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Does Food Processing Mitigate Consumers' Concerns about Crops Grown with Recycled Water?

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ABSTRACT

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Keywords: Water reuse, recycled water, field experiments, consumer willingness to pay, food labeling

This paper presents results of a field experiment designed to evaluate whether food processing alleviates consumers' concerns about crops grown with recycled water. Recycled water has emerged as a safe and cost-effective way to increase supplies of irrigation water. However, adoption of recycled water by U.S. agricultural producers has been modest, in part, because of concerns that consumers will be reluctant to accept recycled water for uses that involve ingestion or personal contact. Therefore, both policymakers and food producers must understand how consumers' aversion to recycled water can be mitigated, especially when the products are safe. To date, most of the existing literature has focused on fresh food, yet our results suggest that, for food, simple processing such as drying or liquefying can relieve some of consumers' concern about use of recycled irrigation water. We find that consumers of processed foods are indifferent between irrigation with recycled and conventional water, however, they are less willing to pay for fresh foods irrigated with recycled water relative to conventional water. We also find that the demographic and behavioral characteristics tested in the experiment mostly had no statistically significant effect. The one exception is age—older consumers are less likely than younger ones to purchase processed foods irrigated with recycled water. Our analysis further reveals that informational nudges that provide consumers with messages about benefits, risks, and both the benefits and risks of using recycled water have no statistically significant effect on consumers' willingness to pay for fresh and processed foods irrigated with recycled water relative to a no-information control group.

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1. Introduction

Water scarcity is a growing concern in many regions of the U.S. and across the world. Currently, 4 billion people worldwide, including 130 million people in the U.S., experience severe water shortages at least part of the year (Mekonnen and Hoekstra, 2016). Projected growth in populations and food demand, coupled with rising temperatures and changing weather patterns, will further strain available water resources. These issues pose a serious challenge for the agricultural sector, which currently uses more than 70% of the world's fresh water resources for irrigation (World Water Assessment Programme, 2016). In the U.S., the agricultural sector is responsible for 80% of the country's total water consumption and 90% of total water consumption in most western states (U.S. Department of Agriculture, 2017). Furthermore, global agricultural output is projected to double in the next 30 years (World Bank, 2014), and therefore alternative sources of irrigation water are critically needed.

Recycled water[1] has emerged as a safe and cost-effective way to provide for the growing demand for irrigation water around the world (Chen et al., 2013). Countries such as Israel and Australia have been using recycled irrigation water for decades, but its use by U.S. agricultural producers has been modest. Though 32 billion gallons of municipal wastewater are produced daily in the U.S. (National Research Council, 2012), only California, Florida, Arizona, and Texas augment their irrigation supplies with recycled water (McNabb, 2017). Perhaps the most

[1] According to the California Department of Water Resources (2018), "recycled water is highly treated wastewater from various sources, such as domestic sewage, industrial wastewater and storm water runoff." This type of water has been referred to by several names, including reclaimed water, reused water, treated wastewater, repurified water, tertiary treated wastewater, advanced purified water, NEWater (Ellis et al., 2018; Lee and Tan, 2016; Rock et al., 2012; Menegaki et al., 2009).

significant hurdle to using recycled water in the U.S. is consumers' lack of acceptance of it, particularly for products that are ingested (e.g. food) or come into direct contact (e.g. bathing, skin care products), despite technological advances that can treat the water so it meets both potable and non-potable standards (Po et al., 2003; Po et al., 2005; Dolnicar and Saunders, 2006; Schmidt, 2008; Haddad et al., 2009; Rozin et al., 2015; Hurlimann and Dolnicar, 2016; Kecinski et al., 2016, 2018, Savchenko et al., 2018b; Kecinski and Messer, 2018; Ellis et al., 2018a). This aversion to recycled water also extends to fresh produce irrigated with recycled water (Savchenko et al., 2018a). Because of the stigma associated with recycled water, some producers have started to advertise their use of fresh irrigation water on product labels (see Figures 1 and 2 for examples). Therefore, it is important for policymakers and agricultural producers to find ways to mitigate consumers' concerns about food grown with recycled water and to "nudge" them toward accepting this safe and sustainable resource.

We use an incentive-compatible framed field experiment involving 329 adult participants from the mid-Atlantic region of the U.S. to study whether processing of fresh foods relieves consumers' concerns about crops irrigated with recycled water (Table 1 summarizes research questions, hypotheses and results). Using a dichotomous-choice experimental design that is both theoretically (Satterthwaite, 1975) and empirically (Taylor et al., 2001) demand-revealing, we elicit consumers' willingness to pay (WTP) for fresh and processed foods irrigated with recycled water. Participants in the experiment used actual money to make actual purchase decisions for grapes and olives presented fresh and after two types of processing: drying, represented by dried grapes (raisins) and olives, and liquid extraction, represented by grape juice and olive oil. These foods were labeled as produced with recycled water, produced with conventional water, or had no specification regarding the irrigation water used. The data collected in the experiment and a survey of participants' demographic characteristics and buying behaviors is then used in an econometric analysis to reveal consumers' responses to use of recycled water for irrigation of fresh and processed food products. We also test a set of information treatments designed to nudge consumers' perceptions of foods produced with recycled water, providing important insight for policymakers, producers, and other organizations interested in better strategies for recycled water programs: information about (1) benefits of recycled water, (2) risks associated with recycled water, and (3) the benefit and risk information combined. Finally, we examine the effect of several demographic characteristics and behavioral attitudes on consumers' WTP for the foods offered in the experiment.

To our knowledge, no prior studies have addressed the question of whether food processing can alleviate consumers' concerns about use of recycled irrigation water for food crops. Most prior studies of food processing have focused primarily on negative consumer responses and stigmatization of foods processed using technologies such as genetic engineering, irradiation, growth hormones, and antibiotics (Kanter et al., 2009; Costanigro and Lusk, 2014; Lusk and Murray, 2015; Messer et al., 2015, 2017). This literature has documented substantial decreases in WTP for foods labeled as processed with those technologies (Hayes et al., 2002; Lusk et al., 2005, 2015; Messer et al., 2017). Food processing, however, has not been previously studied for its potential to mitigate consumer stigma.

Our study also contributes to the growing literature that seeks to understand consumers' behavior related to foods grown with recycled water by using demand-revealing experimental methods. Most prior studies of consumers' responses to recycled water have relied on survey methodologies (Fielding et al., 2018; Savchenko et al., 2018b). Those studies showed that most consumers are concerned about recycled irrigation water used on edible crops (Po et al., 2005; Menegaki et al., 2007; Rock et al., 2012) and found that providing consumers with information about recycled water can increase their acceptance of its use (Hills et al., 2002; Hurlimann, 2007; Dolnicar et al., 2010; Fielding and Roiko, 2014; Simpson and Stratton, 2011; Hui and Cain, 2017). Research designed to identify socio-demographic drivers of acceptance of recycled water has produced mixed results. Menegaki et al. (2007), for example, found that younger respondents were more likely than older respondents to consume produce irrigated with recycled water. In contrast, Dolnicar and Schäfer (2009), found that older consumers were more receptive to recycled water than younger consumers and Po et al. (2005) found that age had no significant effect. In analyses of education level, Rock et al. (2012) reported that greater education was associated with increased acceptance of recycled water while Hui and Cain (2017) found that it had no significant effect on consumers' willingness to use recycled water. Several studies have found that income and gender (Menegaki et al., 2007; Dolnicar et al., 2010) can influence acceptance of recycled water. Women were found to be less likely than men to prefer recycled water (Dolnicar and Schäfer, 2009; Rock et al., 2012; Savchenko et al., 2018b). The lack of consistency in the findings of these studies makes it difficult to draw conclusions. Survey questions generally do not present an incentive-compatible decision environment or allow participants to observe and consider purchasing foods actually irrigated with recycled water (Russell and Hampton, 2006). Thus, the participants do not necessarily reveal their true demand for such products. Unlike these prior studies, we use a non-hypothetical demand-revealing framed field experiment that involves actual decisions about purchasing food products irrigated with recycled water.

The few studies that have used data from economic experiments found that consumers were less willing to pay for wine made from grapes irrigated with recycled water than for grapes irrigated with conventional water (Li et al., 2018) and less willing to pay for fresh produce grown with recycled water than for produce with no label description of the irrigation water used (Savchenko et al., 2018a). Ellis et al., (2018) also showed that the use of recycled water decreased consumers' demand for food products by 87% in the U.S. and that this reduction was dependent upon the type of recycled water used (recycled gray, recycled black and recycled produced). Disgust, safety concerns and neophobia were identified as the three primary drivers of consumers' acceptance or rejection of recycled water (Savchenko et al., 2018b). These three factors can lead to stigmatization of recycled water and foods produced with this water. Stigma is generally difficult to eliminate, particularly for products that are ingested (Rozin, 2001). Studies that use economic experiments to explore stigma associated with recycled water found that several stigma-reducing treatments can be more effective than one specific mitigation step (Kecinski et al., 2016). Social preferences and communication can also help reduce stigma related to recycled drinking water (Kecinski and Messer, 2018). Further, the terms used to refer to recycled water also matter. Ellis et al. (2018b) found that the names traditionally used to refer to recycled water such as reclaimed, treated wastewater, nontraditional and reused water are least preferred by consumers. On the other hand, branding recycled water with names such as eco-friendly water, advanced purified water or pure water generate a more favorable perception of recycled water.

We extend those studies by investigating whether processing of fresh foods can relieve consumers' concerns about the use of recycled irrigation water. Consumers' acceptance of other food technologies, such as bio-engineering, has been shown to be heterogeneous across fresh and processed food categories (He and Bernard, 2011; Lusk et al., 2015). For example, Lusk et al. (2015) showed that genetic engineering results in greater decrease in desirability of fresh than processed food. Our study is the first to examine potential heterogeneity in consumer responses to fresh and processed foods irrigated with recycled water. We further contribute to the literature on use of recycled water by exploring how consumer demographic characteristics and behavioral attitudes affect consumers' decisions related to purchasing crops grown with recycled water.

Our results indicate that food processing can alleviate some consumers' concern associated with recycled irrigation water. We find that consumers of processed foods are indifferent between recycled and conventional irrigation water but are less willing to pay for fresh foods grown with recycled water than for fresh foods grown with conventional water. This heterogeneity in response suggests that consumers are less sensitive to the use of recycled irrigation water for foods that are processed. Interestingly, our analysis also reveals that consumers of processed foods prefer products with no label specifying the source of the irrigation water to labels identifying it as recycled and conventional. This result suggests that consumers prefer to not give much thought to the type of water used on food. Making consumers aware of the various kinds of irrigation water used leads to lower demand for the products, which is consistent with some previous literature (see Li et al., 2018). In addition, we find that the informational nudges tested in the experiment have no statistically significant effects on consumers' WTP for fresh and processed foods irrigated with recycled water (relative to the experimental control). Of the demographic characteristics and behavioral attributes analyzed, only age has a statistically significant effect on WTP and then only for processed foods irrigated with recycled water. We find that older consumers are less likely than younger consumers to purchase processed foods irrigated with recycled water, possibly because they perceive a greater degree of risk given the greater prevalence of health concerns among older adults.

2. Experimental Design

In this framed field experiment (Harrison and List, 2004), we use a single-bounded dichotomous-choice format that includes elements of within-subject and between-subject designs to elicit consumers' WTP for processed and fresh foods (see Table 2 for a summary of experiment design). Dichotomous-choice mechanisms are often used in experimental economics due to their incentive-compatible and demand-revealing properties (Taylor et al., 2001; Satterthwaite, 1975). They also allow one to avoid underestimating WTP values as they provide participants with a simple decision-making setting that closely resembles actual purchasing environments (Wu et al., 2014). To understand whether food processing can alleviate consumers' concerns about the use of recycled irrigation water, we designed the experiment to answer a series of research questions related to consumers' demand for processed and fresh foods irrigated with recycled, conventional and no specification water (a summary of research questions, hypotheses and results is provided in Table 1).

In the experiment, 329 adult participants were randomly recruited from the mid-Atlantic region of the U.S. at a farmer's market. The subjects were each given a $10 participation payment and were told that they could use the money, if they desired, to purchase food products in the experiment at posted prices and that they would keep whatever portion of the \$10 they did not spend. The experiment presented participants with a series of opportunities to make binary yes/no purchase decisions regarding fresh and processed foods labeled as having been irrigated with recycled water, irrigated with conventional water, or no information about irrigation water. All purchasing choices were presented on a single page of a participant's screen. The purchase decisions were presented to each participant in random order to avoid order effects. The posted price for each product presented was randomly drawn from a normal distribution with the mean equal to the average market price for the product and standard deviation of one-half of the mean:

Grapes (1 pound):	$P \sim \mathrm{N}(3, 1.5^2)$
Olives (8 ounces):	$P \sim \mathrm{N}(3.4, 1.7^2)$
Raisins (1 pound):	$P \sim \mathrm{N}(3.4, 1.7^2)$
Dried Olives (8 ounces):	$P \sim \mathrm{N}(2.7, 1.35^2)$
Grape Juice (1 bottle):	$P \sim \mathrm{N}(2.7, 1.35^2)$
Olive Oil (1 bottle):	$P \sim \mathrm{N}(4.4, 2.2^2)$.

Products offered through the experiment were displayed to participants in a designated area where they could easily examine them. All branding information and identifying labels were removed from the products prior to display.

Before proceeding to the purchase decisions, the software interface provided participants with the following formal definitions of recycled and conventional water. These definitions also appeared on the page that displayed purchasing options.

Conventional Water: "Conventional water comes from a variety of sources. Typical sources of conventional water include: surface water, groundwater from wells, rainwater, impounded water (ponds, reservoirs, and lakes), open canals, rivers, streams, and irrigation ditches." (Centers for Disease Control and Prevention, 2016).

Recycled Water: "Recycled water is highly treated wastewater from various sources, such as domestic sewage, industrial wastewater and storm water runoff." (California Department of Water Resources, 2018).

To maintain incentive-compatibility, participants were further informed that their choices were not hypothetical and that one of their decisions would be randomly selected for implementation at the end of the experiment. Therefore, if the participant had chosen to purchase the product offered in the selected decision, the posted price of that product would be subtracted from the $10 participation fee and the participant would receive the product and whatever money remained. If the participant had rejected the product offered in the selected decision, the participant simply received the entire $10 payment and no food. Thus, participants would choose to purchase a food item only when their WTP for the item is greater than or equal to the posted price:

$$\mathrm{D} = \begin{cases} 0 & WTP < P \quad \text{(No)} \\ 1 & WTP \geq P \quad \text{(Yes)}, \end{cases} \tag{1}$$

where D = {0,1} and (D = 1) represents a "yes" decision, (D = 0) represents a "no" decision, and WTP represents individual i's willingness to pay for food product j.

After completing the purchasing decisions, participants filled out a short on-screen survey that collected information on their demographic characteristics and shopping preferences (see Appendix A). Then, the software interface randomly selected one of each participant's decisions for implementation.

The purchasing decisions and survey responses were made on tablet computers placed at individual work stations with dividers attached to ensure participants' privacy. Participants were not allowed to communicate with each other during the experiment to ensure that their decisions were not influenced by others' preferences. Each participant took about fifteen minutes to complete the experiment.

2.1. Behavioral Interventions

To explore whether consumers' WTP for fresh and processed foods changes in response to different kinds of information about recycled water, the participants were randomly assigned to one of three information treatments (benefit information, risk information, and both benefit and risk information) or to the control group in a between-subject design. This random assignment to treatment groups ensured that the participants' observed and unobserved characteristics were independent of the treatment received and, therefore, that a causal relationship could be established between the estimated effects and the treatment. The treatments presented the participants with the following information about recycled water:

Treatment 1 – Benefits of Recycled Water: "According to the United States Environmental Protection Agency (EPA), 'In addition to providing a dependable, locally controlled water supply, water recycling provides tremendous environmental benefits. By providing an additional source of water, water recycling can help us find ways to decrease the diversion of water from sensitive ecosystems. Other benefits include decreasing wastewater discharges and reducing and preventing pollution. Recycled water can also be used to create or enhance wetlands and riparian habitats.'" (Environmental Protection Agency, 2017).

Treatment 2 – Risks of Recycled Water: "According to cropscience.org, 'There have been a number of risk factors identified for using recycled waters for purposes such as agricultural irrigation. Some risk factors are short term and vary in severity depending on the potential for human, animal or environmental contact (e.g., microbial pathogens), while others have longer term impacts which increase with continued use of recycled water (e.g., salt effects on soil).'" (Fourth International Crop Science Congress, 2004).

Treatment 3 – Benefits and Risks of Recycled Water: The information from both treatments 1 and 2 presented in random order.

Participants assigned to the *Control Group* received no information prior to making their purchasing decisions.

2.2. *Data*

Table 3 summarizes the demographic characteristics and behavioral attributes of the 329 adult participants.[2] The average age of the participants was 41 years, 55% were female and 45% were male, and there were one or more children under age 18 in 35% of the households. Approximately 49% of the participants had a bachelor's or graduate degree and slightly more than half reported annual household incomes of less than $50,000. In terms of political affiliation, 26% of participants identified as liberal, 21% as conservative, and 43% as moderate. The majority of participants (73.3%) were their households' primary food shoppers, 61.7% preferred to buy local foods, and almost 40% reported that at least half of the food they consumed was organic. Overall, the participants were mostly aware of recycled water use (69%) before taking part in the experiment.

Table 4 compares the socio-demographic characteristics of our sample to that of the general population of the South Atlantic region of the U.S., where most of our participants resided, and the entire U.S. The participants in our sample are generally comparable to the South Atlantic region of the U.S. and also to the entire U.S. in terms of gender distribution, median age, income distribution, and the number of children under 18 present in households. However, our sample exceeded the general population of the South Atlantic U.S. and the entire U.S. in terms of education.

3. Analysis and Results

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[2] The initial sample included 375 participants. We excluded observations for eight of those participants because of missing data on their incomes, education level, and ages. And to ensure that our sample included only adults, we excluded 38 participants younger than 22 and who identified themselves as students.

Each of the 329 participants in the experiment made nine yes/no purchase decisions, yielding 2,961 observations. The participants chose to purchase a food item in 801 of the decisions (27%) and purchased foods irrigated with recycled water in 288 of those purchases (36%).

We use a random effects logistic model that controls for within-subject comparisons to determine which factors influence participants' WTP for fresh and processed foods irrigated with recycled water:

$$log\frac{D_{ij}}{1-D_{ij}} = \beta_0 + \beta_1 B_{ij} + \beta_2 I^R_{ij} + \beta_3 I^U_{ij} + \beta_4 T^1_{ij} + \beta_5 T^2_{ij} + \beta_6 T^3_{ij} + \beta_7\left(I^R_{ij} * T^1_{ij}\right) + \tag{2}$$

$$\beta_8\left(I^R_{ij} * T^2_{ij}\right) + \beta_9\left(I^R_{ij} * T^3_{ij}\right) + \beta_{10} P_{ij} + \beta_{11}(I^R_{ij} * P_{ij}) + \beta_{12} O_{ij} + \nu_i + \varepsilon_{ij},$$

where $\nu_i \sim N(0,\sigma^2_\nu)$, $\varepsilon_{ij} \sim N(0,\sigma^2)$.

D_{ij} is the probability that participant i will choose to purchase food product j. B_{ij} is the posted price for participant i and food product j. I^R_{ij} and I^U_{ij} are dummy variables indicating foods irrigated with recycled water and unspecified water respectively, with foods irrigated with conventional water as the omitted category. T^1_{ij}, T^2_{ij}, and T^3_{ij} are dummy variables that represent the three information treatments that include benefit information (T^1_{ij}), risk information (T^2_{ij}) and both the benefit and risk information (T^3_{ij}), with no information (T^4_{ij}) as the omitted variable. P_{ij} is a dummy variable that represents processed foods, with fresh foods as the omitted category. O_{ij} is a dummy variable that represents olive products, with grape products as the omitted category. $I_{ij}^{R}*T_{ij}^{1}$, $I_{ij}^{R}*T_{ij}^{2}$, $I_{ij}^{R}*T_{ij}^{3}$ capture the interaction effects between foods irrigated with recycled water and the information treatments. $I_{ij}^{R}*P_{ij}$ is the interaction effect between foods irrigated with recycled water and processed foods.

Table 6 presents estimates from the random effects logit model (equation 2) for the likelihood of purchasing the various food choices presented in the experiment. We used separate regressions to estimate the likelihood of purchasing decision with the four processed foods treated as a single variable (column 1) and with the two types of processing used in the experiment (drying and liquid extraction) as separate variables (column 3). In columns 2 and 4, both regressions were extended to include a set of the demographic and behavioral characteristics (variable definitions are provided in Table 5).

As expected, we find that price has a significant negative impact on consumers' likelihood of purchasing food products across all models. Relative to the conventional-water baseline, consumers are less likely to purchase foods irrigated with recycled water. They also prefer the items that did not specify the type of irrigation water to the conventional-water products.

Our results also show that the behavioral interventions represented by the information treatments had no statistically significant effects on purchasing decisions for foods irrigated with recycled water relative to purchasing foods in the no-information control group. These findings are in line with other studies that also reported insignificant effects of information on acceptance of recycled water (Ellis et al., 2018; Hui and Cain, 2017). The fact that information about benefits of recycled water is unlikely to increase consumers' acceptance of products irrigated with recycled water is particularly interesting and has important policy implications. This result is consistent with a few other studies that found similar effects (Ellis et al., 2018a; Savchenko et al., 2018a). However, our findings do not support the results of prior research that showed consumers lowered their willingness to pay for fresh produce irrigated with recycled water when they received negative information about recycled water and that both positive and negative information increased acceptance of foods irrigated with recycled water (Savchenko et al., 2018a).

The results in Table 6 also indicate that consumers generally prefer fresh versions of the foods to processed foods at their respective market prices (columns 1). From the estimates for processed foods separated into dried and liquid categories (columns 3 of Table 6), we find that consumers' preferences for the dried products drive their preference for fresh over processed food.

In terms of demographic and behavioral characteristics, the estimates indicate that consumers' likelihood of purchasing both fresh and processed foods irrigated with recycled water is greater among relatively educated consumers and consumers who express a preference for local foods. Participants with relatively high incomes are less likely to purchase than participants with relatively low incomes, as are households with children. Age is the only demographic characteristic that had a statistically significant impact on likelihood to purchase foods irrigated with recycled water (*Recycled* × *Age*, –0.0199, $p < 0.058$).[3] This effect may be driven by greater concern among older adults about health risks potentially associated with recycled water.

[3] Interaction effects of *Recycled* with the other demographic and behavioral characteristics were not statistically significant. Those results are available from the authors upon request.

To gain insight into whether processing can alleviate consumers' concerns about food irrigated with recycled water, we analyze the likelihood of purchasing fresh and processed foods separately using the random effects logistic model. We also compute marginal willingness to pay (WTP) values for processed and fresh foods irrigated with different types of water from the estimates of the random effects logistic model. These WTP values capture the differences between participants' WTP for foods irrigated with conventional water baseline and their WTP for foods irrigated with recycled and unspecified water types. Estimation results and marginal WTP values are summarized in Table 7 for proceed foods and in Table 8 for fresh foods.

The results presented in Tables 7 and 8 point to important heterogeneity in consumers' responses to processed and fresh foods irrigated with recycled water. We find no statistically significant difference in likelihood of purchasing processed foods based on recycled versus conventional irrigation water. For fresh food, however, consumers are less willing to purchase products irrigated with recycled water than products irrigated with conventional water. In fact, participants were willing to pay $1.23 less for fresh foods irrigated with recycled water relative to the conventional water baseline. These findings suggest that processing can mitigate some of the concern associated with recycled water found in previous studies. Consumers' lack of acceptance of fresh foods irrigated with recycled water may be related to aversion (Po et al., 2003; Wester et al., 2016; Kecinski et al., 2016, 2018; Ellis et al., 2018a, Savchenko et al., 2018b, Kecinski and Messer, 2018) and/or its actual and perceived risks as discussed previously. Food processing may provide consumers with a degree of physiological separation between the recycled water and their food, making them less sensitive to its use.

Interestingly, we also find that consumers of processed foods still prefer no specification regarding water to products labeled as having recycled and conventional irrigation water. Participants were willing to pay a premium of \$0.87 for processed foods irrigated with unspecified water relative to the conventional water baseline. This result suggests that consumers do not necessarily think about how their food is produced in a detailed way and that raising the question of the type of water used leads to concerns about agricultural water in general. This finding is consistent with Li et al. (2018) in their study of the effect of information about recycled water on demand for wine. The authors found that consumers lowered their WTP for wine when they received information about the source of irrigation water used in wine production.

Our analysis of the demographic and behavioral drivers of consumers' purchasing decisions related to processed (column 2 of Table 7) and fresh foods (column 2 of Table 8) shows that a higher level of education and a preference for local food increases consumers' willingness to purchase fresh and processed food, while a relatively high income decreases the likelihood. We find that presence of a child in the household has a negative effect on purchasing fresh foods. As with the previous analysis, age is the only demographic characteristic that has a statistically significant effect on consumers' decisions with older consumers less willing to buy processed foods irrigated with recycled water (*Recycled* × *Age*, –0.0264, $p < 0.016$).[4]

[4] The interaction effects of *Recycled* with the other demographic and behavioral characteristics were not statistically significant.

4. Conclusion

As water shortages become increasingly common in the U.S. and around the world, recycled wastewater can provide a valuable and sustainable source of water for irrigation of agricultural crops, which currently consume about 80% of the U.S. water supply. Current technologies can purify wastewater not only for non-potable uses but to meet standards for safe drinking water. However, numerous studies have shown that consumers in the U.S. are reluctant to accept recycled water when used for products that are ingested or involve personal contact because of its "yuck factor" (Po et al., 2003; Rozin et al., 2015; Kecinski et al., 2016, 2018, Savchenko et al., 2018b). Consumers' aversion extends to produce from plants irrigated with recycled water (Savchenko et al., 2018a), presenting a serious barrier to widespread adoption of recycled water by U.S. agricultural producers. Therefore, it is important for policymakers, producers and the food industry to thoroughly understand this stigma and ways to mitigate it.

Using an incentive-compatible, dichotomous-choice, framed field experiment involving 329 adult consumers, this study explores the potential for processing to relieve some of the stigma associated with foods produced using recycled water. We find that consumers are equally accepting of processed foods irrigated with recycled and conventional water but are less accepting of fresh foods irrigated with recycled water relative to the conventional-water baseline. Our results suggest that compared to a no-information control, messages about benefits, risks or both benefits and risks associated with recycled water do not have statistically significant effects on consumers' likelihood of purchasing processed or fresh foods irrigated with recycled water. Finally, though most of the demographic and behavioral characteristics tested in the experiment had no statistically significant effects, age was a factor for processed foods labeled as irrigated with recycled water. Older consumers were less likely than younger consumers to purchase those products.

The findings of this study suggest that processing can alleviate some of consumers' concern about food products irrigated with recycled water, providing important insight for policymakers and producers interested in promoting its use in U.S. agriculture. These results suggest, as well, that crops such as grains irrigated with recycled water may be more acceptable to consumers as ingredients in highly processed foods such as baked goods or that consumers may be less concerned about eating meat from animals that grazed on pastures irrigated with recycled water. These ideas would be potentially fruitful areas of future study.

The results of the information treatments tested in this study are also important because they indicate that positive information about the type of water used for food products meant to relieve concerns about recycled water may be unlikely to succeed. The three information treatments used in this study had no statistically significant effect on WTP for fresh or processed foods irrigated with recycled water. However, the regressions did identify reductions in likelihood of purchasing food products bearing labels that identified the source of irrigation water used relative to products with no such labeling. These results suggest that labeling products as irrigated with fresh water could backfire and reduce consumers' desire to purchase those products.

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Figure 1: Photo of the front of a package of blueberries labeled with information on water source, emphasis added.

Figure 2: Photo of the label on sweet pea shoots with information on water source, emphasis added.

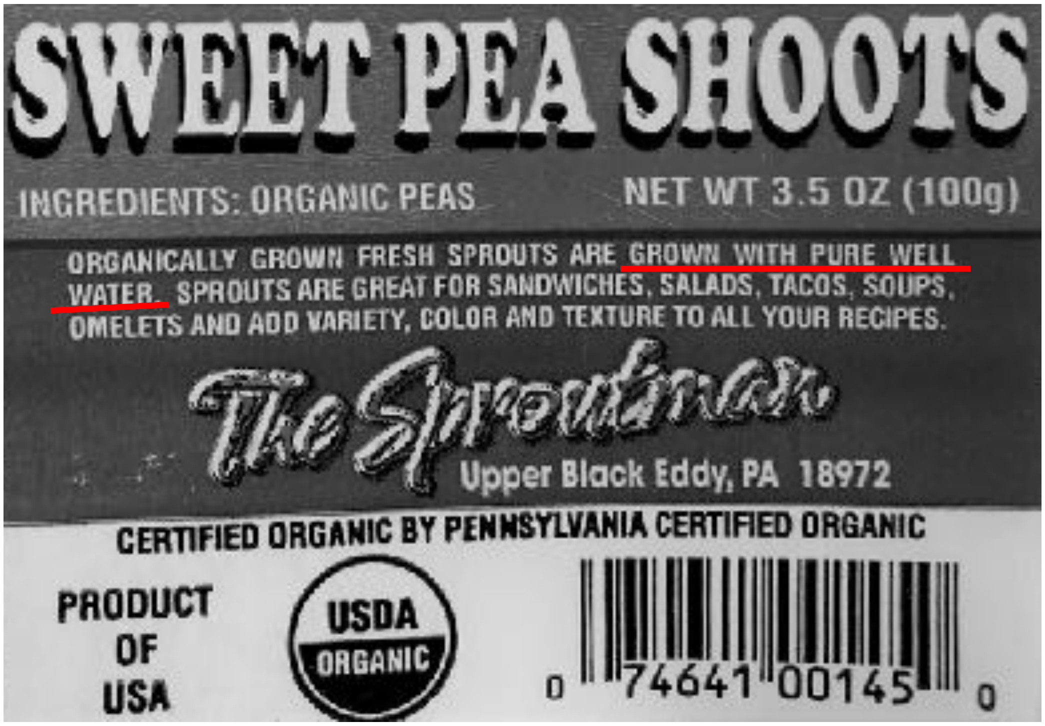

Table 1: Summary of Research Questions, Hypothesis Tests, and Results.

Research Question	Hypothesis Test*	Results
Irrigation Water Type and Food Type		
(1) Does consumers' WTP for *processed foods* change when they know it has been irrigated with *recycled water* relative to their WTP for the same processed foods irrigated with *conventional* type of water?	H_0: $WTP^R_P = WTP^C_P$ H_A: $WTP^R_P \neq WTP^C_P$	Fail to Reject H_0. Consumers of processed foods were indifferent between recycled and conventional water types.
(2) Does consumers' WTP for *processed foods* change when they know it has been irrigated with *unspecified water* relative to their WTP for the same food products irrigated with a *conventional* type of water?	H_0: $WTP^U_P = WTP^C_P$ H_A: $WTP^U_P \neq WTP^C_P$	Reject H_0. Consumers had higher WTP for processed foods irrigated with unspecified water relative to conventional water baseline.
(3) Does consumers' WTP for *fresh foods* change when they know it has been irrigated with *recycled water* relative to their WTP for the same processed foods irrigated with *conventional* type of water?	H_0: $WTP^R_F = WTP^C_F$ H_A: $WTP^R_F \neq WTP^C_F$	Reject H_0. Consumers lowered their WTP for fresh foods irrigated with recycled water relative to conventional water baseline.
(4) Does consumers' WTP for *fresh foods* change when they know it has been irrigated with *unspecified water* relative to their WTP for the same food products irrigated with a *conventional* type of water?	H_0: $WTP^U_F = WTP^C_F$ H_A: $WTP^U_F \neq WTP^C_F$	Fail to Reject H_0. Consumers of fresh food were indifferent between conventional and unspecified water types.
Information Treatment Effects		
(3) Does exposure to information about *benefits* of recycled water change consumers' WTP for food products irrigated with *recycled* water?	H_0: $WTP^{Benefit} = WTP^{Control}$ H_A: $WTP^{Benefit} \neq WTP^{Control}$	Fail to Reject H_0. Information treatment was not significant.
(4) Does exposure to information about *risks* associated with recycled water change consumers' WTP for food products irrigated with *recycled* water?	H_0: $WTP^{Risk} = WTP^{Control}$ H_A: $WTP^{Risk} \neq WTP^{Control}$	Fail to Reject H_0. Information treatment was not significant.

(5) Does exposure to information about *both benefits and risks* associated with recycled water change consumer's WTP for food products irrigated with *recycled* water?	H_0: $WTP^{Both} = WTP^{Control}$ H_A: $WTP^{Both} \neq WTP^{Control}$	Fail to Reject H_0. Information treatment was not significant.

* For recycled water (R), conventional water (C), processed food (P), and fresh food (F).

Table 2: Experimental Design.

			Number of Participants	Total
Between-subject Treatments				
	No Information Control		82	
	Benefit		81	
	Risk		86	
	Benefit and Risk		80	329
Within-subject Treatments				
Processed Foods	Raisins	No Specification	40	
		Conventional		
		Recycled		
	Dried Olives	No Specification	66	
		Conventional		
		Recycled		
	Olive Oil	No Specification	66	
		Conventional		
		Recycled		
	Grape Juice	No Specification	58	
		Conventional		
		Recycled		

Fresh Foods	Grapes	No Specification	47	
		Conventional		
		Recycled		
	Olives	No Specification	52	
		Conventional		
		Recycled		329

Table 3: Summary of Respondents' Demographic Characteristics and Behavioral Attributes

Variable	
Number of respondents	329
Average age (years)	41.1
	Percentage of participants
Female	55.6
Children under 18 in the household	35.9
Education	
Some high school	2.7
High school graduate	18.2
Some college	19.5
Associate degree	10.6
Bachelor's degree	27.7
Graduate degree/Professional degree	21.3
Household Income	
Less than \$10,000	10.9
\$10,000–\$14,999	5.8
\$15,000–\$24,999	12.2
\$25,000–\$34,999	9.7
\$35,000–\$49,999	13.1
\$50,000–\$74,999	19.2
\$75,000–\$99,999	10.3
\$100,000–\$149,999	10.9
\$150,000–\$199,999	4.9
\$200,000–\$249,999	2.1
\$250,000 and above	0.9
Prefer Local Food	61.7
Primary Food Shopper	73.3
Know the Source of Water at Home	59.3
Heard of Recycled Water	69.3

Organic food comprises at least half of food consumption	38.6

Table 4: Comparison of the experiment sample and 2010 Census statistics for South Atlantic and the U.S.

	Sample	2010 Census	
	Experiment Participants	South Atlantic	U.S.
Number of respondents/population	329	59,777,037	308,746,965
Median age (years)	39	38.3	37.2
Female	55.6%	51.2%	50.8%
Children under 18 in the household	35.9%	28.6%	29.8%
Education			
Percent high school graduate or higher	97.3%	87.2%	87.0%
Percent bachelor's degree or higher	49.0%	30.5%	30.0%
Household Income (2015)			
Less than $10,000	10.9%	7.6%	7.2%
$10,000–$14,999	5.8%	5.4%	5.3%
$15,000–$24,999	12.2%	10.9%	10.6%
$25,000–$34,999	9.7%	10.6%	10.1%
$35,000–$49,999	13.1%	13.9%	13.4%
$50,000–$74,999	19.2%	17.8%	17.8%
$75,000–$99,999	10.3%	11.6%	12.1%
$100,000–$149,999	10.9%	12.3%	13.1%
$150,000–$199,999	4.9%	4.8%	5.1%
$250,000 and above	2.1%	5.0%	5.3%

Table 5: Description of Explanatory Variables

Variable	Description
Price	Randomly posted price
Recycled	Equals 1 for foods irrigated with recycled water
Unspecified	Equals 1 for foods irrigated with unspecified water
T1: Benefits	Equals 1 if participant is in the group that received information only about benefits of recycled water
T2: Risks	Equals 1 if participant is in the group that received information only about risks associated with recycled water
T3: Benefits and Risks	Equals 1 if participant is in the group that received a balanced information treatment that includes information about benefits and risks
Processed	Equals 1 for processed foods
Olive	Equals 1 for olive foods
Liquid	Equals 1 for liquid foods
Dried	Equals 1 for dried foods
Demographic Characteristics	
Age	Participants' age
Female	Equals 1 for female participants
Income	Categorical (1–lowest, 11– highest)
Education	Equals 1 for participants with a bachelor or graduate/professional degree
Children	Equals 1 if a child under 18 in the household
Behavioral Attributes	

Local Food	Equals 1 for participants who prefer local food
Primary Shopper	Equals 1 for primary food shopper
Water Source	Equals 1 for participants who know the source of water in their household
Heard	Equals 1 for participants who heard about recycled
	Equals 1 if organic food comprises at least half of food consumption
Organic	Organic food comprises at least half of total food consumption

Table 6: Comparison of Likelihood of Purchasing Food Products at the Posted Price.

	All Processed Foods Represented by a Single Variable				Liquid and Dried Processed Foods Represented by Separate Variables			
Decision (yes/no)	(1)		(2)		(3)		(4)	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Price	–0.464***	0.049	–0.462***	0.049	–0.487***	0.048	–0.485***	0.048
Recycled	–0.698**	0.340	–0.703**	0.339	–0.715**	0.347	–0.719**	0.346
Unspecified	0.230*	0.132	0.229*	0.132	0.232*	0.134	0.231*	0.134
T1: Benefits	0.0535	0.318	–0.0569	0.328	0.0565	0.324	–0.058	0.333
T2: Risks	–0.160	0.330	–0.218	0.323	–0.163	0.335	–0.222	0.327
T3: Benefits & Risks	–0.409	0.324	–0.472	0.313	–0.406	0.328	–0.470	0.318
Recycled x T1	0.0846	0.420	0.0899	0.418	0.095	0.429	0.099	0.427
Recycled x T2	–0.135	0.431	–0.138	0.432	–0.132	0.439	–0.137	0.440
Recycled x T3	0.0536	0.442	0.0488	0.441	0.0746	0.451	0.068	0.451
Processed	–0.277**	0.118	–0.277**	0.118				
Recycled x Processed	0.191	0.192	0.196	0.192				
Olive	–0.129	0.212	–0.123	0.205	–0.0904	0.217	–0.0845	0.209
Liquid					0.0462	0.145	0.044	0.145

Recycled x Liquid					0.244	0.239	0.248	0.239
Dried					–0.611***	0.138	–0.609***	0.138
Recycled x Dried					0.161	0.228	0.164	0.228
Age			–0.001	0.007			–0.0013	0.007
Female			0.017	0.216			0.0074	0.220
Income			–0.061*	0.032			–0.0605*	0.033
Education			0.779***	0.226			0.785***	0.229
Children			–0.383*	0.230			–0.392*	0.233
Local Food			0.534**	0.227			0.540**	0.230
Primary Shopper			–0.010	0.222			–0.007	0.227
Water Source			0.113	0.206			0.110	0.210
Heard			0.131	0.244			0.128	0.247
Organic			0.075	0.212			0.081	0.215
Constant	0.442	0.315	0.165	0.551	0.480	0.315	0.207	0.556
Observations	2,961		2,961		2,961		2,961	

Note: Robust standard errors are shown in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 7: Comparison of Likelihood of Purchasing Processed Foods at the Posted Price.

	(1)		(2)			
Decision (yes/no)	Coeff.	S.E.	Coeff.	S.E.	WTP	95% CI
Price	–0.423***	0.051	–0.420***	0.0507		
Recycled	–0.388	0.370	–0.384	0.371	–$0.92	[–2.65 0.81]
Unspecified	0.369**	0.151	0.371**	0.151	$0.87**	[0.16 1.59]
T1: Benefits	0.0802	0.331	–0.0093	0.339		
T2: Risks	–0.0335	0.336	–0.0599	0.330		
T3: Benefits & Risks	–0.462	0.328	–0.489	0.322		
Recycled x T1	0.117	0.452	0.115	0.451		
Recycled x T2	–0.223	0.462	–0.234	0.463		
Recycled x T3	0.244	0.471	0.233	0.473		
Dried	–0.635***	0.149	–0.630***	0.149		
Recycled x Dried	–0.0957	0.250	–0.095	0.251		
Olive	0.197	0.217	0.185	0.211		
Age			–0.0002	0.00711		
Female			–0.0677	0.221		
Income			–0.0406	0.0328		
Education			0.645***	0.221		
Children			–0.334	0.231		
Local Food			0.506**	0.229		
Primary Shopper			–0.0835	0.229		
Water Source			0.146	0.212		

Heard			0.146	0.251
Organic			0.0859	0.216
Constant	0.149	0.312	–0.189	0.562
Observations	1,974		1,974	

Note: Robust standard errors are shown in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. Marginal WTP 95% confidence intervals are obtained using delta method.

Table 8: Comparison of Likelihood of Purchasing Fresh Foods at the Posted Price.

	(1)		(2)			
Decision (yes/no)	Coeff.	S.E.	Coeff.	S.E.	WTP	95% CI
Price	–0.657***	0.090	–0.653***	0.087		
Recycled	–0.805*	0.433	–0.837*	0.428	–$1.23*	[–2.47 0.02]
Unspecified	–0.0715	0.194	–0.0815	0.192	–$1.09	[–0.69 0.47]
T1: Benefits	–0.115	0.38	–0.208	0.389		
T2: Risks	–0.488	0.393	–0.573	0.386		
T3: Benefits & Risks	–0.295	0.387	–0.359	0.375		
Recycled x T1	–0.0929	0.588	–0.0723	0.581		
Recycled x T2	0.109	0.571	0.126	0.571		
Recycled x T3	–0.332	0.591	–0.317	0.587		

Olive	–0.464*	0.249	–0.450*	0.241
Age			–0.00235	0.008
Female			0.172	0.260
Income			–0.0946***	0.037
Education			0.781***	0.261
Children			–0.508*	0.261
Local Food			0.498*	0.256
Primary Shopper			0.142	0.271
Water Source			–0.0501	0.238
Heard			0.123	0.267
Organic			–0.00485	0.239
Constant	1.498***	0.403	1.506**	0.637
Observations	987		987	

Note: Robust standard errors are shown in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1. Marginal WTP 95% confidence intervals are obtained using delta method.

Appendix A: Survey Questions

Please answer the following questions:

1. What is your age?

2. What is your zip code?

3. What is your gender?
   - Male
   - Female
   - Other (please specify)

4. Which one of the following categories best describes your employment status:
   - Government
   - Education
   - Business
   - Agriculture
   - Student
   - Other (please specify)

5. Are you:
   - Politically liberal
   - Politically moderate
   - Politically conservative
   - Other (please specify)

6. Which category best describes your household income (before taxes) in 2015?
   - Less than $10,000
   - $10,000-$14,999
   - $15,000-$24,999
   - $25,000-$34,999
   - $35,000-$49,999
   - $50,000-$74,999
   - $75,000-$99,999
   - $100,000-$149,999
   - $150,000-$199,999
   - $200,000-$249,999
   - $250,000 and above

7. What is the highest level of education that you have completed?

- Grade school
- Some high school
- High school graduate
- Some college credit
- Associate degree
- Bachelor's degree
- Graduate degree/Professional

8. Do you have a child/children under the age of 18 years old in your household?

- Yes
- No

9. How often do you consume the following produce:

Fresh Grapes

times per month

Grape Juice

times per month

Raisins

times per month

Fresh Olives

times per month

Olive Oil

times per month

Dried Olives

times per month

10. Are you the primary shopper in your household?
- ◯ Yes
- ◯ No

11. What is the percentage of organic foods in your overall vegetable and fruit consumption?

Non-Organic (50%) Organic (50%)

12. Do you grow your own food?
- ◯ Yes
- ◯ No

13. Which do you prefer?
- ◯ Local Food
- ◯ Non-Local Food
- ◯ Don't care

14. How important are the following produce characteristics to you?

Taste: **5**
Not Important (1) **Very Important (9)**

Appearance: **5**
Not Important (1) **Very Important (9)**

Smell: **5**
Not Important (1) **Very Important (9)**

Price: **5**
Not Important (1) **Very Important (9)**

Organic: **5**
Not Important (1) **Very Important (9)**

Non-Genetically Modified Organisms: **5**
Not Important (1) **Very Important (9)**

Growing Location: **5**
Not Important (1) **Very Important (9)**

Brand: **5**
Not Important (1) **Very Important (9)**

15. Have you ever heard of recycled/reclaimed/reused water before today?
- ◯ Yes
- ◯ No

16. How do you drink your water?
- ◯ Bottled Water
- ◯ Filtered Tap Water
- ◯ Tap Water
- ◯ Other (please specify) ________

20. How do you feel about these different types of non-traditional waters for irrigation?

Grey Water: **5**

It generally refers to the wastewater generated from household uses like bathing and washing clothes.

Dislike (1) **Like (9)**

Black Water: **5**

Also described as Brown Water. It generally refers to the wastewater generated from toilets.

Dislike (1) **Like (9)**

Brackish Water: **5**

It is typically defined as distastefully salty but less saline than seawater (between 1,000 to 10,000 ppm [parts per million] in total dissolved solids [TDS]). In addition to certain surface water settings such as estuaries, brackish water can be found in aquifers.

Dislike (1) **Like (9)**

Industrial Water: **5**

It generally means process and non-process wastewater from manufacturing, commercial, mining, and silvicultural (forestry) facilities or activities, including the runoff and leachate from areas that receive pollutants associated with industrial or commercial storage, handling or processing, and all other wastewater not otherwise defined as domestic wastewater.

Dislike (1) **Like (9)**

Rain Water: **5**

Generally, the term rain water refers to water coming from rooftops and other aboveground surfaces.

Dislike (1) **Like (9)**

Storm Water: **5**

Generally, the term storm water refers to rainwater collected from non-roof surfaces, such as parking lots, hardscapes, and landscapes surrounding urban buildings.

Dislike (1) **Like (9)**

21. Do you reuse waste water at home?

- Yes
- No

22. What is your attitude towards these different types of recycled water?

Primary Treated Recycled Water : **5**

Use of mechanical or physical systems such as sedimentation to treat wastewater is generally referred to as primary treatment.

Dislike (1) **Like (9)**

Secondary Treated Recycled Water : **5**

Use of biological processes such as biological oxidation and disinfection to provide further treatment is generally referred to as secondary treatment.

Dislike (1) **Like (9)**

Tertiary Treated Recycled Water : **5**

Use of more advanced processes such as chemical coagulation, filtration and disinfection to provide further treatment is generally referred to as tertiary treatment.

Dislike (1) **Like (9)**

Finish and Submit

17. Please check the areas in which you're concerned about water availability.

- ☐ Your Community
- ☐ Your State
- ☐ United States
- ☐ Worldwide
- ☐ I'm not concerned.

18. Are you concerned about water availability in the following time periods?

Present: **5**
Not At All (1) Very Concerned (9)

Next 10 Years: **5**
Not At All (1) Very Concerned (9)

Next 30 Years: **5**
Not At All (1) Very Concerned (9)

Greater than 30 years: **5**
Not At All (1) Very Concerned (9)

19. How concerned are you about climate change in...

Your Community: **5**
Not At All (1) Very Concerned (9)

Your State: **5**
Not At All (1) Very Concerned (9)

United States: **5**
Not At All (1) Very Concerned (9)

Worldwide: **5**
Not At All (1) Very Concerned (9)

The Department of Applied Economics and Statistics
College of Agriculture and Natural Resources
University of Delaware

The Department of Applied Economics and Statistics carries on an extensive and coordinated program of teaching, organized research, and public service in a wide variety of the following professional subject matter areas:

Subject Matter Areas

Agricultural Policy	Environmental and Resource Economics
Food and Agribusiness Management and Marketing	International Agricultural Trade
Natural Resource Management	Price and Demand Analysis
Rural and Community Development	Statistical Analysis and Research Methods

The department's research in these areas is part of the organized research program of the Delaware Agricultural Experiment Station, College of Agriculture and Natural Resources. Much of the research is in cooperation with industry partners, the USDA, and other State and Federal agencies. The combination of teaching, research, and service provides an efficient, effective, and productive use of resources invested in higher education and service to the public. Emphasis in research is on solving practical problems important to various segments of the economy.

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