a]WTP for potentially reduced pesticide usage is estimated with respect to the conventional method. Reduced pesticide use or organic information can be found in Li and Kallas (2021).
[b]WTP is compared to organic farming.

IPM practices on food may not affect consumers purchasing behavior because they do not have a clear idea about its benefits (Moser and Raffaelli, 2012). However, similar to reduced pesticide produce, there is currently no established market for IPM produce, suggesting potential biases for a hypothetical approach based on intended purchase behavior (Moser, 2016; Wheeler, Gregg, and Singh, 2019).

Given the importance of information on pesticide use and the lack of such information on food labels, the study has developed a 50% reduced pesticide use label scenario, i.e. half the amount of pesticides used in conventional production. Consumers thus have specific information on how much the pesticides were reduced as they make their purchase decisions. In the next section, we explain the produce attributes of interest used in our choice experiment.

Experimental design

This study uses a discrete choice experiment (DCE) to elicit consumer preferences for organic, reduced pesticide, and conventional tomatoes. The popularity of DCE comes from its advantages: flexibility, avoiding bias from direct elicitation of WTP, straightforward application for attributes of interest, strongly grounded in random utility theory, and good properties of estimation (Carson and Louviere, 2011). In the present DCE, consumers were repeatedly asked to choose their preferred option among several options for one pound of fresh tomatoes.

There are several reasons we chose tomatoes for the choice experiment. They are the second most consumed vegetable in the U.S., after potatoes (USDA Economic Research Service, 2020). They are often eaten fresh, with the skin on. Tomatoes can be produced in Missouri using all the production practices of interest for the research. In a recent survey in Missouri, a majority of growers indicated tomatoes were their primary crop, using high tunnels to extend the growing season in an environmentally safe manner (Piñero and Keay, 2018). Tomatoes can be purchased through various marketing channels (farm stands, farmers' markets, supermarkets, natural stores, and online). Tomatoes also have been widely used in previous studies on WTP for organic and sustainable attributes (e.g., Aye, Takahashi, and Yabe, 2019; Awad et al., 2019; Printezis and Grebitus, 2018).

The tomato options differed in terms of attributes regarding how they are produced (production method), where they are grown (origin label), who produced them (type of producers), and how much they cost (price). The production method was assigned three levels: organic, 50% reduced pesticide use as usual, and conventional. Several studies indicated that some U.S. farmers, including in Missouri, are reducing pesticide use in crop production; they are not yet organic but are not conventional anymore (Baker et al., 2002; Weddle, Welter, and Thomson, 2009; Piñero and Keay, 2018). We chose '50% reduced pesticide use as usual' to make the pesticide reduction explicit to participants. It is the same amount as the eco-friendly label used by Marette, Messéan, and Millet (2012), which enables a comparison of our results to their findings. In addition, 50% reduced pesticide use is in the middle of organic and conventional amounts. The 50% reduced pesticide tomatoes may have a higher quality (less pesticide residue, less environmental impact) than conventional ones but are likely cheaper than organic ones.

Regarding the origin, we considered three labels: local, Missouri Grown, and others (neither local nor Missouri Grown). The 'Missouri Grown' label shows that the product has been certified by the Missouri Grown program[3]. The term 'local' is defined by the consumers[4] and 'others' indicates tomatoes are from other U.S. states or imported. Producer type includes small & medium family farms, large family farms, and large corporations. The price attribute includes three levels: $1.99, $2.99, and $3.99 per pound[5] of tomatoes, which were established through collecting and analyzing the market prices of fresh tomatoes observed at local grocery stores, farmers markets, and online purchases at the time of the study. Table 2 reports the attributes and their levels used in this DCE.

To quantify consumer preferences from the DCE, a Bayesian D-efficient experimental design was used to collect respondents' choice decisions. With the four attributes (production method, origin, type of producers, and price) and three levels per attribute, there are $3^4 = 81$ possible combinations of the attributes and levels. To reduce workload and complexity for participants in a choice experiment, we implement an experimental design that ensures the balance of the attributes and orthogonality of choices while reducing the number of choice sets and the number of choices within each set. There are two stages of the implementation of a Bayesian efficient design. During the first stage, we did a pilot test of the choice experiment with a convenience sample of 30 people to obtain prior information on consumer valuation of

[3]Missouri Grown, an outreach program through the Missouri Department of Agriculture that promotes products grown, raised, or produced and processed in Missouri. Paid members of the program can use the Missouri Grown logo or label on their products (Missouri Grown USA, 2022).

[4]The concept of 'local' remains unclear in the literature. In our survey, while a majority of the respondents define 'local' based on various distances from their residence or even within the state, about one third consider family-owned as a characteristic of 'local' products.

[5]The price levels are equivalent to $4.39, $6.59, and $8.80 per kilogram (kg), respectively.

Table 2. Tomato attribute levels

	Levels		
Attributes	Level 1	Level 2	Level 3
Production method	Organic	50% Reduced pesticide*	Conventional
Label	Local	Missouri Grown	Neither 'Local' nor 'Missouri Grown'
Farm type	Small & medium family	Large family	Large corporation
Price of tomatoes	$1.99/lb.	$2.99/lb.	$3.99/lb.

Notes: (*) the 50% reduced pesticide techniques can be defined as the methods farmers use to reduce by half the pesticide amounts usually used in tomato cultivation.

the attributes. In the second stage, we used these prior values to create a Bayesian D-efficient design which minimized the mean D-error[6] over the prior reference distribution (Traets, Sanchez, and Vandebroek, 2020). The obtained DCE design produced the smallest Bayesian D-error at 0.71 and statistical efficiency[7] of 98.6%. Specifically, for each of nine scenarios, respondents were asked to choose one option among three tomato alternatives or opt-out ('None of these') (the order of scenarios is randomized on the Qualtrics platform[8]). An example of a scenario is provided in Table 3.

Table 3. A scenario in the choice experiment for tomato consumers

Option A	Option B	Option C	
Organic	Conventional	50% Reduced pesticide	
Not local or Missouri Grown	Local	Missouri Grown	
Large family	Large corporation	Large family	
$2.99/lb	$3.99/lb	$1.99/lb	
Which choice for buying tomatoes would you prefer?			
∘ Option A	∘ Option B	∘ Option C	∘ None of them

Data and empirical model

Data

We implemented the choice experiment in the context of an online survey from November 2021 to March 2022. Prior to the final survey, a pretest was conducted with 100 participants from one of our institutions. The results of the pretest were used to improve the presentation of important concepts in the study, including 50% reduced pesticide use as usual, CA, local, and Missouri Grown statements, as well as to refine questions that allowed us to examine the overlap between local and Missouri Grown, local and organic, and environmental attitudes. Also, we changed the matrix of questions into two different versions: mobile-friendly and desktop and set an appropriate time for scenarios to increase the participation and completion rate of the experiment and the survey. We also examined the validity and reliability of the DCE preference results.

We used Amazon's Mechanical Turk (MTurk)[9], an online survey platform, to recruit respondents for the survey. As suggested by recent studies, MTurk samples are found to be a robust alternative to common online samples in the health and medical context or the grocery shopping context (Ouyang and Sharma, 2019, Grashuis, Skevas, and Segovia, 2020). MTurk's respondents needed to satisfy the following requirements: at least 18 years old, residents of Missouri, primary grocery shoppers of their households, and consumed fresh tomatoes in the past 12-month period. There were 411 participants in the survey, but only 343 met our requirements (tomato buyers in the past 12 months and passed the attention check) and completed the DCE. Since respondents stated their choices over nine scenarios, the total number of unique choice observations for the sample is 343*9 = 3087. The dataset also included the demographics of the respondents.

Empirical model

Analysis of consumer preference for food attributes using the DCE data is strongly grounded in Lancaster consumer theory (Lancaster, 1966) and random utility theory (McFadden, 1974). In our experiment, hypothetical consumers or participants made discrete choices among tomato options that varied in levels of production method, origin location, producer type, and price attributes. Thus, assuming preferences are randomly distributed over subjects and heterogenous across consumers, the random utility model is an appropriate econometric approach to obtain estimates of consumer preference parameters and their WTP for '50% reduced pesticide use,' all else equal.

Typically, the utility of respondent '*i*' choosing alternative '*j*' in the choice task '*t*' can be partitioned into two separate components: an observed component V_{ijt} and an unobserved component ε_{ijt}, so that

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} \quad (1)$$

The discrete choice modeling of utility can be described as:

$$U_{ijt} = ASC + \beta' x_{ijt} + \varepsilon_{ijt} \quad (2)$$

where ASC is an alternative-specific constant representing the opt-out option; x_{ijt} are observed or determined attributes of the alternative; $\beta^{'}$ are alternative specific attribute parameters; ε_{ijt}

[6]D-error measures how good or bad a design is at extracting information from respondents in an experiment. Lower D-error indicates a better design (Walker et al., 2018).

[7]Statistical efficiency measures how well a fractional factorial design can represent all possible combinations of attributes and attribute levels (Vanniyasingam et al., 2018). The efficiency score ranges from 0–100%, with higher score indicates lower bias of the design selected.

[8]Qualtrics is a web-based survey software or tool that allows users to create, administer, and analyze online surveys with various features and options. In this research, we used customizable templates of the Qualtrics to manage scenarios of the DCE.

[9]Mturk is a platform provided by Amazon Web Services that allows users to create surveys and recruit participants who are qualified based on user criteria (more details in the Introduction to Amazon Mechanical Turk (Amazon Web Services, 2017)). For this research, we posted the link to the survey stored on Qualtrics and used Mturk to crowdsource the survey, collect the data, and compensate respondents.

are random errors. Given the attributes of the study, the basic or baseline model (3) is specified below:

$$\begin{aligned} Utility\ (choice) = {} & OptOut + \beta_1 Price + \beta_2 Organic \\ & + \beta_3 50\%ReducedPesticide \\ & + \beta_4 Local + \beta_5 MissouriGrown \\ & + \beta_6 SmallFamily + \beta_7 LargeFamily + \varepsilon \end{aligned} \tag{3}$$

where *OptOut* is an intercept term that captures the utility associated with the opt-out option, *Price* is a continuous variable that represents the price attribute. *Organic* and *50% ReducedPesticide* are dummy variables that represent organic and 50% reduced pesticide production compared to the base of conventional production. *Local* and *MissouriGrown* are dummy variables that represent origin labels with the base of neither local nor Missouri Grown. *SmallFamily* and *LargeFamily* are dummy variables that represent small & medium family farms and large family farms vs large corporations. β_k ($k = 1, \ldots, 7$) represent the utility model coefficients associated with price and non-price attributes, and ε is the error term. The mixed logit approach enables the incorporation of both fixed and random effects. *OptOut* and the price coefficient are assumed to be constant. All other parameters are assumed to vary across the sample and follow a normal distribution with the mean μ and the variance σ^2, N (μ, σ^2) for the assumption of heterogeneity in consumer preferences, representing fixed and random effects in the mixed logit approach, respectively (Bansal, Daziano, and Achtnicht, 2018).

Also, an extended model (4) is specified by adding interaction terms between production methods and origin labels to the baseline to examine WTP for combinations of 50% reduced pesticide and local or Missouri Grown and how they differ from organic and local or Missouri Grown tomatoes. As previously mentioned, empirical evidence showed that organic and local attributes could be complements or substitutes (e.g., Gracia, Barreiro-Hurlé, and López-Galán, 2014; Meas et al., 2015; Winterstein and Habisch, 2021). The extended model (4) is presented as follows:

$$\begin{aligned} Utility\ (choice) = {} & OptOut + \beta_1 Price + \beta_2 Organic \\ & + \beta_3 50\%ReducedPesticide \\ & + \beta_4 Local + \beta_5 MissouriGrown \\ & + \beta_6 SmallFamily + \beta_7 LargeFamily \\ & + \beta_8 Organic \times Local \\ & + \beta_9 50\%ReducedPesticide \times Local \\ & + \beta_{10} Organic \times MissouriGrown \\ & + \beta_{11} 50\%ReducedPesticide \times MissouriGrown \\ & + \varepsilon \end{aligned} \tag{4}$$

The WTPs for an attribute in the basic and extended models were derived from estimated distributions of the attribute coefficient and price coefficient. By definition, WTP represents a trade-off between an attribute of interest and its cost and describes how much the cost attribute would be required to change given a change in the interest attribute, such that the change in total utility will be zero. Under our specifications, the WTP for the attribute of interest, x_k, is calculated by taking the ratio of the derivative of the utility with respect to changes in x_k and the derivative of the utility with respect to *Price,* which is given by Equation (5) (e.g., Hensher, Rose, and Greene, 2015; Train, 2009).

$$WTP_k = \frac{\partial U_{ijt} / \partial x_k}{\partial U_{ijt} / \partial Price} = \frac{\beta_k}{\beta_1} \tag{5}$$

where β_1 and β_k represent the marginal utility of price and the attribute, x_k, that are estimated from Equation (3) and Equation (4) as previously mentioned.

Results

Descriptive statistics

Table 4 reports summary statistics for the demographic variables in the sample. A slight majority of respondents are female (56.0%), which is expected for household shoppers. Participants ranged in age from 18 to 85, with a median age of 35 and a median annual income of $58,900. By comparison, the median age and the median annual income for the Missouri population are 38 and $61,043 (U.S. Census Bureau, 2022). The sample is more educated than the Missouri population, as 65.9% of respondents have attained at least a bachelor's degree. Most respondents are Caucasian (79%). Almost 42% of respondents live in a suburban area, while a fourth live in rural areas. Almost half (48.5%) of respondents indicated they have at least one child under the age of 17. In general, the demographic characteristics of our sample are similar to recent consumer studies in Missouri (e.g., Grashuis and

Table 4. Summary statistics

Demographic characteristics	Sample (*N* = 334)	Missouri
Gender		
Male	43.2%	48.6%
Female	56.0%	51.4%
Age (median in years)	35	38
Income (median in $1000)	58.9	61.0
Education		
High school and less	21.0%	59.0%
2 year/Associate's degree	13.1%	11.0%
4 year/Bachelor's degree	41.7%	20.0%
Graduate or professional degree	24.2%	10.0%
Ethnicity		
Caucasian	79.0%	88.0%
African American	12.0%	8.0%
Others	9.0%	4.0%
House location		
Rural	25.1%	30.6%
Suburban	41.7%	55.2%
Urban	33.2%	14.2%
Children		
No children under 17	51.5%	68.1%
At least 1 child under 17	48.5%	31.9%

Source: Own data and Missouri Census Data Center (7 July 2022).

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Su, 2022), and, other than education level, and are reasonably comparable to the Missouri population (Table 4).

Estimates of empirical model and discussion

Results of the baseline and extended empirical models are obtained by the maximum likelihood estimation method (e.g., Train 2009). Estimates of preference parameters, standard deviations for the attributes, and model statistics for both baseline and extended models are presented in Table 5. (Derived WTP estimates are presented in Table 6). The two models are statistically significant at the 1% level, confirming that the specifications are acceptable. Also, most standard deviations of the attribute coefficients are significant, indicating heterogeneity in consumer preferences as expected (Bansal, Daziano, and Achtnicht, 2018), which implies the appropriateness of the mixed logit approach for the study. Looking at goodness-of-fit statistics, the extended model has higher Log-likelihood, higher pseudo-R^2, and lower Akaike information criteria (AIC) than those of the baseline model, indicating that the extended model fits slightly better (Table 5). Given the fact that the estimates are robust across the models, model performance can be improved when accounting for the interactions of interest, which also provides more policy-relevant implications in terms of substitutes or complements for the 'production method' and 'origin' attributes.

Preferences

In the extended model, all the estimates (except the interaction between organic and Missouri Grown) are statistically significant at conventional critical levels. The constant for the opt-out option is negative, indicating a lower utility associated with the 'none of these' choice. This is a common result in past studies using DCE, where consumers are expected to prefer buying rather than choosing opt-out (e.g., Bazzani et al., 2017). Also, the price coefficient is negative, implying that an increase in price decreases utility or the disutility effect of price. Consumers will prefer alternatives with lower

Table 5. Mixed logit regression results

	Baseline model		Extended model	
Attribute-specific variables	Coefficients	Error	Preferences	Error
Opt-out	−4.398***	0.144	−4.738***	0.171
Price	−0.797***	0.035	−0.915***	0.050
Organic	0.459***	0.040	0.509***	0.038
50% Reduced pesticide use	0.126**	0.043	0.097**	0.046
Local	0.109***	0.039	0.154***	0.046
Missouri Grown	0.440***	0.038	0.513***	0.044
Small, medium family farm	0.278***	0.038	0.258***	0.047
Large family farm	0.295***	0.035	0.294***	0.046
Interaction terms				
Organic × Local			−0.227***	0.070
50% Reduced pesticide use × Local			0.143**	0.068
Organic × Missouri Grown			0.021	0.056
50% Reduced pesticide use × Missouri Grown			0.110*	0.067
Heterogeneity (Standard deviation)				
Organic	0.634***	0.051	0.629***	0.051
Reduced 50% pesticide use	0.355***	0.075	0.368***	0.074
Local	0.245**	0.108	0.232**	0.113
Missouri Grown	0.415***	0.069	0.429***	0.069
Small, medium family farm	0.541***	0.061	0.529***	0.063
Large family farm	0.055	0.153	0.061	0.151
Model statistics				
Log-likelihood	−3161		−3153	
Wald χ^2 (df)	211(6)		206(6)	
Pr (>χ^2)	0.000***		0.000***	
AIC	6349		6341	
Pseudo-R^2	23.8%		24.0%	
Number of observations	3087		3087	

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

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Table 6. Willingness-to-pay estimation results

Attribute-specific variables	Derived WTP from baseline model		Derived WTP from extended model	
	Estimates	Error	Estimates	Error
Organic	0.576***	0.047	0.556***	0.041
50% reduced pesticide use	0.158**	0.049	0.106**	0.050
Local	0.137***	0.054	0.168***	0.050
Missouri Grown	0.551***	0.048	0.561***	0.044
Small, medium family farm	0.277***	0.047	0.282***	0.047
Large family farm	0.315***	0.049	0.322***	0.050
Interaction terms				
Organic × Local			−0.249***	0.070
50% Reduced pesticide use × Local			0.157**	0.071
Organic × Missouri Grown			0.023	0.062
50% Reduced pesticide use × Missouri Grown			0.120*	0.072
Heterogeneity (Standard deviation)				
Organic	0.710***	0.065	0.658***	0.062
Reduced 50% pesticide use	0.397***	0.090	0.385***	0.078
Local	0.275**	0.133	0.242**	0.122
Missouri Grown	0.465***	0.085	0.449***	0.075
Small, medium family farm	0.606***	0.076	0.553***	0.071
Large family farm	0.062	0.192	0.064	0.164

prices holding other attributes constant. The coefficients for all non-price attributes are positive, suggesting higher perceived utility derived from these attributes compared to the corresponding reference attribute levels. Consumers have higher preferences for tomatoes carrying organic, 50% reduced pesticide use, local, or Missouri Grown labels, or those produced by small/medium, or large family farms than their counterparts (conventional, neither Missouri Grown nor local, corporations). Put differently, given 'conventional' as the reference level for production methods, consumers are more likely to choose organic or 50% reduced pesticide use rather than conventional tomatoes. While previous studies often compared organic or sustainable with conventional claims (e.g., Biguzzi et al., 2014; Skreli et al., 2017; Printezis and Grebitus, 2018), our findings from the consideration of three production methods at the same time are consistent with premiums for environmentally friendly practices with respect to conventional use. Regarding origin labels, consumers are more likely to buy local or Missouri Grown tomatoes than non-local or non-Missouri Grown ones. These results align with the literature on consumer preferences for local food, where consumers often tend to support the local economy and community (e.g., Carroll, Bernard, and Pesek, 2013; Meyerding, Trajer, and Lehberger, 2019; Grashuis and Su, 2022). Finally, using 'large corporation' as the reference level for the type of producers, consumers are more likely to choose small & medium or large family farms rather than large corporations for tomato purchases. The link between 'local' and 'family-owned farms' has been addressed in the literature where consumers support local farmers or local producers to strengthen local community ties (e.g., see the review of Enthoven and Van den Broeck, 2021).

Regarding our focus on reduced pesticide attributes, 'organic' has a bigger effect on consumer preferences than '50% reduced pesticide use', on average 0.509 vs 0.097, with respect to conventional fresh tomatoes (significant difference with $P < 0.05$ for the Wald test—the test for equality of coefficients in the model of interest) (Table 5). This is not surprising since organic food has broader benefits than pesticide reduction since synthetic fertilizers and genetically modified organisms (GMOs) are also not allowed for organic food production. Consumers may consider organic to have health and environmental benefits while also potentially being more nutritious than 'non-organic' (e.g., Magkos, Arvaniti, and Zampelas 2003; Lairon 2011; Vinha et al., 2014). Our result is in line with Biguzzi et al. (2014), which showed consumers prefer organic to IPM tomatoes, even if organic tomatoes are more expensive.

While '50% reduced pesticide use' is less important than 'organic' in driving consumer preferences for fresh tomatoes in terms of production method, the combinations of 50% reduced pesticide and local or Missouri Grown labels have complementary effects. A positive interaction effect between '50% reduced pesticide use' method and 'local' origin label indicates consumers prefer this combination over '50% reduced pesticide use' tomatoes that are not locally produced. Similarly, consumers prefer 'Missouri Grown' and '50% reduced pesticide use' tomatoes rather than those from other states or countries. Consumers are willing to pay more for 50% reduced pesticide tomatoes that are also local (0.143) or Missouri Grown (0.110), with little difference between local and Missouri Grown labels (Table 5). However, surprisingly, this is not the case for organic tomatoes. Table 5 shows a negative interaction effect between 'organic' and 'local' attributes (−0.227), suggesting consumers have a lower preference for local organic tomatoes compared to those without a local or Missouri Grown label. The interaction between 'organic' and 'local' has been examined but remains indeterminant in the literature. In some past studies, the interaction between organic and local attributes is not statistically significant (e.g., Onozaka and McFadden 2011; Bazzani et al., 2017). In other studies, the interaction is significantly positive (e.g., Gracia, Barreiro-Hurlé, and López-Galán, 2014; Winterstein and Habisch, 2021) or significantly negative (e.g., Meas et al., 2015). In our study, the result is in line with the studies showing substitution rather than complementary effects between 'organic' and 'local' claims. The substitution effect may exist when consumers consider 'local' to share several characteristics of 'organic' and vice versa (USDA, 2016), or the existence of a third factor, like supporting small and family-owned farms, that may imply both 'organic' and 'local' attributes (Meas et al., 2015), or due to heterogeneity in consumer preferences for 'organic' where consumers who support 'local' do not prefer 'organic' (Govindasamy et al., 2017; Kim, Brorsen, and Lusk, 2018). Thus, '50% reduced pesticide use' tomatoes differ from organic ones. The 'reduced pesticide' and 'local/ Missouri Grown' attributes are complements, while the 'organic' and 'local' claims are substitutes in this study.

As expected for the mixed logit approach, the models capture unobserved heterogeneity in consumer preferences. The estimates of standard deviations for 'organic,' '50% reduced pesticide use,' 'local,' 'Missouri Grown,' and 'small & medium family farm' are significant, indicating the individual coefficients of these attributes differ across the population. In other words, consumers, on average, prefer organic or reduced pesticide use over the conventional method, local or 'Missouri Grown' label over the 'neither local nor Missouri Grown' one, and small & medium family farm over large corporation, but these preferences do not necessarily hold for all consumers. Regarding reduced pesticide use, the finding that preferences and WTPs for organic tomatoes may differ across the sample is consistent with past studies (e.g., Emberger-Klein, Zapilko, and Menrad, 2016; Pishbahar, Mahmoudi, and Hayati, 2019). For example, Pishbahar, Mahmoudi, and Hayati (2019) indicated higher income, older, and more knowledgeable consumers have higher WTP for organic tea in Tehran. However, in the work of Emberger-Klein, Zapilko, and Menrad (2016), several consumers even preferred conventional agricultural products over a GMO and an organic variant of the same products in Germany. In this study, we confirm the presence of heterogeneity in consumer preferences for organic and reduced pesticide tomatoes. In addition, consumers are less heterogeneous in terms of WTP for 50% reduced pesticide use rather than for 'organic,' i.e., the standard deviation of 50% reduced pesticide use is 0.368 vs 0.629 for organic (Table 5).

Willingness-to-pay

In the analysis of consumer preferences, WTP measurment is of interest for two essential reasons. First, WTP provides a valuable tool to quantify the value of non-market goods or characteristics. Second, WTP is measured in monetary terms, which is useful for marketing strategies and relevant policies. Using the standard approach for the derivation of WTP in preference space as described by Train (2009), we calculated the mean and standard deviation of WTP values for each coefficient estimate (noting that, given the assumptions of the empirical models, the WTP estimates follow a normal distribution). The derivation results show that most WTP values are statistically significant and consistent with the preference results (Table 6).

Among attributes, the highest mean WTP is for 'Missouri Grown' at 56 cents/lb., followed closely by 'organic,' and then 'large family,' 'small & medium family,' 'local,' and '50% reduced pesticide use' with WTP of 56 cents/lb., 32 cents/lb., 28 cents/lb., 17 cents/lb., and 11 cents/lb., respectively (Table 6 of the extended model). Regarding the production method attribute, the mean WTP results indicate consumers would pay a much higher premium for 'organic' than '50% less pesticide' compared to 'conventional', 56 cents/lb. vs 11 cents/lb. Using a reference price of $1.99/lb. for conventional tomatoes, this is equivalent to a premium of 28% for 'organic' vs 6% for '50% reduced pesticide.' The findings are consistent with a past study that found the premium for 'organic' is about 30% of the regular price on average (Li and Kallas, 2021), and the price for 'reduced pesticide' produce is closer to the price of conventional compared to the price of organic (Marette, Messéan, and Millet, 2012). For the other attributes, the results also show big differences in the premium for 'Missouri Grown' vs 'local,' 56 cents/lb. vs 17 cents/ lb., while all family farms receive the same premiums of about 30 cents/lb. compared to a large corporation.

A positive (negative) interaction term of WTP suggests a higher (lower) WTP for the interaction than the sum of WTP associated with the attributes. In this regard, there is a larger premium for '50% reduced pesticide use' tomatoes that have a local or Missouri Grown label, which indicates positive interaction effects. Table 6 indicates the mean WTP for a combination of 'reduced pesticide and local' is 16 cents/lb. higher than the sum of WTP associated with 'reduced pesticide' and 'local' tomatoes (28 cents/lb.), leading to a WTP for this combination of 44 cents/lb. on average. Similarly, the mean WTP for a combination of 'reduced pesticide and Missouri Grown' is 79 cents/lb., which is 12 cents/lb. higher than the sum of WTPs of 'reduced pesticide' and 'Missouri Grown' tomatoes (67 cents/lb.). Thus, this implies a possible niche market for reduced pesticide tomatoes with either type of origin label. However, this is not the case for 'organic'. A negative WTP for 'organic and local' (−25 cents/lb.) indicates the premium for this combination decreases to 48 cents/lb., given the sum of WTPs of 'organic' and 'local' tomatoes (73 cents/lb.). The results indicate complementarity between 'reduced pesticide' and 'local' or 'Missouri Grown' but substitution between 'organic' and 'local.'

Conclusions

This study uses DCE to investigate consumer preferences for fresh tomatoes with different attributes. Results from the online survey show that consumers are willing to pay higher prices for organic and reduced pesticide use tomatoes compared to conventional ones, for both local and Missouri Grown labels compared to unlabeled tomatoes, and for any size family farm compared to a large corporation. The research contributes to the sparse literature on the demand for reduced pesticide use produce. However, the price premium for '50% reduced pesticide use' is low compared to organic, meaning the price of reduced pesticide tomatoes would be closer to conventional than organic, *ceteris paribus*. While both organic and reduced pesticide produce address health and environmental quality, consumers may be aware that organic farming provides a wider range of benefits than 'reduced pesticide' only, leading to a larger premium for organic produce. A finding that is useful for producers and marketers of more environmentally friendly produce is that the reduced pesticide claim is a complement to local or Missouri Grown labels: the producers earn an additional premium when the produce has lower pesticides as well as being local/Missouri Grown. Reduced pesticide and local/state labels are thus complements, while organic and local labels are substitutes. As indicated by past studies, organic and local attributes may overlap, resulting in a reduction in the total premiums for the two attributes. Comparing both reduced pesticide and organic labels with origin labels enabled us to examine magnitudes of effects as well as interactions between these characteristics. We also found that the organic characteristic had the most heterogeneous WTP.

The information from our study can be used by farmers to inform both their production practices and marketing. While fairly substantial pesticide reductions are needed to earn a premium, growers who reduce pesticides and also market their products based on locational characteristics can earn a higher premium. Our research also implies nationwide markets for those reducing but not eliminating pesticides may be limited. It also implies that farmers who essentially produce organically but want to avoid costly certification procedures can benefit from local labels.

Our findings also have implications for organizations that develop marketing strategies and programs for family farmers. The high WTP for certified organic tomatoes indicates the success of that label. Labels like Missouri Grown also have value for farmers. Policy makers of state agricultural marketing promotion programs like Missouri Grown can build on the success of the state logo and inform local producers interested in reducing chemical use about the complementary effect of these claims. Reduced pesticide produce is viewed as distinct from both organic and conventional produce, and the product can have a market share. However, production practices like IPM that reduce pesticide use would benefit from labels that provide clarity for both producers and consumers. Hence, it is critical to develop labels with clear or explicit information on pesticide use to facilitate markets for this type of product. Finally, heterogeneity in consumer preferences for both organic and reduced pesticide claims supports the existence of various consumer segments. If they can be identified, farmers can improve their bottom line and possibly reduce the negative impacts of pesticides on people and the environment.

Future research on this topic could identify determinants of this heterogeneity, for example, identifying characteristics of consumers who are willing to pay higher prices for reduced pesticide, but not fully organic, produce. Also, more research might be needed to design a reduced pesticide use label. Our research implies that consumers don't have a neat utility function regarding pesticides where a little less pesticide is a little more preferred. Therefore, examining the WTP for other levels of pesticide reduction, e.g. 75%, may be useful. A study with a pesticide reduction of 100%, rather than using the organic label, may be able to more clearly separate the effect of not using commercial pesticides from the other attributes of organic produce. The optimal design of a label would also consider the costs to farmers of attaining these reductions, as well as the environmental and consumer benefits.

While the findings contribute to the literature on WTP for produce attributes, this research has several caveats or limitations. Including a limited number of attributes in the experiment is statistically necessary but also helps to reduce the complexity of decision-making, especially under the time restrictions of online surveys. However, production methods may affect some other features of vegetables and fruits, e.g., appearance, taste, and freshness, that were not examined in this research.

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