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Biotechnology to sustainability: Consumer preferences for food products grown on biodegradable mulches

Kuan-Ju Chen[a,*], Thomas L. Marsh[a], Peter R. Tozer[b], Suzette P. Galinato[c]

[a] School of Economic Sciences, Washington State University, United States
[b] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[c] IMPACT Center, School of Economic Sciences, Washington State University, United States

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ABSTRACT

This study evaluates consumer preferences for an agricultural product grown on biodegradable mulch film, which is an environmentally friendly soil cover that sustains plant growth, but that avoids the environmental harm of plastic pollution from non-biodegradable mulches in the field or upon disposal. Using a dichotomous-choice contingent valuation method, we assessed the willingness to pay for strawberries grown on biodegradable mulch with a randomized information treatment on 1510 consumers across different regions of the United States. On average, consumers are willing to pay 10.3% more for food –strawberries in our case– grown on biodegradable mulches. Consumers who are female, earn a higher income, have stronger environment-friendly attitudes, or received the information treatment on the benefits of biodegradable mulches, also expressed more willingness to pay a premium price for strawberries grown on biodegradable mulches. Our findings support that consumers are willing to internalize a price premium for food products on biodegradable mulches, suggesting that agricultural producers could realize private benefits from price premiums that could, in turn, generate social benefits by increasing biodegradable mulch use, leading to a reduction of plastic pollution. By providing empirical evidence on the potential adoption of biotechnology in the food production system, our results allow agricultural crop producers to make more informed decisions on growing and pricing strategies. Our research will also facilitate agricultural scientists and policymakers to articulate industry-supporting policies for sustainable development.

1. Introduction

Consumer preferences for environmentally friendly products support a sustainable food chain from the producer to the retail market. Shifts in environmental attitudes underlie the development of recycled products, innovative bio-technologies, and the proliferation of environmentally friendly products (Mobley, Painter, Untch, & Rao Unnava, 1995; Tsen, Phang, Hasan, & Buncha, 2006). In particular, this trend reflects consumer behavior for purchasing green products at a price premium, that is, at a price above that the consumer would pay for conventional products (Laroche, Bergeron, & Barbaro-Forleo, 2001; Straughan & Roberts, 1999; Yue et al., 2010; Yue et al., 2016). In this paper, we focus on how consumer preferences for biodegradable mulches as soil covers sends price signals to upstream firms to make more sustainable decisions that reduce plastic pollution.

Plastic pollution in agricultural soils is an important environmental issue with uncertain and complex policy solutions (Brodhagen et al., 2017). Despite the advantages of conventional plastic mulches, for instance, reducing weed growth, increasing crop yield, and improving water-use efficiency; residual fragments from conventional plastic mulches may remain in the ground, potentially contaminating the soil and suppressing crop growth. Scarascia-Mugnozza, Sica, and Russo (2012) point out issues of plastic mulches due to residual fragments in the soil and with plastic waste collected from the field. In agriculture the removal and disposal process of conventional plastic mulches is labor-intensive and costly, and the cost of plastic disposal and recycling is exacerbated by soil and agrochemical contamination. Steinmetz et al. (2016) investigate the comparison between short-term agronomic benefits and long-term soil degradation of using plastic mulches in agriculture, and found that mulch films could decrease soil quality in the long-term due to non-biodegradability from plastic fragment residuals.

Total use of plastics in the U.S. increased to a historic peak of $295.4 billion in 2015 (Barron, 2016). Moreover, plastic use in agriculture is

* Corresponding author.
E-mail addresses: kuan718.chen@wsu.edu (K.-J. Chen), tl_marsh@wsu.edu (T.L. Marsh), P.Tozer@massey.ac.nz (P.R. Tozer), sgalinato@wsu.edu (S.P. Galinato).

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projected to increase to meet world food demand. The agricultural films market is expected to surpass 9.2 million tons in production and exceed $15.13 billion in value by 2024 due to expanding production of high-quality crops (Global Market Insights Inc., 2016). As a result, conventional plastic use and its potential pollution will likely continue to increase, accentuating the need for innovative biotechnologies.

Biodegradable mulches (BDM) are an innovative bio-technology intended to retain the productive characteristics of conventional plastic mulches. ASTM International (2011) defines BDM as a type of plastic material that degrades from the process of naturally occurring micro-organisms, such as bacteria, fungi, and algae. Field studies have compared BDM with conventional plastic mulches in impacts on yield and crop quality (Arméndariz, Macua, Lahoz, Santos, & Calvillo, 2006; Candido, Miccolis, Castronuovo, Margiotta, & Manera, 2006; Martín-Closas, Bach, & Pelacho, 2008; Miles et al., 2012; Moreno, Moreno, & Mancebo, 2009; Olsen & Gounder, 2001; Rangarajan & Ingall, 2006), efficacy for weed suppression (Anzalone, Cirujeda, Aibar, Pardo, & Zaragoza, 2010; Jenni, Brault, & Stewart, 2004; Minuto, Guerrini, Pini, & Capurro, 2008), and functional performance and degradability (Briassoulis, 2006; Cascone, D'Emilio, Buccellato, & Mazzarella, 2008; Kapanen, Schettini, Vox, & Itävaara, 2008; Kijchavengkul, Auras, Rubino, Ngouajio, & Fernandez, 2008; Ngouajio et al., 2008; Scarascia-Mugnozza et al., 2006; Tocchetto, Benson, & Dever, 2001). For example, Anzalone et al. (2010) evaluate weed control and crop yield in processing tomatoes comparing several biodegradable mulch materials and conventional plastic mulches. They found that paper mulches outperform BDM in terms of weed control and tomato yield in Spain. Devetter, Zhang, Ghimire, Watkinson, and Miles (2017) select strawberries as an experimental crop to measure mulch performance, weed suppression, marketable yield, plant biomass, and fruit quality compared different commercial plastic and paper biodegradable mulch products with conventional plastic mulches. They suggested BDM products are sustainable for conventional strawberry production in the U.S. Pacific Northwest Region. Summarizing, BDM may be a viable alternative to conventional plastic mulches because of the similarities in the two types of mulches in terms of color, texture, thickness, elasticity, and installation time. Paper mulch will be difficult to place in the field especially in raised beds due to the paper's inelasticity (Coolong, 2010). Commercially, almost all strawberries in the U.S. are produced using raised beds and covered with plastic mulch (Devetter et al., 2017; UF IFAS, 2018). Some advantages of BDM are the mitigation of plastic pollution and sustainability of specialty crop production (Brodhagen et al., 2017; Corbin et al., 2013). Brodhagen et al. (2017) discuss the importance and use of standards to mitigate plastic pollution surrounding BDM up the supply chain, but they do not address the role of consumers in the pollution policy agenda down the supply chain. Our study shows how a price premium derived from consumers' willingness to pay (WTP) could generate a higher revenue for growers. In turn, this may induce producers to adopt BDM in their production processes, despite being more expensive (1.8 to 6 times) than conventional plastic mulches (Chen et al., 2018).

In the current study, BDM are proposed as an alternative to conventional petroleum-based mulches. It is biodegradable in the field, which mitigates pollution and saves disposal costs from combustion or disposal. It also saves time and the labor cost to remove mulch at the end of the production season. Biodegradable polymers are an enhanced material from the sustainability and industrial-ecology points of view due to the ease of disposal at the end of productive life. In addition, biodegradable polymers lower cumulative energy use and greenhouse gas emissions (Dornburg, Lewandowski, & Patel, 2003). Other studies have compared bio-based products and petroleum-based products, where the former is considered to be a sustainable substitute for the latter (Hayes et al., 2012). For instance, Khoo, Tan, and Chng (2010) concluded that bio-bags are 80% more environmentally friendly than plastic bags when clean and renewable energy is used throughout their life-cycle production stages.

We chose to focus on strawberries because they are a high-value crop in the United States that provide an ideal case study for several reasons. Strawberries are mostly grown with conventional mulch covers. The United States is one of the largest strawberry producers in the world, accounting for approximately 28% of total production (Wu, Guan, & Whidden, 2012). Annual U.S. strawberry production averaged 1.26 million tons between 2000 and 2015, and the production of strawberries in 2015 totaled 1.54 million tons, representing a 2% increase from 2014 (National Agricultural Statistics Service, 2016). Total harvested acres moderately varied in the past 15 years, averaging 53,900 acres and an average yield of 23.17 tons per acre (National Agricultural Statistics Service, 2016). According to the Non-citrus Fruits and Nuts Summary report of the National Agricultural Statistics Service (2016), the monthly average retail price per pound of strawberries was $3.42/pound in 2015 compared to an average of $2.57/pound between 2000 and 2015. California and Florida are the top two strawberry producing states, with California producing over 91% of strawberries in the U.S. Over the last decade, the U.S. strawberry industry has experienced an upward trend in per-person consumption, which is attributed to increased awareness of healthy diet, expanded domestic supply driven by yield improvements, and year-round availability of imports (Economic Research Services, 2014).

Using a dichotomous-choice contingent valuation methodology, the current study identifies consumer preferences for food grown on BDM, as well as factors that determine their WTP, and quantifies the WTP premiums for the new technology. Based on sample surveys of 1510 randomly selected consumers, we found that consumers are willing to pay a premium of 8.6% - 12.6% to purchase strawberries grown on BDM, compared to those grown on conventional mulches. As farmers can command higher revenue from consumer preferences for environmentally friendly production methods, it becomes feasible for farmers to use BDM despite being 1.8 to 6 times more expensive than their conventional counterparts. In particular, higher income, positive information, female indication, and environmental consciousness also make a positive contribution to consumer WTP for strawberries grown on BDM. In summary, our study informs industry stakeholders or policymakers on the important attributes that are valued by environmentally conscious consumers.

The remainder of this article is organized as follows. Section 2 presents the empirical methodology and Section 3 summarizes the data and the collection process. Section 4 analyzes the results, followed by section 5 which concludes with policy implications.

2. Method

The consumer survey solicited information on respondents' WTP for strawberries grown on BDM, shopping habits, environment-friendly attitudes, and demographic characteristics. Prior to fielding the survey, a pre-test sampling was completed and minor modifications were made. The survey, consisting of 21 questions, was then disseminated online using Qualtrics™ in August 2016. Participants were randomly selected across different regions of the United States, with each participant receiving a cash incentive upon survey completion. On average, it took 10 to 15 min for a participant to complete the survey.

WTP analysis is commonly adopted in estimating the value consumers place on environmentally friendly products, such as apples, coffee, etc. (e.g., Laroche et al., 2001; Loureiro, McCluskey, & Mittelhammer, 2001; Royne, Levy, & Martinez, 2011; Sörqvist et al., 2013). The dichotomous-choice Contingent Valuation (CV) method was used in the analysis of the factors that affect consumers' choices to estimate the WTP for strawberries grown on BDM that use environmentally friendly production practices. A double-bounded logit model is widely used in estimating individual WTP based on the responses to market-type questions with dichotomous choices (Kanninen, 1993; Venkatachalam, 2004), and is asymptotically more efficient than the single-bounded model (Hanemann, Loomis, & Kanninen, 1991). However, the double-bounded model might be biased due to a fixed initial bid proposed. This starting-point bias is outweighed by the gain in efficiency (Flachaire & Hollard, 2006; Hanemann et al., 1991). We used the current market price for strawberries as the initial bid, and it likely served as a reference point that consumers would be aware of in a single-bounded model.

In addition, previous studies emphasize that in decision making, consumers may adjust their WTP when provided with more information regarding product characteristics or product attributes (Chen, Anders, & An, 2013; Hellyer, Fraser, & Haddock-Fraser, 2012; Rousseau & Vranken, 2013; Vlaeminck, Jiang, & Vranken, 2014). Consequently, respondents were randomly assigned to either one of the two groups; the treatment group was provided with information on the BDM, whereas the control group was not (please see the Appendix for the specific statement).

Responses to the dichotomous choice bid questions resulted in four possible outcomes in the double-bounded model: (1) the respondent is not willing to purchase a 1-lb box of strawberries grown on BDM at the initial price (B_0) and does not want to buy it even at the discount price (B_D) (i.e., "no" to both bids); (2) the respondent is not willing to purchase a 1-lb box of strawberries grown on BDM at the initial price (B_0) but is willing to buy it at the discounted price (B_D) (i.e. "no" followed by "yes"); (3) the respondent is willing to purchase a 1-lb box of strawberries grown on BDM at the initial price (B_0) but is not willing to buy it at the premium price (B_P) (i.e. "yes" followed by "no"); (4) the respondent is willing to purchase a 1-lb box of strawberries grown on BDM at the initial price (B_0) and also willing to purchase it at the premium price (B_P) (i.e. "yes" followed by "yes"). The individual's true WTP for a 1-lb box of strawberries grown on BDM will fit into one of the following four intervals: $(-\infty, B_D)$, $[B_D, B_0)$, $[B_0, B_P)$, $[B_P, +\infty)$. For each respondent, three premium prices (increases of \$0.50/lb., \$0.75/lb., \$1.00/lb) or discounted prices (decreases of \$0.50/lb., \$0.75/lb., \$1.00/lb) were randomly assigned. The discrete outcomes of the bidding process are as follows:

$$D = \begin{cases} 1 & WTP \le B_D \quad (\text{No, No}) \\ 2 & B_D \le WTP \le B_0 \quad (\text{No, Yes}) \\ 3 & B_0 \le WTP \le B_P \quad (\text{Yes, No}) \\ 4 & B_P \le WTP \quad (\text{Yes, Yes}) \end{cases} \tag{1}$$

where WTP is the variable that denotes the individual's WTP for a 1-lb box of strawberries grown on BDM. The WTP function for individual i is represented as:

$$Y_i = \alpha - \rho B_i + \delta H_i + \lambda' Z_i + \varepsilon_i \text{ for } i = 1, 2, 3, 4 \tag{2}$$

where Y_i is the individual's WTP for strawberries grown on BDM, B_i is the ultimate bid amount offered to each consumer i, H_i is the information treatment randomly provided to the consumer, and Z_i is a vector of observable characteristics of individual i, ε_i is the error term capturing the unobservable characteristics, and α, ρ, δ, and λ are the unknown parameters to be estimated.

The probability for each discrete outcome in Eq. (1) is:

$$\Pr(Y_i = j) = \begin{Bmatrix} F(\alpha - \rho B_{Di} + \delta H_i + \lambda' Z_i) \\ F(\alpha - \rho B_{0_i} + \delta H_i + \lambda' Z_i) - F(\alpha - \rho B_{D_i} + \delta H_i + \lambda' Z_i) \\ F(\alpha - \rho B_{P_i} + \delta H_i + \lambda' Z_i) - F(\alpha - \rho B_{0_i} + \delta H_i + \lambda' Z_i) \\ 1 - F(\alpha - \rho B_{P_i} + \delta H_i + \lambda' Z_i) \end{Bmatrix} \tag{3}$$

where F(g) is a cumulative distribution function characterizing the random components of utility. Then, the log-likelihood function is shown as:

$$\ln L = \sum_{i=1}^{n} \begin{Bmatrix} I_{Y_{i=1}} \ln F(\alpha - \rho B_{D_i} + \delta H_i + \lambda' Z_i) + \\ I_{Y_{i=2}} \ln[F(\alpha - \rho B_{0i} + \delta H_i + \lambda' Z_i) - F(\alpha - \rho B_{Di} + \delta H_i + \lambda' Z_i)] + \\ I_{Y_{i=3}} \ln[F(\alpha - \rho B_{P_i} + \delta H_i + \lambda' Z_i) - F(\alpha - \rho B_{0_i} + \delta H_i + \lambda' Z_i)] \\ I_{Y_{i=4}} \ln[1 - F(\alpha - \rho B_{P_i} + \delta H_i + \lambda' Z_i)] \end{Bmatrix} \tag{4}$$

where $I_{Y_{i=j}}$ is the indicator for each j outcome ($j = 1, 2, 3, 4$) for the individual i. The function F(g) is defined to be the standard logistic distribution with mean zero and variance $\sigma^2 = (\pi/\sqrt{3})^2$.

3. Data

In total, 1510 questionnaires were randomly delivered across the United States. The sample included two information groups with 749 respondents in the treatment group and 761 respondents in the control group. Table A.1 in the appendix shows the summary statistics for consumer socio-demographic backgrounds in this study. There were 51% male and 49% female participants in the study sample, and most of the respondents (68%) did not have children under 18 years old living with them. The average age of individuals was around 40 years old, and the median age was approximately 35 years old compared to the U.S. median age of 38 years old in 2015 (United States Census Bureau, 2016a). In the sample, 12% of the respondents had advanced or professional degrees or above, 39% were bachelor's degree holders, and 38% had some type of college or associate degree. Household income ranged from less than \$29,999 to greater than \$200,000, but the majority of respondents (69%) earned less than \$70,000 annually. Half of the respondents (50%) worked in the private sector, and the majority of the sample population (77%) identified as White/Caucasian (non-Hispanic). Samples were geographically dispersed in each state in approximately equal proportions. Most of the participants were from the southern region (36%) and the western region (22%) of the U.S. Regions are defined as Northeast, Midwest, South, and West in appendix Table A.2.

Table 1 presents the comparison of census population and sample demographic statistics. Our sample is similar to the national estimates (United States Census Bureau, 2016b) in terms of median age, gender distribution, median household income, ethnic affiliations, and the percentage in geographic regions. However, the education level of the respondents was higher than the Census data with 99.6% holding a high school diploma and 50.6% with a college degree or above. The proportion of respondents who are single (never married) was 50.9%, which was higher than the national average of 32%; with the rest being married (39.1%) or separated/divorced/widowed (9.3%). In consideration of the above, our sample was broadly representative but the educational level and single respondents were slightly above compared with the national estimates. Summary statistics for shopping characteristics are presented in Table 2. The respondents paid an average price of \$3.19 per pound for good quality fresh strawberries. 93% of the respondents purchased strawberries at least every few months, and 7.1% respondents rarely purchased strawberries. 75% often bought strawberries from a retail store or supermarket, and the primary grocery shopper made up a large proportion of the sample population (86%). Also, 71%[1] of the survey sample was very likely or somewhat likely to purchase strawberries grown on BDM, and 68% had below average or no knowledge about BDM.

[1] This indicates that 71% of the respondents will not be against buying strawberries grown on BDM.

Table 1
Comparison of national estimates and sample statistics (2015).

	National estimates *	Sample statistics
Population	322,060,152	1510
Median age (years)	38	35
Variables		
Male	49.2%	51.3%
Female	50.8%	48.4%
Children under age 18 in household	40.0%	31.9%
Education		
High school diploma	87.0%	99.6%
Bachelors' degree	30.0%	50.6%
Marital status		
Single (never married)	32.0%	50.9%
Married	49.0%	39.1%
Separated/divorced/widowed	16.0%	9.3%
Median household income	$53,889	$53,758
Race		
White/Caucasian	77.1%	77.1%
Hispanic/Latino/Spanish	17.6%	5.5%
American Indian	1.2%	0.7%
African-American	13.3%	7.2%
Asian	5.6%	8.3%
Others	2.0%	1.2%
Region		
Northeast	17.5%	19.5%
Midwest	21.1%	21.5%
South	37.7%	35.8%
West	23.6%	21.6%

Source: * United States Census Bureau (2016b): www.census.gov/quickfacts/table/PST045216/00.

Table 2
Summary statistics of shopping characteristics (n = 1510).

Variable	Description	Frequency (%)
The price paying for 1 pound box of strawberries	Less than or about $2.00	6.29%
	$2.00–$2.49	20.13%
	$2.50–$2.99	32.45%
	$3.00–$3.49	21.92%
	$3.50–$3.99	10.99%
	$4.00–$4.49	4.57%
	Above $4.50	3.64%
Mean per pound for strawberries purchased	$3.19	
The frequency of buying strawberries	More than once a week	1.45%
	Once a week	19.56%
	More than once a month	27.32%
	Once a month	22.02%
	Every few months	22.55%
	Very few times	7.10%
The place of most often buying strawberries	Retail store/supermarket	74.83%
	Wholesale store	6.57%
	Convenience store	0.13%
	Organic store	6.77%
	Farmer's market	9.76%
	Others	1.93%
Primary grocery shopper	Yes	85.95%
	No	14.05%
How likely to purchase strawberries grown on BDM	Very likely	25.18%
	Somewhat likely	45.86%
	Neither likely nor unlikely	21.47%
	Somewhat unlikely	4.04%
	Very unlikely	2.19%
	Not sure	1.26%
Knowledge about BDM	Above average	1.79%
	Average	30.13%
	Below average	39.55%
	Nothing	28.53%

Factors determining respondents' strawberry purchases were measured by a five-point Likert scale (from 1 = "extremely important" to 5 = "not at all important"). According to the mean ratings, the factors that respondents perceived to be extremely or very important were, in descending order: freshness, quality, appearance, nutrition/health, price, and produced without chemicals. Environmentally friendly production practices and origin of production were perceived to be moderately important by the respondents; brand was perceived as slightly important. All details about driving factors of strawberry purchases are listed in appendix Table A.3.

Respondent perception of environmental friendliness was also measured by a five-point Likert scale (from 1 = "strongly agree" to 5 = "strongly disagree"). Results show that, on average, respondents strongly agreed that they have an opportunity to recycle products where they live. However, the mean ratings show that the respondents are impartial to other statements about recycling and environmentally friendly products. More details are presented in appendix Table A.4.

Another important variable is the WTP bid responses of the treatment group and control group that represent the value they place on strawberries grown on BDM, a more environment-friendly product than conventional mulches. The frequency of "yes" response to the initial bid ($3.50/lb) was higher in the treatment (69%) than control group (63%), while the frequency of "no" response to the second bid increased with the premium price (see appendix Table A.5).

4. Results and discussion

The estimated parameters based on Eq. (2) are presented in Table 3 together with the estimated marginal effects of selected variables and 90% confidence intervals. The explanatory variables used in the analysis are described in appendix Table A.6. The ultimate bid had a negative effect on WTP at a 1% significance level, implying that the probability of a consumer purchasing strawberries grown on BDM decreased as the bid amount increased. Information had a significantly positive effect on WTP at the 5% level, and additional information regarding BDM influenced the decision process of consumers. The marginal effect shows that the provision of information will increase WTP by $0.08/lb. for strawberries grown on BDM.

Our results show that higher income, female respondents, and increasing age had significantly positive effects on WTP at the 5% significance level. In particular, WTP will increase by $0.08/lb. due to a higher income or within the 18–35 age range, indicating that strawberries are a normal good. Consistent with the previous studies, WTP increases by $0.11/lb. for female. Gracia, De Magistris, and Nayga (2012) and Laroche et al. (2001) suggest that females are more willing to pay a premium for sustainable or green products. Also, Loureiro et al. (2001) reveal that female respondents have a higher chance of purchasing eco-labeled apples, although respondents with children are less likely to purchase eco-labeled apples. In this context, female respondents with dependents under 18 years old had lower WTP by a significant margin, decreasing by $0.17/lb. Intuitively, they need to make purchases for necessities, such as food, kitchen items, school supplies, or health care expenses, such that the residual income earmarked for purchasing the premium-priced strawberries grown on BDM would be curtailed.

More price-sensitive consumers are less likely to purchase strawberries grown on BDM, in particular, and would pay $0.35 less per pound of strawberries; this effect is statistically significant at a 1% level. Whereas, the more knowledgeable are consumers about BDM, the more likely they are to purchase those strawberries. Specifically, consumers, who are more knowledgeable about BDM, are willing to pay a

Table 3
Coefficient estimates and marginal effects of selected explanatory variables.

Variable	Coefficient	Std. error	Z-stats.	Marginal effect	Std. error	T-values	90% confidence interval	
							Lower bound	Upper bound
Constant	10.503***	0.459	22.904					
Bid	−3.004***	0.092	−32.717					
Gender	0.329***	0.127	2.589	0.110***	0.042	2.594	0.040	0.179
Age	0.239**	0.113	2.118	0.075**	0.035	2.128	0.017	0.133
Education	0.078	0.106	0.730	0.026	0.035	0.730	−0.032	0.084
Child	0.194	0.166	1.170	0.065	0.055	1.170	−0.026	0.155
Income	0.228**	0.108	2.108	0.076**	0.036	2.111	0.017	0.135
Employment	0.063	0.110	0.575	0.021	0.037	0.575	−0.039	0.081
White	−0.203	0.126	−1.611	−0.068	0.042	−1.612	−0.136	0.001
Information	0.241**	0.102	2.362	0.080**	0.034	2.365	0.025	0.136
Frequency	0.150	0.108	1.387	0.050	0.036	1.388	−0.009	0.109
Location	−0.043	0.123	−0.352	−0.014	0.041	−0.352	−0.082	0.053
Shopper	0.019	0.154	0.121	0.006	0.051	0.121	−0.078	0.090
Price importance	−1.041***	0.115	−9.085	−0.347***	0.037	−9.244	−0.408	−0.285
Origin importance	−0.101	0.145	−0.698	−0.034	0.048	−0.698	−0.113	0.045
Brand importance	0.109	0.255	0.429	0.036	0.085	0.429	−0.103	0.176
Chemical importance	0.237*	0.143	1.653	0.079*	0.048	1.654	0.001	0.157
Eco-production importance	0.603***	0.154	3.924	0.201***	0.051	3.937	0.117	0.284
Appearance importance	0.002	0.146	0.014	0.001	0.049	0.014	−0.079	0.080
Freshness importance	0.258	0.235	1.095	0.086	0.078	1.095	−0.043	0.214
Nutrition importance	0.225*	0.116	1.948	0.075*	0.039	1.949	0.012	0.138
Environmentalism	0.987***	0.124	7.935	0.328***	0.041	8.064	0.262	0.395
Knowledge	0.347***	0.114	3.029	0.115***	0.038	3.035	0.053	0.178
Northeast	0.245	0.158	1.546	0.081	0.053	1.547	−0.005	0.168
Midwest	−0.128	0.152	−0.837	−0.042	0.051	−0.837	−0.126	0.041
South	0.107	0.137	0.779	0.035	0.046	0.779	−0.039	0.110
Gender*Child	−0.522**	0.220	−2.374	−0.174**	0.073	−2.378	−0.294	−0.054

* p-value < .1.
** p-value < .05.
*** p-value < .01.

$0.12/lb. premium compared to those who identify themselves to be non-knowledgeable about BDM; this positive effect is statistically significant at a 1% level.

Yue et al. (2016) quantify consumer WTP for plants labeled with "sustainable" to be $0.08 per plant above non-sustainably labeled counterparts. In Yue et al.'s example, consumers made choices based on plant attributes and might pay a higher premium for other attributes in plants (e.g., energy-saving or water-saving) rather than "sustainably produced". In our study, the corresponding figure is $0.20 per pound when environmentally friendly production practices, such as biodegradable mulches, are deployed.

Environmentally conscious consumers, discussed in previous studies by McCluskey, Durham, and Horn (2009), Laroche et al. (2001), and Pickett-Baker and Ozaki (2008), have a significantly positive effect on WTP when purchasing environmentally friendly products. The marginal effect in our study shows that this type of consumer exhibits an increase in WTP by $0.33/lb., which is similar to Loureiro et al. (2001) who find that consumers with environmentally friendly attitudes are more likely to purchase eco-labeled apples.

Following Hanemann (1989), the estimated mean WTP was calculated as

$$WTP = \frac{1}{\hat{\rho}}(\hat{\alpha} + \hat{Z}'\overline{X}) \quad (5)$$

where $\overline{X}$ denotes the vector of expected values of the explanatory variables. As shown in Table 4, the estimated mean WTP is $3.80 per pound for the control group and $3.94 per pound for the treatment group. These estimates represent an 8.6% and 12.6% premium over the national average market price of $3.50 per pound at a 1% significance level. The prices between treatment and control groups are also different from each other at a 10% significance level. On average, consumers are willing to pay $3.86 for a 1-lb box of strawberries grown on BDM, which represents a 10.3% premium above the average market price of $3.50 per pound as of 2015, and the 95% confidence interval for that premium falls in the range of $3.73/lb. to $3.99/lb.

Strawberry producers could promote their product by providing information on BDM or other marketing strategies to consumers. The WTP estimates are statistically different from the average market price at the 1% significance level across groups. This result is consistent with the findings of other studies. For instance, Belcher, Germann, and Schmutz (2007) revealed a 10% to 20% premium for environmentally produced beef products, while a 5% premium is identified for eco-labeled products (Loureiro et al., 2001).

In addition, there are regional differences in WTP. The coefficients and marginal effects of bids and consumer attributes on WTP vary across regions. For instance, female respondents in the Northeast and Midwest regions exhibited they were more likely to pay a premium of $0.31 and $0.21 per pound respectively (see appendix Table A.6 for more details). The mean WTP estimates across the four regions are significantly higher than the average market price of $3.50/lb.; for example, the Northeast region has a mean WTP estimate with $3.95/lb (see appendix Table A.8).

A price premium can also be translated upstream to offset higher production costs and incentivize sustainability by increasing use of BDM. For example, in Washington State, a partial budget analysis using Galinato and Walters (2012) with a return to the grower of $3.25/pound [i.e., 8.6% premium added to $2.99/pound retail price in the

Table 4
WTP estimates for strawberry grown on BDM ($/pound).

Segmented market	WTP	95% confidence interval
All group ($n = 1510$)	$3.86***	($3.73, $3.99)
Information		
Control ($n = 761$)	$3.80***	($3.67, $3.93)
Treatment ($n = 749$)	$3.94***	($3.81, $4.07)

*** *p*-value < .01.

Northwest region (Fresh Fruit Portal, 2015) minus marketing costs], material cost of BDM at $46 to $190 per 1000 ft. (Chen et al., 2018), mulch removal and disposal cost savings, and cost of tilling BDM after the growing season (about $180/acre considering 6 h/worker times $15/h for 2 workers), showed a net change in profit of 40% to 75% relative to conventional plastic mulch. The increase in profits are mainly attributed to the additional revenue from the price premium (95% of benefits) and to labor cost savings during the post-harvest season, specifically plastic mulch removal and disposal (5% of benefits), justifying the use of BDM which is at least 1.8 times more expensive than conventional plastic mulch. There is a reduction in the cost of disposal to the grower, but perhaps more importantly a reduction in plastic introduced into the waste stream that generally improves social welfare. The above example demonstrates a scenario where a price premium can enable strawberry growers to cover the additional input costs associated with BDM adoption that promotes sustainable production practices.

5. Conclusion

The main objective of this study was to investigate the role of consumers in technology use and plastic pollution in food production. To do so, we examined relationships between market information, consumer preferences, and willingness to pay for an agricultural product grown on BDM by using a dichotomous-choice CV survey. BDM are an environmentally friendly soil cover that sustains plant growth but avoids the environmental harm of non-biodegradable mulches in the field or upon disposal. We empirically quantified the factors influencing WTP and whether or not consumers will pay premiums for strawberries grown on BDM, and estimated these premiums for the U.S. and across regions.

Our study shows that respondents who are earning a higher income, exhibiting stronger environment-friendly attitudes, more knowledgeable about BDM, or female are more likely to pay a premium of $0.08/lb., $0.33/lb., $0.12/lb., and $0.11/lb., respectively. In addition, dissemination of positive information to the potential consumers will increase WTP by $0.08/lb. Furthermore, in selected scenarios, our partial budget analysis suggests that in the right circumstances, growers may benefit from using BDM in contrast to the less sustainable conventional plastic mulches. Hence, BDM not only have a high likelihood of offering private incentives to growers to adopt BDM and increase profitability, but also have social incentives to reduce externalities and improve sustainability. The upshot is that labeling or marketing food as grown on biodegradable products may provide opportunities for growers to increase revenues while they simultaneously practice more sustainable production.

It is important to understand consumer preferences for food products grown in a more environmentally sustainable manner with green technologies, and how market mechanisms translate retail prices into more sustainable crop production that help mitigate environmental damage. Characterizing consumer purchasing behavior enables us to identify the adoptability of biotechnology by agricultural producers, which enables policymakers and agricultural scientists to make more informed decisions on industry-supporting policies. From a broader perspective, other more standard policy options could be explored. For example, a government may impose a Pigouvian tax to discourage the use of conventional plastic mulches, wherein tax revenue could be used to cross-subsidize the adoption of BDM by agricultural producers. Coupled with standards and charges along the supply chain, there then may be a feasible bundle of actions (including final consumers) that form a transformative policy solution to the plastic pollution problem in food production.

There are limitations in this study. To begin with, we consider the impact of plastic mulches only on the WTP for strawberries, but contend this study is extendable into other crops. Moreover, depending on research objectives, alternative or more specific information content could be provided on biodegradable material. While our analysis is restricted to double-bounded contingent valuation method, other non-hypothetical methods, such as choice experiments or auctions, could be deployed to evaluate the WTP. Last but not least, it would be interesting to differentiate among different consumer segments (e.g., income or education level) to identify the differences in purchasing behavior, and hence, WTP for strawberries.

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Appendix A

The following is the information presented to the treatment group immediately prior to the WTP question:

"Biodegradable mulches are an alternative to conventional plastic mulches and are intended to be tilled into the soil at the end of the season thereby reducing labor and disposal costs. With biodegradable mulches, which are designed to decompose in the field, farmers can avoid open field burning and landfilling of the conventional mulches. In addition, the use of biodegradable mulches may increase sustainability of specialty crop production."

Table A.1
Summary statistics for demographic variables (n = 1510).

Variable	Description	Frequency (%)
Gender	Male	51.29%
	Female	48.38%
Age	18 to 25	14.98%
	26 to 35	44.60%
	36 to 45	21.21%
	46 to 55	10.74%
	56 to 65	6.83%
	66 or above	1.33%

(continued on next page)

Table A.1 (*continued*)

Variable	Description	Frequency (%)
Education	Some high school or lower	0.40%
	High school graduate	10.68%
	Some college/technical/vocational training	26.48%
	Associate degree	11.81%
	Bachelor degree	38.62%
	Advanced or profession degree	10.48%
	Ph.D. degree	1.46%
Children	None	68.08%
	One or more	31.92%
Income	Lower than $29,999	23.99%
	$30,000–$49,999	25.38%
	$50,000–$69,999	19.42%
	$70,000–$89,999	11.66%
	$90,000–$99,999	6.56%
	$100,000–$149,999	8.61%
	$150,000–$199,999	1.79%
	Greater than $200,000	0.93%
Marriage	Single (never married)	50.94%
	Married	39.08%
	Separated/divorced/widowed	9.25%
Occupation	Government employee	5.37%
	Private sector employee	49.57%
	Academic institution	4.84%
	Student	5.30%
	Retired	2.72%
	Unemployed	10.14%
	Self-employed	17.56%
	Others	4.51%
Race	White/Caucasian	77.14%
	Hispanic/Latino/Spanish	5.50%
	American Indian	0.73%
	Asian	8.28%
	African American	7.16%
	Others	1.20%
Region	Northeast	19.54%
	Midwest	21.45%
	South	35.84%
	West	21.58%

Table A.2
Census regional divisions by the United States Census Bureau (2013).

Region	States	Number of states
Northeast	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, Pennsylvania	9
Midwest	Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota	12
South	Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, District of Columbia, Delaware, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, Texas	17
West	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, Alaska, California, Hawaii, Oregon, Washington	13

Table A.3
Important criteria when purchasing strawberries (n = 1510).

Variable	Mean	Std. Dev.
Scale: 1 = Extremely important, 2 = Very important, 3 = Moderately important, 4 = Slightly important, 5 = Not at all important		
Price	2.24	0.96
Origin of production	3.33	1.19
Brand	4.33	0.94
Produced without chemical	2.96	1.30
Environmentally friendly production practice	3.17	1.23
Appearance	1.72	0.96
Quality	1.50	0.79
Freshness	1.46	0.77
Nutrition/Health	2.20	1.10

Table A.4
Consumers' attitudes for environment (n = 1510).

Variable	Mean	Std. Dev.
Scale: 1 = Strongly agree, 2 = Somewhat agree, 3 = Neither agree nor disagree, 4 = Somewhat disagree, 5 = Strongly disagree		
I only buy products in packages that can be recycled	3.52	1.12
I have convinced my family or friends not to buy some products that are harmful to the environment	3.45	1.25
I recycle every product	3.15	1.29
I buy 'environmentally friendly' products, even if they are more expensive	3.17	1.18
I have an opportunity to recycle products where I live	1.99	1.24

Table A.5
Distributions of the initial bid ($3.50/lb) responses for each group.

Stage	Response	All group	Control group	Treatment group
Initial bid	No	33.84%	36.66%	30.97%
	Yes	66.16%	63.34%	69.03%
Second bid	No/$2.50	14.51%	12.62%	16.67%
	No/$2.75	21.13%	13.16%	30.30%
	No/$3.00	44.89%	47.00%	42.11%
	No/$4.00	36.39%	42.18%	31.36%
	No/$4.25	59.67%	64.86%	54.40%
	No/$4.50	63.61%	69.33%	58.43%
	Yes/$2.50	85.49%	87.38%	83.33%
	Yes/$2.75	78.87%	86.84%	69.70%
	Yes/$3.00	55.11%	53.00%	57.89%
	Yes/$4.00	63.61%	57.82%	68.64%
	Yes/$4.25	40.33%	35.14%	45.60%
	Yes/$4.50	36.39%	30.67%	41.57%

Table A.6
Descriptions of selected explanatory variables.

Variable	Description
Bid	Random bid offered to each participant
Treatment	1 = Information about BDM is provided, 0 = no information
Knowledge	1 = Knowledgeable about BDM, 0 = otherwise
Demographics	
Gender	1 = Female, 0 = otherwise
Age	1 = Youth (age between 18 and 35), 0 = otherwise
Education	1 = Bachelor's degree or higher, 0 = otherwise

(continued on next page)

Table A.6 (*continued*)

Variable	Description
Child	1 = Present of child under18 in the household, 0 = otherwise
Income	1 = Last year household income more than $50,000, 0 = otherwise
Employment	1 = Full-time employed, 0 = otherwise
White	1 = White/Caucasian, 0 = otherwise
Region	
Northeast	1 = Survey conducted in Northeast, 0 = otherwise
Midwest	1 = Survey conducted in Midwest, 0 = otherwise
South	1 = Survey conducted in South, 0 = otherwise
West	1 = Survey conducted in West, 0 = otherwise
Shopping habit	
Frequency	1 = More than once a month or higher, 0 = otherwise
Location	1 = Most often buying strawberries at retail store or supermarket, 0 = otherwise
Shopper	1 = Primary grocery shopper, 0 = otherwise
Important criteria	
Price importance	1 = Extremely or very important, 0 = Otherwise
Origin importance	1 = Extremely or very important, 0 = Otherwise
Brand importance	1 = Extremely or very important, 0 = Otherwise
Chemical importance	1 = Extremely or very important, 0 = Otherwise
Eco-production importance	1 = Extremely or very important, 0 = Otherwise
Appearance importance	1 = Extremely or very important, 0 = Otherwise
Freshness importance	1 = Extremely or very important, 0 = Otherwise
Nutrition importance	1 = Extremely or very important, 0 = Otherwise
Consumers' awareness	
Environmentalism	1 = Strongly or somewhat agree, 0 = Otherwise

Table A.7
Coefficient estimates and marginal effects of selected variables by region.

	Northeast		West		South		Midwest	
	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect
Bid	−2.896***		−3.503***		−3.057***		−3.160***	
Constant	11.374***		13.035***		10.691***		10.377***	
Information	0.577**	0.199**	0.059	0.017	−0.004	−0.001	0.352	0.111
Price importance	−0.848***	−0.293***	−1.220***	−0.348***	−1.046***	−0.342***	−1.251***	−0.396***
Origin importance	−0.272	−0.094	0.099	0.028	−0.258	−0.084	−0.206	−0.065
Brand importance	0.067	0.023	−1.090**	−0.311**	0.839*	0.275*	0.803	0.254
Chemical importance	0.197	0.068	0.152	0.043	0.150	0.049	0.669**	0.212**
Eco-production importance	0.080	0.028	0.884***	0.252***	0.913***	0.299***	0.203	0.064
Appearance importance	−0.474	−0.164	0.216	0.062	0.087	0.028	0.078	0.025
Freshness importance	−0.212	−0.073	−0.351	−0.100	−0.055	−0.018	1.031**	0.326**
Nutrition importance	0.146	0.050	0.816***	0.233***	0.179	0.059	−0.026	−0.008
Environmentalism	0.854***	0.295***	1.110***	0.317***	1.179***	0.386***	1.047***	0.331***
Knowledge	0.530*	0.183*	0.116	0.033	0.477**	0.156**	0.141	0.045
Frequency	−0.266	−0.092	−0.050	−0.014	0.408**	0.134**	0.415*	0.131*
Shopper	−0.012	−0.004	−0.047	−0.013	0.287	0.094	−0.056	−0.018
Location	0.050	0.017	−0.146	−0.042	−0.031	−0.010	−0.130	−0.041
Female	0.899***	0.310***	0.198	0.056	−0.135	−0.044	0.673**	0.213**
Youth	0.297	0.103	0.174	0.050	0.045	0.015	0.430*	0.136*
Children	0.494	0.170	0.110	0.031	−0.231	−0.076	0.438	0.139
Education	−0.531**	−0.183**	−0.058	−0.017	0.305*	0.100*	0.347	0.110
Employment	−0.029	−0.010	−0.017	−0.005	0.185	0.060	−0.024	−0.008
Income	0.294	0.101	0.599**	0.171**	0.196	0.064	−0.148	−0.047
White	−0.363	−0.125	−0.258	−0.073	−0.063	−0.020	−0.218	−0.069
Female * Child	−0.952*	−0.329*	−0.997**	−0.285**	0.184	0.060	−0.520	−0.164

* p-value < .1.
** p-value < .05.
*** p-value < .01.

Table A.8
WTP estimates for strawberry grown on BDM across regions ($/pound).

Segmented market	WTP	95% Confidence Interval
Region		
Northeast (n = 296)	$3.95***	($3.63, $4.26)
Midwest (n = 325)	$3.78***	($3.53, $4.03)
South (n = 543)	$3.89***	($3.67, $4.11)
West (n = 327)	$3.85***	($3.57, $4.13)

*** p-value < .01.

References

Anzalone, A., Cirujeda, A., Aibar, J., Pardo, G., & Zaragoza, C. (2010). Effect of biodegradable mulch materials on weed control in processing tomatoes. *Weed Technology, 24*(3), 369–377.

Arméndariz, R., Macua, J. I., Lahoz, I., Santos, A., & Calvillo, S. (2006). The use of different plastic mulches on processing tomatoes. *Acta Horticulturae, 724*, 199–202.

ASTM International (2011). *ASTM D883-11: international Standard Terminology Relating to Plastics*. West Conshohocken, PA: ASTM International.

Barron, J. (2016). SPI: The Plastics Industry Trade Association releases Annual Global Business Trends Report at GPS 2016: The Global Plastics Summit. http://www.plasticsindustry.org/article/spi-plastics-industry-trade-association-releases-annual-global-business-trends-report-gps.

Belcher, K. W., Germann, A. E., & Schmutz, J. K. (2007). Beef with environmental and quality attributes: preferences of environmental group and general population consumers in Saskatchewan, Canada. *Agriculture and Human Values, 24*(3), 333–342.

Briassoulis, D. (2006). Mechanical behaviour of biodegradable agricultural films under real field conditions. *Polymer Degradation and Stability, 91*(6), 1256–1272.

Brodhagen, M., Goldberger, J. R., Hayes, D. G., Inglis, D. A., Marsh, T. L., & Miles, C. A. (2017). Policy considerations for limiting unintended residual plastic in agricultural soils. *Environmental Science & Policy, 69*, 81–84.

Candido, V., Miccolis, V., Castronuovo, D., Margiotta, S., & Manera, C. (2006). Mulching studies in greenhouse by using eco-compatible plastic films on fresh tomato crop. *Acta Horticulturae, 710*, 415–420.

Cascone, G., D'Emilio, A., Buccellato, E., & Mazzarella, R. (2008). New biodegradable materials for greenhouse soil mulching. *Acta Horticulturae, 801*, 283–290.

Chen, Q., Anders, S., & An, H. (2013). Measuring consumer resistance to a new food technology: A choice experiment in meat packaging. *Food Quality and Preference, 28*(2), 419–428.

Chen, K.-J., Galinato, S. P., Ghimire, S., MacDonald, S., Marsh, T. L., Miles, C. A., ... Velandia, M. M. (2018). *Using biodegradable plastic mulch*. Washington State University Extension Publication (in press).

Coolong, T. (2010). Performance of paper mulches using a mechanical plastic layer and water wheel Transplanter for the production of summer squash. *HortTechnology, 20*(2), 319–324.

Corbin, A., Cowan, J., Hayes, D., Dorgan, J., Inglis, D., & Miles, C. A. (2013). *Using biodegradable plastics as agricultural mulches*. Washington State University Extension Publication (FS081E. 6 p).

Devetter, L. W., Zhang, H., Ghimire, S., Watkinson, S., & Miles, C. A. (2017). Plastic biodegradable mulches reduce weeds and promote crop growth in day-neutral strawberry in western Washington. *Hortscience, 52*(12), 1700–1706.

Dornburg, V., Lewandowski, I., & Patel, M. (2003). Comparing the land requirements, energy savings, and greenhouse gas emissions reduction of biobased polymers and bioenergy. *Journal of Industrial Ecology, 7*(3–4), 93–116.

Economic Research Services (2014). *U.S. strawberry industry. Washington D.C.*: United States Department of Agriculture. Retrieved from http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1381.

Flachaire, E., & Hollard, G. (2006). Controlling starting-point Bias in double-bounded contingent valuation surveys. *Land Economics, 82*(1), 103–111.

Fresh Fruit Portal (2015). USDA Price. https://www.freshfruitportal.com/precios-frutas/precios-usda/?country=united.

Galinato, S. P., & Walters, T. W. (2012). *2011 Cost estimates of producing fresh market field-grown strawberries in Washington: Appendix to the high-tunnel strawberry bnterprise budget*. Washington State University Extension Publication (FS093E).

Global Market Insights Inc (2016). Agricultural films market size is anticipated to exceed $15.13 billion and growing at a CAGR of above 6.2% by 2024. http://www.abnewswire.com/pressreleases/agricultural-films-market-size-is-anticipated-to-exceed-1513-billion-growing-at-a-cagr-of-above-62-by-2024_87353.html.

Gracia, A., De Magistris, T., & Nayga, R. M. (2012). Importance of social influence in consumers' willingness to pay for local food: Are there gender differences? *Agribusiness, 28*(3), 361–371.

Hanemann, M. W. (1989). Welfare evaluations in contingent valuation experiments with discrete response data: Reply. *American Journal of Agricultural Economics, 71*(4), 1057–1061.

Hanemann, M., Loomis, J., & Kanninen, B. (1991). Statistical efficiency of double-bounded dichotomous choice contingent valuation. *American Journal of Agricultural Economics, 73*(4), 1255–1263.

Hayes, D. G., Dharmalingam, S., Wadsworth, L. C., Leonas, K. K., Miles, C. A., & Inglis, D. A. (2012). Biodegradable agricultural mulches derived from biopolymers. *Degradable polymers and materials: Principles and practice* (pp. 201–223). (*2nd Edition*). American Chemical Society.

Hellyer, N. E., Fraser, I., & Haddock-Fraser, J. (2012). Food choice, health information and functional ingredients: An experimental auction employing bread. *Food Policy, 37*(3), 232–245.

Jenni, S., Brault, D., & Stewart, K. A. (2004). Degradable mulch as an alternative for weed control in lettuce produced on organic soils. *Acta Horticulturae, 638*, 111–118.

Kanninen, B. J. (1993). Optimal experimental design for double-bounded dichotomous choice contingent valuation. *Land Economics*, 138–146.

Kapanen, A., Schettini, E., Vox, G., & Itävaara, M. (2008). Performance and environmental impact of biodegradable films in agriculture: A field study on protected cultivation. *Journal of Polymers and the Environment, 16*(2), 109–122.

Khoo, H. H., Tan, R. B. H., & Chng, K. W. L. (2010). Environmental impacts of conventional plastic and bio-based carrier bags. *The International Journal of Life Cycle Assessment, 15*(3), 284–293.

Kijchavengkul, T., Auras, R., Rubino, M., Ngouajio, M., & Fernandez, R. T. (2008). Assessment of aliphatic–aromatic copolyester biodegradable mulch films. Part I: Field study. *Chemosphere, 71*(5), 942–953.

Laroche, M., Bergeron, J., & Barbaro-Forleo, G. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. *Journal of Consumer Marketing, 18*(6), 503–520.

Loureiro, M. L., McCluskey, J. J., & Mittelhammer, R. C. (2001). Assessing consumer preferences for organic, eco-labeled, and regular apples. *Journal of Agricultural and Resource Economics, 26*(2), 404–416.

Martín-Closas, L., Bach, M. A., & Pelacho, A. M. (2008). Biodegradable mulching in an organic tomato production system. *Acta Horticulturae, 767*, 267–273.

McCluskey, J. J., Durham, C. A., & Horn, B. P. (2009). Consumer preferences for socially responsible production attributes across food products. *Agricultural and Resource Economics Review, 38*(3), 345–356.

Miles, C., Wallace, R., Wszelaki, A., Martin, J., Cowan, J., Walters, T., & Inglis, D. (2012). Deterioration of potentially biodegradable alternatives to black plastic mulch in three tomato production regions. *Hortscience, 47*(9), 1270–1277.

Minuto, G., Guerrini, S., Pini, S., & Capurro, M. (2008). Weed control with biodegradable mulch in vegetable crops. *Acta Horticulturae, 801*, 291–297.

Mobley, A. S., Painter, T. S., Untch, E. M., & Rao Unnava, H. (1995). Consumer evaluation of recycled products. *Psychology and Marketing, 12*(3), 165–176.

Moreno, M. M., Moreno, A., & Mancebo, I. (2009). Comparison of different mulch materials in a tomato (Solanum lycopersicum L.) crop. *Spanish Journal of Agricultural Research, 7*(2), 454–464.

National Agricultural Statistics Service (2016). *Citrus fruits and noncitrus fruits and nuts 2015 summary*. Washington D.C.: United States Department of Agriculture. Retrieved from http://usda.mannlib.cornell.edu/usda/current/NoncFruiNu/NoncFruiNu-07-06-2016.pdf.

Ngouajio, M., Auras, R., Fernandez, R. T., Rubino, M., Counts, J. W., Jr., & Kijchavengkul, T. (2008). Field performance of aliphatic-aromatic copolyester biodegradable mulch films in a freshmarket tomato production system. *HortTechnology, 18*(4), 605–610.

Olsen, J. K., & Gounder, R. K. (2001). Alternatives to polyethylene mulch film—A field assessment of transported materials in capsicum (*Capsicum annuum* L.). *Australian Journal of Experimental Agriculture, 41*(1), 93–103.

Pickett-Baker, J., & Ozaki, R. (2008). Pro-environmental products: Marketing influence on consumer purchase decision. *Journal of Consumer Marketing, 25*(5), 281–293.

Rangarajan, A., & Ingall, B. (2006). *Biodegradable mulch product testing 2006.* Unpublished Manuscript Ithaca, NY: Cornell University, Department of Horticulture. Retrieved from: http://www.vegetables.cornell.edu/alt/Biodegradable%20Mulch%20Product%20Testing%2020063.pdf (> 7Dec.2010) .

Rousseau, S., & Vranken, L. (2013). Green market expansion by reducing information asymmetries: Evidence for labeled organic food products. *Food Policy, 40*, 31–43.

Royne, M. B., Levy, M., & Martinez, J. (2011). The public health implications of Consumers' environmental concern and their willingness to pay for an eco-friendly product. *Journal of Consumer Affairs, 45*(2), 329–343.

Scarascia-Mugnozza, G., Schettini, E., Vox, G., Malinconico, M., Immirzi, B., & Pagliara, S. (2006). Mechanical properties decay and morphological behaviour of biodegradable films for agricultural mulching in real scale experiment. *Polymer Degradation and Stability, 91*(11), 2801–2808.

Scarascia-Mugnozza, G., Sica, C., & Russo, G. (2012). Plastic materials in European agriculture: Actual use and perspectives. *Journal of Agricultural Engineering, 42*(3), 15–28.

Sörqvist, P., Hedblom, D., Holmgren, M., Haga, A., Langeborg, L., Nöstl, A., & Kågström,

J. (2013). Who needs cream and sugar when there is eco-labeling? Taste and willingness to pay for "eco-friendly" coffee. *PLoS One, 8*(12), e80719.
Steinmetz, Z., Wollmann, C., Schaefer, M., Buchmann, C., David, J., Tröger, J., ... Schaumann, G. E. (2016). Plastic mulching in agriculture. Trading short-term agronomic benefits for long-term soil degradation? *Science of the Total Environment, 550*, 690–705.
Straughan, R. D., & Roberts, J. A. (1999). Environmental segmentation alternatives: A look at green consumer behavior in the new millennium. *Journal of Consumer Marketing, 16*(6), 558–575.
Tocchetto, R. S., Benson, R. S., & Dever, M. (2001). Outdoor weathering evaluation of carbon- black-filled, biodegradable copolyester as substitute for traditionally used, carbon-black-filled, non-biodegradable, high-density polyethylene mulch films. *Journal of Polymers and the Environment, 9*(2), 57–62.
Tsen, C.-H., Phang, G., Hasan, H., & Buncha, M. R. (2006). Going green: A study of consumers' willingness to pay for green products in Kota Kinabalu. *International Journal of Business and Society, 7*(2), 40.
UF IFAS (2018). Strawberry production around the world. Retrieved from http://www.hos.ufl.edu/protectedag/Strawberry.htm.
United States Census Bureau (2013). Census bureau regions and divisions with state FIPS codes. Retrieved from https://web.archive.org/web/20130921053705/http://www.census.gov/geo/maps-data/maps/pdfs/reference/us_regdiv.pdf.
United States Census Bureau (2016a). *Demographic and housing estimates (2011–2015 American Community Survey (ACS) 5-year estimates)*.
United States Census Bureau (2016b). Quick facts. Retrieved from https://www.census.gov/quickfacts/table/PST045216/00.
Venkatachalam, L. (2004). The contingent valuation method: A review. *Environmental Impact Assessment Review, 24*(1), 89–124.
Vlaeminck, P., Jiang, T., & Vranken, L. (2014). Food labeling and eco-friendly consumption: Experimental evidence from a Belgian supermarket. *Ecological Economics, 108*, 180–190.
Wu, F., Guan, Z., & Whidden, A. (2012). *Strawberry industry overview and outlook.* Unpublished Manuscript Gainesville, Florida: Gulf Coast Research and Education Center, University of Florida. Retrieved from: http://www.fred.ifas.ufl.edu/pdf/webinar/Strawberry.pdf.
Yue, C., Hall, C. R., Behe, B. K., Campbell, B. L., Dennis, J. H., & Lopez, R. G. (2010). Are consumers willing to pay more for biodegradable containers than for plastic ones? Evidence from hypothetical conjoint analysis and nonhypothetical experimental auctions. *Journal of Agricultural and Applied Economics, 42*(4), 757–772.
Yue, C., Campbell, B., Hall, C., Behe, B., Dennis, J., & Khachatryan, H. (2016). Consumer preference for sustainable attributes in plants: Evidence from experimental auctions. *Agribusiness, 32*(2), 222–235.