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Food Waste: The Role of Date Labels, Package Size, and Product Category

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Abstract

The presence of food waste, and ways to reduce food waste, has generated significant debate among industry stakeholders, policy makers, and consumer groups in the United States and elsewhere. Many have argued that the variety of date labels used by food manufacturers leads to confusion about food quality and food safety among consumers. Here we develop a laboratory experiment with treatments that expose subjects to different date labels (Sell by, Best by, Use by, and Fresh by) for six food products; we include both small and large-sized ready-to-eat cereal, salad greens, and yogurt. Our results show that, holding other observed factors constant, that date labels do influence subjects' value of food waste. We find that subjects will waste food across all date labels, but that the value of waste is greatest in the "Use by" treatment, the date label suggestive of food safety, and lowest for the "Sell by" treatment. Two-way ANOVA tests provide evidence that subjects respond differentially to date labels by product. Pair-wise comparison indicate that the "Sell by" treatment generates a waste value that is different than other date labels. We see subjects have different values of waste depending on date label and product. The value of waste for cereal is more responsive to "Fresh by"; for salad, the value of waste is more responsive to all date labels except for "Fresh by"; for yogurt, subjects adjusted their value of waste the most to the "Sell by" treatment. Date labels influence food waste despite the limited information provided by the labels.

Keywords: Consumer preferences; Date labels; Experimental economics; Food quality; Food safety; Public policy analysis.
JEL classification: Q13, Q18

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1. Introduction

The presence of food waste, and ways to reduce food waste, has generated significant debate among industry stakeholders, policy makers, and consumer groups. Arguably, food waste has become one of the top issues for individuals and organizations involved in food marketing and food policy in the United States and elsewhere. The U.N. Conference on Sustainable Development acknowledges food waste and food loss as important components of food insecurity in their Zero Hunger Challenge (Halloran, Clement, Kornum, Bucatariu, & Magid, 2014). In June 2013, the USDA and the EPA partnered to launch the U.S. Food Waste Challenge, an initiative to reduce food waste throughout the food supply chain.[1] Some have estimated that annual food waste costs in the United States are approximately $160 billion, representing resources that went into the production, distribution, and marketing of food products (Buzby, Wells, & Hyman, 2014; Newsome et al., 2014). Food waste is also a food security concern as it symbolizes a lost opportunity to feed the 17.5 million food insecure U.S. households (Coleman-Jensen, Gregory, & Singh, 2014).

Buzby et al. (2014) estimate that 31% of food is wasted; this is the total of food wasted by consumers (21%) and producers (10%). Because the largest share of food waste is associated with consumers, and because there are several efforts underway to address food waste issues in the production, distribution, and storage stages, we propose to examine opportunities for interventions to reduce household food waste by better understanding consumer behavior. Specifically, we focus on how consumers respond to information that may have the potential to affect the level of food waste. As part of this proposed research, we will also shed new light on quantifying current levels of food waste in the United States.

There has been much written about the role of date labels on food waste. Critics argue that date labels are confusing for consumers, and that this confusion encourages unnecessary levels of food waste (Newsome et al., 2014; Wansink & Wright, 2006; WRAP (Waste & Resources Action Programme), 2011). Evidence suggests that consumers waste food products as they near the date posted on the date label (open date label) for perceived food safety reasons (Kantor & Lipton, 1997; Miles & Frewer, 2001; Newsome et al., 2014; Woodburn & Van Garde, 1987). In addition to food being discarded for reasons related to perceived food safety, others have shown that consumers waste food for reasons related to food quality (Theotokis, Pramatari, & Tsiros, 2012; Tsiros & Heilman, 2005). Wansink and Wright (2006) find that as consumers observe an approaching "Best if Used By" date label, it decreases consumer acceptance, as well as the perceived healthfulness and freshness of the product.

Despite discussions about the quantity and value of food waste in the United States, little empirical work exists that provides primary data to quantify food waste and describes how food waste may vary across different populations and across different products. Understanding consumer behavior is a key factor in developing a better understanding of the causes of food waste and the consequences of changes that might be employed to mitigate food waste. As part of this discussion, we have witnessed a range of public policy recommendations to mitigate the amount of food waste. Such initiatives have proposed to change the language used on food as it relates to date labels (Newsome et al., 2014).

The purpose of this research is to understand better how consumers respond to date labels and how this response varies across package sizing and across product categories. We developed an experiment to study the factors that influence food waste across product categories and across package sizes; we focus on three different products each in two different sizes. Specifically, we develop an experiment that uses a series of auctions to collect economic data on consumer response to labels and information for two yogurt products (5.3 ounce (150.3 grams) and 32 ounce (907.2 grams)), two ready-to-eat cereal products (10 ounce (283.5 grams) and 40.7 ounce (1.15 kilograms)), and two pre-washed salad green products (5 ounce (141.7 grams) and 10 ounce (283.5 grams)).

1.1. Contextual Background

In the United States, rules about open date labels differ by state, but overall they are widely unregulated. With the exception of infant formula, which is regulated under the 1980 Infant Formula Act, the FDA does not require food products to display specific open date labels. However, some poultry, meat, and egg products under USDA jurisdiction necessitate date documentation, but rather vague phrases including "sell by" and "use before" can be used interchangeably (Leib et al., 2013; Newsome et al., 2014). The USDA does not set out strict guidelines for terminology commonly used on food products. The use of the following date label phrases have been summarized by Tsiros and Heilman (2005):

- "Sell By" conveys to the retailer the last date the product can be displayed for sale. It is not an indication of a product's safety or quality.
- "Best if Use By," "Best Before," or "Best By" are used to suggest the date after which the food's quality or flavor may deteriorate.
- "Use By" recommends the last date by which the product should be consumed, but does not necessarily convey safety information.

The authority to enact additional food date labeling laws rests with state and local authorities, which can include the Department of Health, Department of Agriculture, Department of Commerce, among other agencies. Additionally, other qualifying phrases such as "Fresh By" or “Enjoy By” can be used by food manufacturers; however, neither are indicators of a product quality or product safety. They do, however, have the potential to send signals to consumers and influence preferences (Leib et al., 2013). Overall, this lack of jurisdiction by a single agency coupled with manufacturer discretion over the application of date labels has the capacity to foster inconsistencies in terminology and confusion about product safety and quality among consumers (Leib et al., 2013).

Despite the brief, non-binding framework offered, labels such as “Best Before” are sometimes perceived to indicate microbial safety rather than freshness, while “Use By” may be interpreted to imply quality, depending on accompanying information; this confusion contributes to unnecessarily disposing edible food (Newsome et al., 2014; WRAP, 2011). Evidence also suggests some consumers believe a product past the open expiration date is no longer safe for consumption (Newsome et al., 2014). Such evidence implies people place heavier reliance on expiration dates than temperature control, the latter of which is much more important in determining food safety because date labels do not guarantee microbiological food safety (Newsome et al., 2014; Woodburn & Van Garde, 1987).

Even though expiration dates do not ensure a food is safe to consume, Van Garde and Woodburn (1987) found that consumers often disposed of food products that were past the open expiration date without additional sensory evaluation. Results from Kantor (1997) support this claim; consumers reported not trusting their senses as an accurate judge of a food’s edibility, thus preferring to discard food when the quality or safety was questioned. Past experiences and the risk a consumer associates with a food product also influence how often a person examines the open date label (Tsiros & Heilman, 2005). Specifically, Kantor (1997) found that negative experiences with a food product made consumers more inclined to prematurely discard that product. This increased tendency to waste food because of the expiration date despite lack of apparent safety concerns may be partially attributable to increased consumer awareness and fear of food safety issues (Miles & Frewer, 2001).

In addition to food products being discarded for safety reasons, a food's quality as signaled by date labels also contributes to premature food waste. Tsiros and Heilman (2005) found that depending on the product category, between 69% and 84% of consumers believe perishable products deteriorate in quality over time. This is supported by Theotokis et al. (2012), who provide evidence that products priced lower as they near the expiration date prompts consumers to have negative perceptions of brand quality. While the psychological effects of expiration date-based pricing vary among consumers depending on associated risk and brand loyalty, Theotokis et al. (2012) suggest expiration dates influence how consumers perceive the product, and expiration date-based price changes signal inferior quality and ultimately affects consumer purchasing decisions.

Kantor (1997) also finds that bulk purchases contribute to food waste. Marketing tactics, such as "buy one get on free," may also facilitate impulse purchases, which coupled with poor meal planning, thwarts households from consuming food products before the open date nears (Farr-Wharton et al., 2014). Inadequate storage facilities and practices further contribute to avoidable food waste, as consumers are prone to forgetting or miscalculating what food they currently have in stock (Kantor & Lipton, 1997). This culture of abundance and reliance on date labels may induce consumers to dispose of food products past the open date label (Godfray et al., 2010). Through the use of an economic experiment and by carefully examining how consumers respond to different date labels across products categories and across package sizes, we hope to provide new insights that will allow stakeholders to better understand the causes and consequences of food waste.

2. Material and methods

We designed an experiment allowing us to collect data to study the drivers of food waste among consumers. Data were collected from 200 non-student subjects that participated in our framed field experiment. Subjects were randomly placed in one of four treatments differentiated by the date label language (Best by, Fresh by, Use by, and Sell by). Each session consisted of between 16 and 25 subjects, and each treatment was replicated in two sessions (for the "Best by" treatment we ran three sessions). All subjects in all treatments went through one practice round and six auction rounds for the six products. At the end of the auction rounds all subjects completed a short computerized survey with questions related to demographic variables and food consumption habits.

2.1. The auction

All subjects were presented with the same six products but ordered differently in each session; for each product, subjects were asked to place a willingness to pay (WTP) bid and indicate the percentage of the product that they expect that their household will consume. Subjects did this exercise for two versions of each product (small and large). The sizes varied by product to reflect actual sizes in the market. For each product the subjects stated their WTP and percentage of consumption for three dates (near, middle, and far) of each product. The dates varied by the product to reflect commonly found dates of products in the market (cereal: 1 month, 3 months, and 1 year; salad: 1 day, 3 days and 1 week; and yogurt: 1 day, 3 weeks, and 1 month). In Appendix A we provide a screenshot of the auction for one of the food products. All dates were presented as MM/DD/YYYY. Subjects saw only one date label (Best by, Fresh by, Sell by or Use by), and the date label was repeated throughout their session.

In all treatments, we used the Becker-DeGroot-Marschak (BDM) auction to elicit bids for the six products from all subjects. Given that subjects may have a wide range of valuations, the BDM is an ideal elicitation method because subjects do not bid against each other. Rather, they submit a sealed bid for each product and then have the chance to "win" a product if their bid exceeds a randomly drawn price. After all bids were submitted in a session, we randomly chose a market price for a selected product.

2.2. A measure of food waste

To study the impact of date labels on food waste, and to better understand the implications of alternative policies that might be used to mitigate food waste, it is critical to assess an accurate measure of food waste. There exist a wide range of estimates for food waste in the United States, and much of the range is attributable to the methods employed to calculate the quantity and/or value of food wasted. Measuring food waste could be done using food recall surveys or by observing individuals in a public setting. Food waste might also be measured as part of a consumer-based experiment, and we argue that a properly designed experiment might be a more ideal arena to understand current levels of food waste and the effects of tools that might influence food waste.

Experimental economists have established credible methods to collect price data that are incentive compatible—see Lusk and Hudson (2004) and Lusk, Fields and Prevatt (2008) for a nice summary of the most common experimental designs used by food and agricultural economists. Little research in the economic literature exists that uses experiments to collect consumption data, and no earlier work that uses experimental methods to collect data on food waste. Price data collected as part of an incentive compatible experiment could be used to infer food consumption (and food waste), but there are additional complexities associated with such inference.

Here we develop a measure of food waste that we refer to as the consumer's willingness to waste (WTW). The WTW is based on the information we collect from subjects that describe their value of each product and the amount of the product they expected to consume. More specifically, we asked subjects the amount they would be willing to pay for the selected food items and the amount of the product that they expected to consume. The expected consumption level ranges from 0% to 100%; we then subtracted this value from 100% to attain the expected percentage of waste for each product. We then multiply the waste percentage times the maximum WTP for each version of the products. This WTW measure follows a concept that has been employed in nutrition literature (e.g., Woodburn & Van Garde, 1987) that measures the "cost of discarded food" as a measure of food waste.

3. Theory and Hypotheses

Based on the literature, we expect that consumers will waste food based on the date labels regardless of the intent or purpose of the date label. Even at the point of purchase we expect that a large share of customers will intend to waste some portion of the product (Farr-Wharton et al., 2014); that is, consumers have a baseline WTW regardless of the product, the package size, and the date label. However, we also expect that product category, package size, and the date label will have meaningful impacts on the total WTW. We develop six hypotheses that we test with a series of statistical tests. The treatments in our experiment are the date labels, and we use the "Sell by" date label as our control treatment as it is the least restrictive of the date labels of the four that we study. Our first hypothesis relates to the effects of the date label.

H1: Date labels differentially affect WTW.

In line with the literature, the presence of the date label influences consumer perception of the quality and safety of the product. However, to-date, we know of no research that shows if different date labels cause differences in the perceived value of the product and by extension the consumers' WTW. We test this hypothesis by evaluating the WTW of each date label jointly and pairwise. Extending the first hypothesis, our second hypothesis focuses more specifically on two of the four date label treatments.

H2a: The "Sell by" relative to the other treatments yields the lowest WTW.

H2b: The "Use by" relative to the other treatments yields the highest WTW.

As discussed previously, "Sell by" is the least restrictive of the date labels as it simply indicates the time that retailers should remove the product from the shelves. Therefore, we hypothesize that the "Sell by" date label will generate the lowest WTW of the date labels. We argue that consumers understand that this date label is not directly aimed at them; however, we hypothesize that consumers will respond with a non-zero WTW because of concerns of food safety and quality. Furthermore, we hypothesize that the "Use by" date label will lead to the highest level of WTW because this date label suggests that the product must be consumed or processed by a certain date or the product will no longer be edible. The third hypothesis considers the effects of product category, shelf life, and product size.

H3a: WTW varies by the perishability of products.

H3b: WTW differs by the date.

H3c: WTW differs by product size.

We hypothesize that consumers are more responsive to date labels for products that are relatively more perishable than other products. In our setting we argue that salad and yogurt will have a larger response to the date labels and by extension will have a larger differential response to date labels. We further hypothesize that the WTW will vary by date and product size; dates that are nearer and larger product sizes will generate larger WTW.

4. Results

Our sample contains 3600 observations from 200 hundred subjects; each subject provided information for three versions of six products. The mean WTW for the entire data set is $0.412 with a 95% CI=0.381, 0.443 [$t(3599)=26.227$; $p<0.001$]. The mean WTW values by treatment are as follows: "Best by" 0.345 (n=1188) with a 95% CI=0.313, 0.376 [$t(3599)=21.389$; p<0001]; "Fresh by" 0.462 (n=810) with a 95% CI=0.403, 0.521 [$t(3599)=15.451$; p<0001]; "Sell by" 0.298 (n=864) with a 95% CI=0.260, 0.337 [$t(3599)=15.217$; p<0001] and "Use by" 0.599 (n=738) with a 95% CI=0.483, 0.716 [$t(3599)=10.0967$; p<0001]. The mean WTW value for cereal is 0.550 (n=1200) with a 95% CI=0.494, 0.607 [$t(1199)=19.133$; p<0001]; for salad is 0.409 (n=1200) with a 95% CI=0.354, 0.463 [$t(1199)=14.722$; p<0001]; and for yogurt is 0.277 (n=1200) with a 95% CI=0.229, 0.325 [$t(1199)=11.375$; p<0001].

In Figure 1, we present the mean expected WTW and one standard error for each expiration date for the three product categories. Subjects have the highest WTW for cereal and lowest WTW for yogurt**.** In Figure 1 the vertical axis shows the WTW in dollars per product and the shaded bars show the WTW results across the four date label treatments. Here we see that the "Use by" date label consistently generates the greatest WTW and the "Sell by" treatment generates the smallest WTW. As suggested earlier, we expect that the term "Use by" suggests that the food needs to be consumed by that date otherwise the product may be subject to a food quality concern. However, "Sell by" suggests that the retailers need to move product for marketing purposes rather than for safety reasons. The "Best by" and "Fresh by" date labels are most reflective of the so-called “food quality” date labels, and they generate similar food waste values, and values that fall below those under the “Use by” date label.

To assess the effects of the treatments, we use a series of parametric and non-parametric tests. We assess the treatments jointly across products, in pairwise comparisons for all products, and for each product separately. Additionally, we evaluate the treatment effects over the dates and sizes. Through the various analysis presented we find evidence that subjects respond differentially to date labels.[2]

In Table 1, we assess the difference of the four date labels jointly, which forms the basis for testing H1. The *F*-tests show the following results which reject the null hypothesis that the treatments are the same: all products [$F(3,3596)=16.90$; $p>0.000$], cereal [$F(3,1196)=8.352$, $p=0.0393$], and salad [$F(3,1196)= 23.992$; $p<0.001$]. However, we fail to reject the null hypothesis at a *p*-value less than 0.05 that the treatments are different for yogurt [$F(3,1196)=6.713$; $p=0.0816$]. Similarly, the joint tests suggest that the WTW is different across all treatments for all products except yogurt based on *F*-test while the nonparametric Kruskal-Wallis Equality test indicates that the populations are different regardless of the product: all products [$\chi^2(3)=20.626$; $p<0.001$], cereal [$\chi^2(3)=5.09$; $p=0.0017$], salad [$\chi^2(3)=13.51$; $p<0.001$], and yogurt [$\chi^2(3)=4.12$; $p=0.0064$].

Additionally, we ran two-way ANOVA for the effect of the treatment interacted with product, date, and size (see Table 2). Here we show results from three models: the Product Model recognizes the three products (cereal, salad, and yogurt); the Date Model recognizes the three different dates (near, middle, and far); and the Size Model recognizes the two different sizes of the products (small and large). We find statistical significance for the treatment effects for each model: Product Model [$F(3,3599)=17.19$, $p<0.001$], Date Model [$F(3,3599)=16.94$,

$p<0.001$], and Size Model [$F(3,3599)=17.35$, $p<0.001$]. The titular variable for each model is statistically significant: Product Model [$F(2,3599)=25.90$, $p<0.001$], Date Model [$F(2,3599)=6.94$, $p=0.001$], and Size Model [$F(1,3599)=98.41$, $p<0.001$]. However, only the Product Model has a statistically significant interaction between the titular variable and the treatment: Product Model [$F(6,3599)=3.03$, $p=0.005$], Date Model [$F(6,3599)=0.63$, $p=0.706$], and Size Model [$F(3,3599)=0.93$, $p=0.426$]. Across all models, we see that the treatment and the titular variable (product, date, and size) each influence the WTW. We further find that by product the treatment is different. However, the same is not true, at least in aggregate, over date and size. These findings provide some support for H3a: WTW varies by the perishability of products. However, the insignificant interactions in the Date Model and in the Size Model fail to the support H3b and H3c.

In Table 3, we provide the pairwise comparisons of treatment means across all products. Based on a test of equivalence of the variances, we rejected the null hypothesis. Thus, we use *t*-test for samples with unequal variances for all of the pairwise comparisons, except for "Best by" and "Sell by" because this pair had statistically equal variances. We also ran the *t*-test assuming equal variance, and the results do not change. Tests of the mean differences between the treatments provide evidence to reject the null hypothesis of equivalence: "Best by" versus "Fresh by" [0.345 vs. 0.462; $t(1273.34)=3.461$; $p<0.001$], "Best by" versus "Use by" [0.345 vs. 0.599; $t(846.74)= 4.141$; $p<0.001$], "Fresh by" versus "Sell by" [0.462 vs. 0.298; $t(1409.52)=4.581$; $p<0.001$], "Fresh by" versus "Use by" [0.462 vs. 0.599; $t(1094.6)=2.063$; $p=0.0394$], and "Sell by" versus "Use by" [0.298 vs. 0.599; $t(897.48)=4.814$; $p<0.001$]. The one exception is the *t*-test for "Best by" and "Sell by" where we fail to reject the null of equal variances of the WTW [0.345 vs. 0.298; $t(2050)=1.833$; $p=0.0686$]. These results provide evidence that subjects reported different WTW under the each of the treatments. This result also supports H2a: “Sell by” relative to the other treatments yields the lowest WTW and H2b: “Use by” relative to the other treatments yields the highest WTW.

Beyond the test of equivalent means, we test the equality of the distributions with the Kolmogorov-Smirnov Tests and show the results in the final column in Table 3. We reject the null hypothesis of equivalent distributions for four of the six treatment pairs: “Best by” versus “Fresh by” [*K-S* statistic=0.0623; *p* =0.047], “Best by” versus “Sell by” [*K-S* statistic=0.0712; *p* =0.012], “Fresh by” versus “Sell by” [*K-S* statistic=0.127; *p*=0.001], and “Sell by” versus “Use by” [*K-S* statistic=0.079; *p* =0.013]. We fail to reject the null hypothesis of equivalent distributions for “Best by” versus “Use by” [*K-S* statistic=0.0596; *p* =0.079] and “Fresh by” versus “Use by” [*K-S* statistic=0.0673; *p* =0.061]. Not only are the means (and variances) of the WTW different under the different treatments, we also find evidence that some of the treatment pairs have different distributions. Of particular note is the “Sell by” treatment relative to the other treatments which further supports H2a.

All of the tests discussed thus far provide joint and pairwise parametric and nonparametric tests of statistical significance across products or for selected products. We also disaggregate the data further and consider nonparametric statistical tests for treatment pairs by product (in Table 4), and by size and date (in Table 5). The results in these tables suggest a particular pattern of treatment effects. In both tables, we use the Wilcoxon rank-sum test to test whether the samples under each treatment pairs come from the same population and the Pearson's Chi Squared to test the medians across the treatments.

In Table 4, we test the null hypothesis that the samples under each treatment are the same across all products and for specific products. The common finding is that the “Sell by” treatment is different than the other treatments. As seen in Figure 1, the “Sell by” treatment has the lowest WTW of all four treatments for all products. Based on results from the Wilcoxon rank-sum test and the Pearson's Chi Squared test, we reject the null hypothesis at the $p<0.01$ for all products and each product separately that the samples in the “Fresh by” versus “Sell by” treatments are the same. The WTW under the “Fresh by” treatment is greater than under the “Sell by” treatment for all products and each product separately. This result is consistent with all the other parametric and nonparametric tests reported, and it further supports H2a.

In Table 4 we also report results for the three product categories. The “Sell by” treatment is statistically different than the “Best by” treatment for salad [z=3.371; p<0.001 and $\chi^2(1)$8.103; p=0.004] and yogurt [z=2.206; p=0.0274 and $\chi^2(1)$=4.359; p<0.037]. Furthermore, “Sell by” is statistically different than “Best by” for all products according to the Pearson's Chi Squared test of medians [$\chi^2(1)$=9.111; p=0.003]. The “Sell by” treatment is also different than the “Use by” treatment for all products [z =3.053; p=0.0023 and $\chi^2(1)$=4.993; p=0.025] and salad [z =4.982; p<0.001 and $\chi^2(1)$=14.489; p<0.001].

A less consistent result is the differences associated with “Use by”, “Fresh by”, and “Best by”. On average, the “Use by” treatment has the highest WTW for each product and for salad and yogurt. Compared to the “Best by” treatment sample, the “Use by” treatment sample is different for all products [z =3.153; p=0.0016] and for salad [z =2.372; p=0.0177]. In contrast, the “Use by” treatment sample is different from the “Fresh by” treatment sample for cereal [z=-2.702; p=0.0069] with the Wilcoxon rank-sum test. With the Pearson's Chi Squared test, “Use by” has a different median for all products [$\chi^2(1)$=6.8034; p=0.009], cereal [$\chi^2(1)$=9.414; p=0.002] and yogurt [$\chi^2(1)$=5.426; p=0.020]. Similarly, “Best by” and “Fresh by” are statistically different for all products [z =-2.269; p=0.0233 and $\chi^2(1)$=5.776; p=0.016] and cereal [z=-2.437; p=0.0148 and $\chi^2(1)$=6.309; p=0.012].

The results for cereal show that the "Fresh by" treatment has a significantly higher WTW than the other treatments: compared to "Best by" [z=-2.437; p=0.0148 and $\chi^2(1)$=6.309; p=0.012], "Sell by" [z=2.586; p=0.0097 and $\chi^2(1)$=7.160; p=0.007], and "Use by" [z=-2.702; p=0.0069 and $\chi^2(1)$=9.414; p=0.002]. Additionally, salad and yogurt do not have the same pattern of statistical significance associated with the "Fresh by" treatment. In contrast, salad has statistically different treatment samples for "Sell by" relative to "Best by" [z=-3.371; p=0.0007 and $\chi^2(1)$=8.103; p=0.004], "Fresh by" [z=3.399; p=0.0007 and $\chi^2(1)$=0.680; p=0.002], and "Use by" [z=4.982; p<0.001 and $\chi^2(1)$=14.489; p<0.001]. Yogurt has a less consistent pattern of statistical significance with the "Sell by" treatment. The breakdown is largely due to statistical insignificance of the "Sell by" treatment relative to the "Use by" treatment [z=0.942; p=0.355 and $\chi^2(1)$=0.285; p=0.593]. The upshot of this set of results suggests that subjects have different WTW depending on date label and product: The value of waste for cereal is more responsive to "Fresh by". For salad, the value of waste is more responsive to all date labels except for "Fresh by", while for yogurt, subjects adjusted their value of waste the most to the "Sell by" treatment.

In Table 5, we test the treatment differences of the samples by date and by package size. In our experiment, subjects provided valuation and consumption information for three different dates per product: far, middle, and near. We differed the dates of the three time periods to reflect commonly found dates in retail environments. We also considered a small and a large size for each product. The actual sizes varied by product, but reflected commonly found versions of each product in the grocery and represented both small and large package sizes. Across the dates and sizes, we find that the "Sell by" treatment is statistically different than the other three treatments, yet the “Sell by” versus “Use by” result had only one statistically significant test for the Pearson's Chi Squared test (Near date [$\chi^2(1)$=4.13; *p*=0.042]). The “Fresh by” and “Use by” treatments have no statistically significant differences across sizes and dates, and the “Best by” and “Fresh by” treatments have only one statistically significant treatment effect for the Near date under the Pearson's Chi-Squared test [$\chi^2(1)$=4.69; *p*=0.030]. The Middle date has no statistically significant treatment differences. These results provide evidence in support of H3b and H3c; however, the evidence is limited mainly to the “Sell by” treatment relative to the other three treatments.

5. Discussion and Conclusions

The results from our experiment show that subjects responded differentially to the different date labels jointly and on a pairwise basis over all products, dates, and sizes. On average, subjects tended to indicate a lower WTW under the “Sell by” treatment relative to the other treatments. This difference holds regardless of the product under consideration, the size or the date of the product. On the surface, this result suggests that if manufacturers move exclusively to the “Sell by” date label, the WTW will decrease and this could lead to less waste in the food system. One critical issue we observe is that subjects are willing to waste product based on a date label that has little do with food safety or food quality directly. The “Sell by” date label is largely used as a signal to retailers, and yet it prompts subjects to register a non-zero WTW. The other treatments generate higher levels of WTW, and overall the “Use by” treatment generates a WTW that is twice as large as that under the “Sell by” treatment.

Another interpretation of our general finding is that the “Sell by” date label may serve as a lower bound for the WTW such that customers have a predetermined value of product that they expect to waste regardless of the date label. We calculated subjects’ WTW by using their stated responses for WTP and their expected consumption rate; thus, we were able to have subjects reveal an anticipated value loss even before purchase. Across the different treatments we found evidence that subjects had different WTW for different products. Cereal had the highest WTW followed by salad then yogurt. This order is consistent with the ordering of the retail value of these products. However, across the treatments salad had the most different WTW, and this difference was most pronounced for the “Sell by” date label.

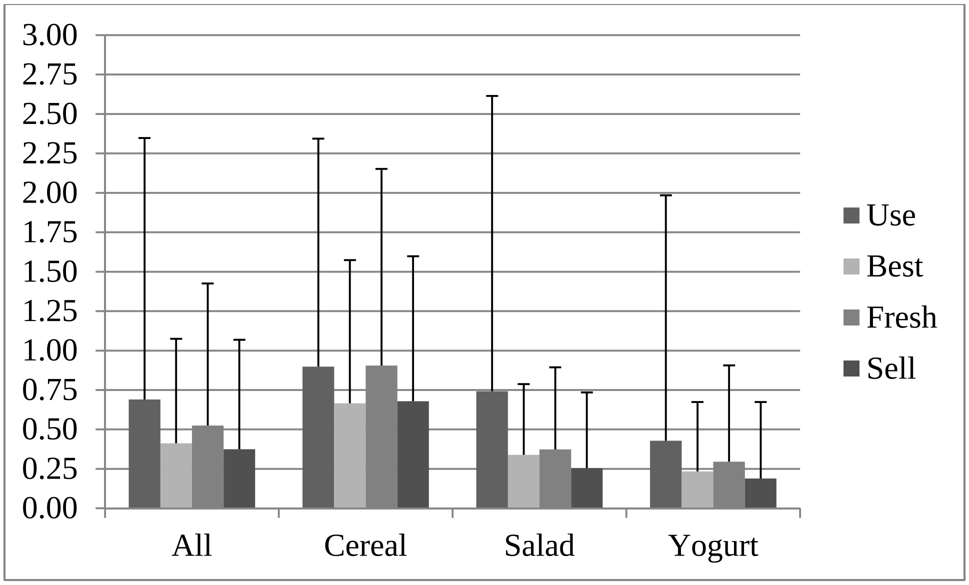
There is much speculation on the efficacy of various mechanisms and policies that might be used to reduce food waste, but there is little economic research examining the alternatives carefully. Our research uses data collected in an incentive compatible experiment to assess how consumers respond to different date labels for food products in small and large package sizes. We find that the value of consumer food waste does respond to date labels, and that the effects vary across food categories. Our research, by necessity, focused on a subset of food products sold at retail markets, but we believe that our results shed light on the issue of food waste more generally. Furthermore, we introduce a carefully designed experimental auction that allowed us to control many aspects of consumer choice for the selected food products, and we present a novel method to calculate the value of food wasted by end consumers. Our framework can be extended to examine a wide range of issues related to food waste, and the results can be then used to investigate the effects of specific policies designed to mitigate food waste.

Endnotes

[1] A summary of the USDA report can be found at (http://www.usda.gov/oce/foodwaste/usda_commitments.html).

[2] There were a few subjects that may have misread the dates for selected products as they reported to consume more for products with the later date labels. Therefore, we ran the analysis with a restricted dataset that dropped these observations and found that it did not change the general thrust of the results reported here.

Figure 1. Maximum Willingness to Waste Mean Values (in Dollars) for Each Treatment with One Standard Deviation for All Data



Note: The columns represent the mean values of each treatment. The bars are one standard deviation from the mean values.

Table 1. Joint Comparison of Date Labels

Product	F-test		Kruskal-Wallis Equality of Population amongst the Four Treatments
	F-statistic (*p*-value)	d.f.	$\chi^2_{3\ d.f.}$ statistic (*p*-value)
All	16.90*** (0.00)	3,3596	20.626*** (0.0001)
Cereal	8.352* (0.0393)	3,1196	5.09** (0.0017)
Salad	23.992*** (0.000)	3,1196	13.51*** (0.000)
Yogurt	6.713 (0.0816)	3,1196	4.12*** (0.0064)

p<0.001=***, *p*<0.01=**, *p*<0.05=*

Table 2. Two-Way Analysis of Variance of the Value of the Willingness to Waste of Treatment by Product, Date and Size

	Product		Date		Size	
	F-statistic (*p*-value)	d.f.	*F*-statistic (*p*-value)	d.f.	*F*-statistic (*p*-value)	d.f.
Model	11.07*** 0.000	11,3559	6.18*** (0.000)	11,3599	21.76*** (0.000)	7,3599
Treatment	17.19*** 0.000	3,3599	16.94*** (0.000)	3,3599	17.35*** (0.000)	3,3599
Product	25.90*** 0.000	2,3599				
Product x Treatment	3.03** 0.005	6,3599				
Date			6.94*** (0.001)	2,3599		
Date x Treatment			0.63 (0.706)	6,3599		
Size					98.41*** (0.000)	1,3599
Size x Treatment					0.93 (0.426)	3,3599

$p<0.001$=***, $p<0.01$=**, $p<0.05$=*

Table 3. Pairwise Comparisons of Means and Distributions of Date Labels

Treatments	*t*-test with Unequal Variance[a]		Kolmogorov-Smirnov Test for Equality of Distribution Functions
	Statistic (*p*-value)	d.f.	*K-S* statistic (*p*-value)
Best vs. Fresh	3.461*** (0.0006)	1273.35	0.0623* (0.047)
Best vs. Sell[b]	1.833 (0.0686)	2050	0.0712* (0.012)
Best vs. Use	4.141*** (0.000)	846.74	0.0596 (0.079)
Fresh vs. Sell	4.581*** (0.000)	1409.52	0.127*** (0.000)
Fresh vs. Use	2.0628* (0.0394)	1094.6	0.0673 (0.061)
Sell vs. Use	4.814*** (0.000)	897.48	0.079* (0.013)

$p<0.001$=***, $p<0.01$=**, $p<0.05$=*

[a] We use the Satterthwaite's degrees of freedom for *t*-test of unequal variances because we reject the null hypotheses of equal variances with *F*-tests ($p<0.001$).

[b] For "Best by" and "Use by", we fail to reject the null hypothesis of equal variances thus we use the t-test of equal variances.

Table 4. Nonparametric Comparisons of Date Labels

Treatments	Rank Sum z-value (*p*-value)				Pearson Test of Medians Over Treatments $\chi^2_{1\ d.f.}$ statistic (*p*-value)			
	All	Cereal	Salad	Yogurt	All	Cereal	Salad	Yogurt
Best v. Fresh	-2.269* (0.0233)	-2.437* (0.0148)	-0.383 (0.702)	-0.991 (0.322)	5.776* (0.016)	6.309* (0.012)	0.0997 (0.752)	1.301 (0.254)
Best vs. Sell	0.026 (0.079)	1.316 (0.188)	3.371*** (0.0007)	2.206* (0.0274)	9.111** (0.003)	0.137 (0.711)	8.103** (0.004)	4.349* (0.037)
Best vs. Use	3.153** (0.0016)	0.331 (0.741)	2.372* (0.0177)	-0.980 (0.327)	0.249 (0.618)	0.8056 (0.369)	2.135 (0.144)	2.0283 (0.154)
Fresh vs. Sell	5.022*** (0.000)	2.586** (0.0097)	3.399*** (0.0007)	3.008** (0. 0026)	3.895*** (0.0001)	7.160** (0.007)	9.680** (0.002)	8.844** (0.003)
Fresh vs. Use	-1.606 (0.1084)	-2.702** (0.0069)	1.828 (0.0676)	-1.803 (0.0714)	6.8034** (0.009)	9.414** (0.002)	1.989 (0.158)	5.426* (0.020)
Sell vs. Use	3.053** (0.0023)	-0.242 (0.809)	4.982*** (0.000)	0.942 (0.355)	4.993* 0.025	0.260 (0.610)	14.489*** (0.000)	0.285 (0.593)

p<0.001=***, *p*<0.01=**, *p*<0.05=*

Table 5. Nonparametric Pairwise Comparisons of Date Labels

Treatments	Rank Sum z-value (*p*-value)					Pearson Test of Medians Over Treatments $\chi^2_{1\,d.f.}$ statistic (*p*-value)				
	Dates			Sizes		Dates			Sizes	
	Far	Middle	Near	Small	Large	Far	Middle	Near	Small	Large
Best v. Fresh	-1.37	-0.88	-1.63	-1.74	-1.60	1.00	1.37	4.69**	2.68	3.78
	(0.17)	(0.38)	(0.10)	(0.082)	(0.110)	(0.32)	(0.24)	(0.030)	(0.102)	(0.052)
Best vs. Sell	2.342*	1.162	2.15*	2.47*	2.15*	6.744***	0.67	3.61	5.09*	4.27*
	(0.019)	(0.25)	(0.032)	(0.014)	(0.032)	(0.00)	(0.41)	(0.057)	(0.024)	(0.039)
Best vs. Use	-0.259	0.110	0.95	0.366	0.30	0.22	0.57	0.13	0.36	0.010
	(0.80)	(0.91)	(0.34)	(0.71)	(0.77)	(0.64)	(0.45)	(0.72)	(0.55)	(0.92)
Fresh vs. Sell	3.34***	1.885	3.60***	3.90***	3.444***	10.99***	2.83	14.05***	14.99***	10.73***
	(0.00)	(0.059)	(0.00)	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)	(0.00)	(0.00)
Fresh vs. Use	-1.41	-0.67	-0.553	-1.18	-1.15	1.77	2.543	2.60	3.34	2.74
	(0.16)	(0.50)	(0.58)	(0.24)	(0.25)	(0.18)	(0.11)	(0.11)	(0.068)	(0.098)
Sell vs. Use	1.83	1.03	2.66***	2.45*	2.027*	3.59	0.00	4.13*	3.73	1.64
	(0.067)	(0.30)	0.008	(0.014)	(0.043)	(0.058)	(0.98)	(0.042)	(0.054)	(0.20)

p<0.001=***, *p*<0.01=**, *p*<0.05=*

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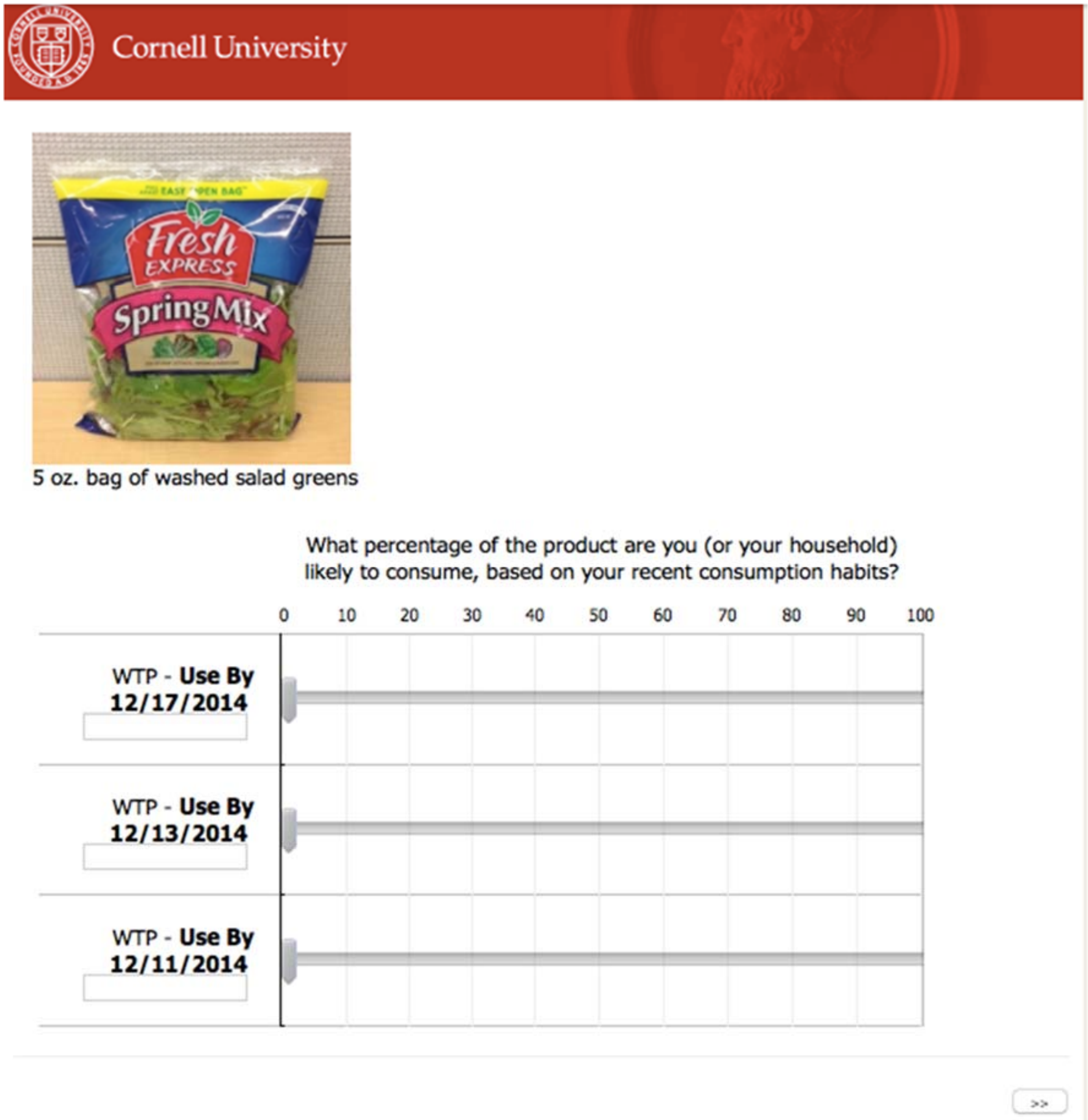
Appendix A: Screenshot of the Auction Procedure (from 12/10/2014)



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