Received: 26 December 2023 | Accepted: 22 November 2024

DOI: 10.1002/aepp.13507

SUBMITTED ARTICLE

AAEA Agricultural & Applied Economics Association WILEY

Food waste, date labels, and risk preferences: An experimental exploration

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Funding information
USDA NIFA, Grant/Award Number: 2016-67023-24817; Alabama Agricultural Experiment Station; National Science Foundation, Grant/Award Number: 2115405

Editor in charge: Alessandro Bonanno

Abstract

This study provides theoretical and experimental evidence that consumers adjust their premeditated food waste by date labels and their risk and loss preferences. The "Use by" date label leads to more premeditated food waste than "Best by" for deli meat and spaghetti sauce. However, changing date labels may not lower premeditated food waste relative to no label at all. Greater loss aversion correlates with higher premeditated food waste regardless of date labels and products. For participants with high loss aversion, they have higher premeditated waste with no statistical difference in response for "Best by" and "Use by" labels. These results highlight the heterogeneous response to date labels.

KEYWORDS

date labels, food waste, loss aversion, premeditated waste, risk aversion, willingness to pay

JEL CLASSIFICATION

Q18, L66, D81, C91, D11

In the United States, actors in the food supply chain waste 40% of the food produced, which has considerable negative environmental impacts (cf Bellemare et al., 2017; Buzby & Hyman, 2012; Buzby et al., 2014; Cox & Downing, 2007; Jaglo et al., 2021; Leib et al., 2016, 2019; Muth et al., 2019; Qi & Roe, 2016; Yu & Jaenicke, 2020). One potential source of food waste is the influence of date labels printed on food packaging (e.g., "Best by," "Best if enjoy by," "Best if used by," "Sell by," and "Use by"). A body of research regarding date labels suggests that they likely confuse consumers or alter their perceptions of foods, leading consumers to discard edible food items (Aschemann-Witzel, 2018a, 2018b, 2018c; Barone & Aschemann-Witzel, 2022; Chu et al., 2020; Kosa et al., 2007; Li et al., 2020; Neff et al., 2019; ReFED, 2016, 2017; Roe et al., 2018; Schanes et al., 2018; Secondi, 2019; Smith & Landry, 2021). Previous studies suggest that consumers believe the labels have a meaning or represent different attributes for different foods regardless of the label's intent and that such a mismatch between consumers' beliefs and the intent causes food waste (Leib et al., 2016, 2019; Neff, 2014; Neff et al., 2019; Newsome et al., 2014; Ray et al., 2024; Rickard et al., 2023; Theotokis et al., 2012; Tsiros & Heilman, 2005; Van Boxstael et al., 2014; Wansink & Wright, 2006; Wilson et al., 2017, 2018, 2019). However, some papers have questioned the importance of date labels alone in contributing to waste (Badiger et al., 2023; D'Amato et al., 2023).

To address the confusion caused by food date labels, industry groups and policymakers in the United States have proposed simplifying date labels into two categories (one for quality and one for safety) to mitigate the confusion. For instance, in 2017, the Food Manufacturing Institute and the Consumer Brands Association (formally the Grocery Manufacturers Association) announced that the food industry would voluntarily simplify date labels to "Best if Use by" and "Use by" (US GAO, 2019). The USDA Food Safety and Inspection Service (FSIS) recommended but did not require "food manufacturers and retailers that apply product dating use a 'Best if Used By' date" (USDA FSIS, 2023). Further, the US Food and Drug Administration (FDA) acknowledged the industry standard but noted, "FDA is not addressing the use of a 'Use by' product date label for safety reasons at this time" (Yiannas, 2019). In this policy environment, the US Government Accounting Office (GAO) Congressional Report assessed the state of date labels in the US market (US GAO, 2019). The GAO recognized the use of multiple date labels and the limited coordination across agencies to address data label use. GAO recommended better coordination between USDA, FDA, and stakeholders on the meaning and use of date labels. Subsequently, US Senator Richard Blumenthal and Representative Chellie Pingree introduced the Food Date Labeling Act of 2023, which, if enacted, would federally mandate "Best if Used by" for quality and "Use by" for safety food labels.[1] These policy moves imply that simple communication can mitigate complex behavior such as food waste (Schanes et al., 2018). These moves implicitly assume homogeneity of consumers: All consumers will respond to the two labels in ways consistent with the safety and quality signals.

The present study examines changes in consumers' premeditated waste (PW) and willingness to pay (WTP) when exposed to simple communication of a food quality ("Best by") date label versus a safety ("Use by") one. It also explores how the change is mediated by food items and consumers' risk preferences measured by risk aversion, loss aversion, and probability weighting under the framework of prospect theory. The analysis aims to provide insights into the impact of simplifying date labels and to contribute to the food waste literature on the heterogeneous effects of food waste mitigation strategies.

The research on food waste is a burgeoning literature that has found tremendous heterogeneity in food waste and in consumers' responses to food waste mitigation (Aschemann-Witzel, 2018a, 2018b, 2018c, 2021; Bilska et al., 2020; Ellison et al., 2022; Fan et al., 2022; Rickard et al., 2023; Stangherlin et al., 2019). For example, the heterogeneity of responses to food waste includes differences by region or municipality (Secondi, 2019; Secondi et al., 2015). D'Amato et al. (2023) and Li et al. (2020) provide evidence that participants have different preferences for potential waste over the time gradient. Weis et al. (2021) document differential responses between the United States and UK to labels and over products. Wilson et al. (2017)

note differences in food waste by product size, among other characteristics. While an extensive literature considers the socioeconomic and demographic factors of the heterogeneity, the literature also considers behavioral factors, such as uncertainty concerning food safety, that might influence food waste (Aschemann-Witzel, 2018a, 2018b, 2018c, 2021; Leib et al., 2016; Neff et al., 2019; Qi & Roe, 2016; Schanes et al., 2018; Secondi et al., 2015; Toma et al., 2020; Van Garde & Woodburn, 1987).

One reason for food waste is consumers' concerns over food safety at the point of food purchase and beyond. Date labels interact with these concerns and may indirectly contribute to food waste. Earlier research has long documented that consumers discard foods over food safety (Kantor et al., 1997; Van Garde & Woodburn, 1987). For example, Van Garde and Woodburn (1987) report that younger households needed additional information beyond package dates since food safety concerns were a major reason for discards for these consumers. Wilson et al. (2018) document that some consumers are confused by date labels, conflating quality (e.g., taste and texture) and safety. Thus, when studying food waste, we should consider the risk caused by food consumption and how date labels communicate this risk regarding quality and safety. Therefore, risk preferences could be a potential lens for understanding food waste via date labels. Given that food waste decisions pertain to the tradeoff between losing food and the possibility of losing health, prospect theory, which focuses on people's decision-making in the loss domain, is a reasonable choice to employ to examine food waste. Furthermore, prospect theory can also accommodate people's decision bias that overweights low probability events and underweights high probability events.[2]

A few studies have used prospect theory to examine food waste issues; however, they do not explicitly estimate the impact of loss aversion. For instance, Just and Wansink (2013) find that prospect theory does not explain consumers' willingness to pay and food waste under various size labels for food. Wansink (2018) use prospect theory to explain why households prepare too much food at the cost of food waste. He argues that based on prospect theory, the cook in a household is more sensitive to the "loss" caused by disappointing their guests or children with insufficient food served than the "gains" from having no food left from a meal. Therefore, a cook over-prepares, leading to food waste. Recently, Huang et al. (2021) use prospect theory to examine how message framing would affect food waste behavior at a buffet dinner. However, none of these studies have quantified the impact of date labels on food waste from the perspective of prospect theory. We aim to fill this gap.

In this paper, we consider the role of date labels in food waste by product while accounting for risk and loss preferences. We first develop a stylized food waste decision model based on prospect theory to formalize willingness to pay and premeditated waste of a food item, focusing on the impact of date labels and consumers' risk and loss preferences on willingness to pay and premeditated waste. We do so to offer theory-based hypotheses for our empirical analysis and future research. We find that under general assumptions, more loss-averse consumers tend to waste more food than other consumers. However, the impact of risk aversion on food waste is ambiguous. The results suggest that altering perceptions of safety and quality can lead to greater or less food waste in light of risk aversion, loss aversion, and probability weighting.

We then present an empirical analysis based on data from 200 non-student participants via in-person experiment sessions conducted in Alabama and New York. We estimate the treatment effects of quality and safety date labels on willingness to pay (WTP) and premeditated waste. We assess the moderation of treatment effects of date labels by risk and loss preferences. We chose two products (prepackaged turkey deli meat and meatless spaghetti sauce) representing perishable and shelf-stable products. We took products as they were in the marketplace and did not manipulate or create new date labels.

Our empirical findings show that the quality (i.e., "Best by") and safety (i.e., "Use by") date labels relative to no date label lowered the willingness to pay for deli meat but had no statistically significant effect on spaghetti sauce.[3] Relative to no date label, "Best by" lowered the premeditated waste for spaghetti sauce, but "Use by" increased the premeditated waste for the deli meat. However, "Use by" led to larger premeditated waste for both foods than "Best by." Greater loss aversion correlates with higher premeditated waste regardless of date labels and products. For participants with high loss aversion, the effect of the date labels "Best by" and "Use by" on food waste was not statistically different. Given that the product remained constant except for the change in date labels, the results mean that date labels affect differentially premeditated food waste at the point of purchase with little to no effect on the willingness to pay. These findings suggest that the imposition of a simple date label plan may have a limited effect on food waste, and those benefits may dissipate along the loss aversion gradient under different assumptions. Thus, simplifying date labels could be a good first step to reducing food waste, but other policies are needed to see a substantial reduction in food waste.

The contributions of the present study are fourfold. First, to the best of our knowledge, this study is the first attempt to apply prospect theory to understanding the impact of date labels on food waste at the consumer level. Second, based on prospect theory and the experimental data, the study quantitatively measures the effect of loss aversion and date labels on food waste. Third, by showing the association between consumers' loss aversion and food waste, this study complements existing studies that attribute food waste to consumers' misinterpreting date labels. Lastly, we proffer policy recommendations to mitigate food waste via modifying date labels.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

We now conceptually explore how consumers' WTP and PW might be influenced by their risk and loss preferences and date labels based on prospect theory. Here, we highlight only a few key features and major findings of the model from which our hypotheses are derived. A fully developed theoretical model based on prospect theory is presented in Appendix A in the Supporting Information.

To facilitate discussion, we first introduce how prospect theory evaluates random outcomes. Unlike the well-known expected utility theory, which uses risk aversion parameters to reflect risk preferences, prospect theory introduces three new concepts—reference point, loss aversion, and probability weighting—while retaining the risk aversion parameter. The reference point is the threshold value that differentiates gains and losses. If the outcomes are better (worse) than the reference point, then they are deemed as gains (losses). Loss aversion indicates the decision-maker's preferences regarding losses. Studies have shown that people tend to be more sensitive to a loss than a same-sized gain (Brown et al., 2024). For instance, the pain of losing $1000 may be felt much more acutely than the happiness of gaining $1000. Probability weighting reflects the empirical findings that decision-makers tend to overweight small probabilities but underweight large probabilities. Risk aversion, as in the expected utility theory, is reflected by the curvature of the value function.

Loss aversion and risk aversion measure a decision-maker's two distinct preferences. Specifically, loss aversion measures a decision-maker's (disproportionate) dislike of losses, regardless of the certainty of the losses. As discussed above, the degree of loss aversion is reflected by the magnitude of the kink at the reference point. Risk aversion, on the other hand, concerns the certainty of gains *or* losses. A risk-averse decision-maker prefers a sure gain to a random gain with the same mean as the sure gain, but she would prefer a random loss to a sure loss with the same mean as the random loss. That is, a risk-averse decision-maker in the gain domain is actually risk-loving in the loss domain.

We now employ prospect theory to understand a representative consumer's food waste decision regarding the remainder of a food item that has been purchased and how date labels may affect this decision. To be concrete, let q denote the quantity of the remainder. Suppose the consumer believes that with probability p the remainder is in "good quality," denoted by $g > 0$, and with probability $1 - p$ in bad quality status, denoted by $b < 0$. Based on prospect theory, the utility that the consumer obtains from consuming the remainder can be written as

$$U(q,g,b,p) = w(p)v(q \cdot g) + w(1-p)v(q \cdot b), \tag{1}$$

where the value function $v(\cdot)$ is:

$$v(x) = \begin{cases} x^{1-\sigma} & \text{for}\, x \geq 0 \\ -\lambda(-x)^{1-\sigma} & \text{for}\, x < 0 \end{cases}, \tag{2}$$

and the probability weighting function $w(\cdot)$ is

$$w(p) = \exp[-(-\ln p)^{\alpha}]. \tag{3}$$

Note that in the value function (i.e., Equation 2), the reference point is set to be 0, λ is the loss aversion parameter, and σ is the risk aversion parameter.

Figure 1 provides a visual presentation of the value function. In Figure 1, loss aversion, measured by λ, is reflected by the kink of the value function curve at the reference point. When

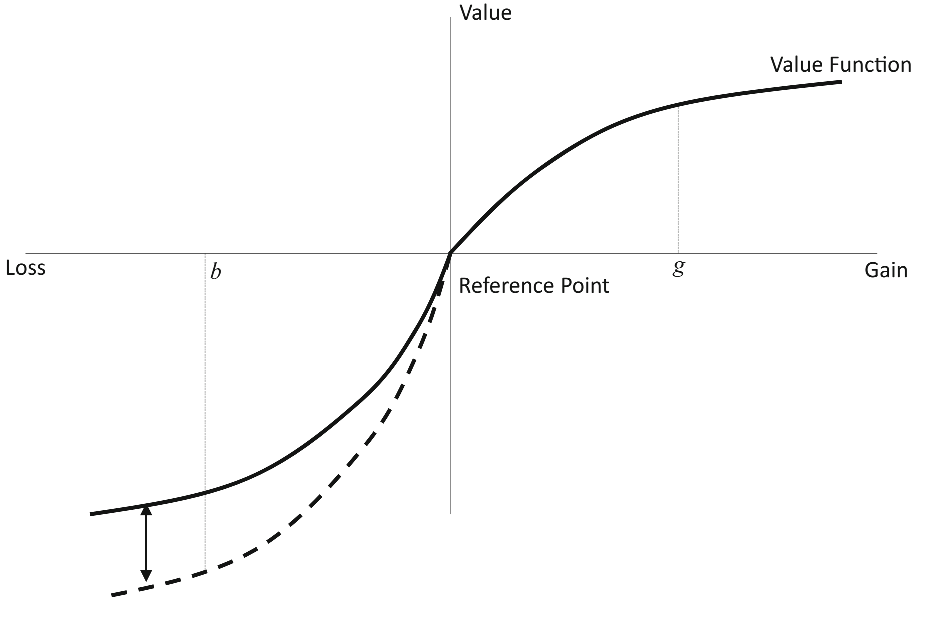

FIGURE 1 The value function of prospect theory. The dashed line represents an increase in the loss parameter in the loss domain.

$\lambda = 1$ (i.e., no kink), the consumer is loss-neutral. When $\lambda > 1$, the consumer is loss-averse; and when $\lambda \in (0,1)$, loss-seeking. When a decision-maker becomes more loss-averse, the value function curve in the loss domain will tilt downward (e.g., from the solid black line to the dashed black line in Figure 1). The risk aversion parameter, $\sigma < 1$, governs the curvature of the value function curve and risk preferences. When $\sigma = 0$, the value function curve is linear, indicating risk neutrality. When $\sigma \in (0,1)$, the value function curve is concave in the gain domain and convex in the loss domain, indicating risk aversion and risk seeking in these two domains. When $\sigma < 0$, the opposite is true.

If the consumer chooses not to consume the remaining food, she will not obtain utility (or disutility) from the remainder. Instead, she will lose the remaining food valued at $q \cdot \tau$, where τ can be viewed as the moral value of not wasting one unit of food.[4] Therefore, food wasted can be considered a sure loss to the consumer. We denote her utility when the remaining food is wasted by U_0, which can be written as,

$$U_0 = -\lambda(-(-q \cdot \tau))^{1-\sigma} = -\lambda(q \cdot \tau)^{1-\sigma}. \tag{4}$$

The wasting decision will be made based on the comparison between $U(q,g,b,p)$ and U_0. If $U(q,g,b,p) \geq U_0$ then the remaining food will be consumed; and if $U(q,g,b,p) < U_0$ then the remainder will be wasted.

Now, let us consider the consumer's sequential decision-making processes to form her WTP and PW for a food item. The first decision pertains to forming her WTP, and the second concerns a food waste decision conditional on food purchase. Through backward induction, the WTP in the first decision process incorporates the consumer's expectation of PW in the second, where the consumer's food waste decision is modeled as described above. This modeling approach aligns well with our experiment design (to be discussed below), where participants are asked about their WTP and the expected consumption in percentage (i.e., the complementary percent of PW) for a food item. More specifically, when making the food waste decision, the consumer compares the expected benefit of consuming with the expected cost of discarding the remaining portion of the purchased food item based on their belief about the possible quality of the food and their risk and loss preferences. Consuming the remaining food may be risky because of a non-zero probability that the food has deteriorated over time, causing discomfort or even food poisoning. Discarding the food will cause the consumer a sure loss (of food and moral value). Date labels may alter consumers' beliefs, affecting their food waste decisions.

In addition to some intuitive findings such as the WTP (PW) increases (decreases) in the probability of the remaining food being of good quality and the level of good quality, our conceptual framework also shows that consumers who are more loss averse are less willing to pay for a food item than do other consumers. If the moral value of not wasting food is low, then consumers who are more loss averse are more likely to waste the remaining food than other consumers. The intuition is that, in this case, the concern for possibly diminished health caused by consuming the food outweighs the concern for losing food. When the probability of the remaining food being spoiled is small, consumers who are more likely to overweight small probabilities tend to waste more food and to have lower WTP than other consumers.

Similarly, the impact of risk aversion on food waste depends on the perceived quality of spoiled food. However, if the loss from consuming the food when it is spoiled exceeds the benefit of consuming the food when it is fresh, consumers who are more risk-averse in gains waste less than other consumers. This seemingly counter-intuitive conclusion arises from a feature of prospect theory discussed above: consumers who are more risk-averse in gains are also more risk-loving in losses. In other words, not wasting food is equivalent to taking a gamble (i.e., an uncertain loss of health) over the sure bet that the food should be discarded (i.e., a sure loss of food and moral value). Therefore, a consumer who is more risk-averse in the gain domain, thus more risk-loving in the loss domain, will be more likely to take the gamble over the sure bet, implying wasting less.

The above discussion regarding WTP, PW, risk and loss preferences, and the probabilities and levels of the quality of the remaining food provides a framework to consider how information from date labels can alter willingness to pay and premeditated waste. The impact of date labels on food waste depends on how date labels affect consumers' perceptions about the quality of the food remainder and associated probability. In our conceptual framework, "quality" covers all attributes related to a food item, such as taste, freshness, and even safety. The higher the perceived quality, the higher the value the food will provide, reflecting the conflation observed in the literature.

Based on the literature, we conjecture that when compared with no date labels, a date label such as "Best by" or "Use by" provides consumers with more information about the quality of a food item along the temporal dimension.[5] For instance, when a consumer sees only a date such as July 1, 2024, printed on a food item without any date label (e.g., "Best by" or "Use by"), she conceives a quality of the food up to that date (e.g., at quality "*good*" with probability p and quality "*bad*" with probability $1-p$). If she sees a date label such as "Best by July 1, 2024," then her belief regarding the quality of the food by July 1, 2024, may change to quality "*good*" with probability 1 and quality "*bad*" with probability 0. If this is the case, then the date label "Best by," when compared with no date label, will increase the overall value of food consumption and reduce food waste. Consistent with this argument, Li et al. (2020) suggested that food waste would be less when products had date labels before the expiry date than when products had no date labels.

In contrast, "Use by" may raise the alarm about the food quality in terms of food safety. By raising the food safety alarm, the "Use by" date label may cause consumers to assign an unreasonably large probability to quality "*bad*," resulting in lower aggregate expected value from consumption and increasing food waste. Thus, we hypothesize that in advance of the posted expiry date: A date label yields a different willingness to pay for food than no date label, and a date label yields a different premeditated food waste than no date labels. We anticipate differential waste responses to the date labels as well. Thus, we hypothesize that in advance of the posted expiry date: "Best by" yields a different willingness to pay than "Use by," and "Best by" yields a different premeditated food waste than "Use by."

Moreover, the effect of date labels on consumers' perceptions depends on the food item (Rickard et al., 2023; Weis et al., 2021; Wilson et al., 2017). The shelf lives of foods differ, and the magnitude of "bad quality" toward the end of shelf life varies significantly across food items. For instance, deli meat has a much shorter shelf life than spaghetti sauce, and the quality of deli meat may drop considerably at the end of its shelf life. Therefore, "Best by" and "Use by" may convey different messages to deli meat consumers than spaghetti sauce consumers. Thus, moving a product from a quality label to a safety label may lead to a strong reaction that results in greater than expected food waste for a product, while moving from a safety label to a quality label may lead to a reduction of food waste. We, therefore, anticipate that the food type will moderate the date labels' treatment effects. Thus, we hypothesize that in advance of the posted expiry date: The food type will moderate a date label's effect on willingness to pay, and the food type will moderate a date label's effect on premeditated waste.

The concerns of food safety and potential loss associated with poor food quality, such as inferior taste or food-borne illness, may alter willingness to pay and premeditated waste, as discussed in the conceptual framework. Like the moderation by food, we anticipate risk aversion, loss aversion, and probability weighting will moderate the treatment effects of the date labels. Thus, we hypothesize that in advance of the posted expiry date: Risk aversion (loss aversion or probability weighting) will moderate a date label's effect on willingness to pay, and risk aversion (loss aversion or probability weighting) will moderate a date label's effect on premeditated waste.

EXPERIMENTAL DESIGN

To test these hypotheses, we conducted an in-person laboratory experimental auction.[6] The experiment had two components: (i) a Becker–DeGroot–Marschak (BDM) auction of two foods and (ii) a solicitation of risk and loss preferences of each participant. A detailed survey followed the experiment to collect socioeconomic variables associated with the participants. The script for the experiment is available in Appendix B in the Supporting Information. In total, we conducted 16 sessions of the experiment. The recruitment yielded 206 non-student participants for the experiment series, among which 104 were from Auburn, Alabama, and 102 from Ithaca, New York, in 2016 and 2017. We excluded data from six participants because of incompleteness or reporting errors.[7]

Following Wilson et al. (2017), we used a BDM auction for our experiment. The agricultural and applied economics literature has used the BDM extensively (Asioli et al., 2021; Banerji et al., 2018; Jiang et al., 2023; Morgan et al., 2020; Ortega et al., 2018; Shi et al., 2018; Vecchio, 2017; Waldman & Kerr, 2018). While the BDM auction is still commonly used, other methods such as Vickery second price auction, *n*th price auctions, multiple price list, and choice experiments can elicit willingness to pay. Some literature has called into question the incentive compatibility of the BDM auction (Banerji & Gupta, 2014; Bohm et al., 1997; Cason & Plott, 2014; Horowitz, 2006) and the ease of this method (Asioli et al., 2021; Ortega et al., 2018). Further, literature has raised an issue of misperception (Martin & Munoz-Rodriguez, 2022). However, Banerji et al. (2018) have found no difference in the willingness to pay for BDM, *k*th price, and choice experiments. Mamadehussene and Sguera (2022) have provided empirical and theoretical evidence supporting the use of BDM, reaffirming its incentive compatibility. To address the challenge of misperception, we conducted a training module for each session with a test product to familiarize our participants with the BDM auction.

In contrast to Wilson et al. (2017), evidence suggests that different date labels affect the same person differently (Rickard et al., 2023; Weis et al., 2021). Researchers use within-subject designs to identify the effect of a treatment on a single person. In medical trials, researchers use crossover designs to evaluate the effectiveness of each intervention on the same patient for treating chronic diseases where the treatment is not curative.[8] Compared to parallel designs, participants in crossover experiments serve as their own controls. While crossover designs have the benefit of lowering the needed sample size, participants must experience a "washout" period to remove the effect of one treatment to evaluate the second treatment (Lui, 2016; Raghavarao & Padgett, 2014). For the crossover design of the auction, participants faced a base condition of no date labels and two treatments ("Best by" and "Use by") presented in random order. Our experiment used games to solicit participants' risk and loss preferences as activities in the "washout" period, discussed below. Participants gave bids and expected consumption followed by the risk, loss, and ambiguity solicitations over three randomized experimental rounds ($q = 1, 2, 3$).[9] Based on the power calculation for the crossover design, we would need a minimum of 184 participants for our baseline calculation (see Appendix C in the Supporting Information for a discussion of the power calculation).

In the base condition, the participants indicated their maximum willingness to pay for a 24 oz (709.57 mL) jar of marinara spaghetti sauce and, separately, for a 10 oz (283.50 g) package of sliced turkey deli meat. The participants also indicated the percentage of the product that they expected to consume. For each product, the participants knew the posted expiry date on the product, but the date label (i.e., "Best by" or "Use by") in the base case was absent. In the two treatments, participants saw the same products with the randomized date labels ("Best by" or "Use by") over subsequent rounds. To control the effect of the posted date, we maintained the same posted date for each label by food within an experimental session. We updated the dates to reflect the same shelf-life for the products for each session (1 month for spaghetti sauce and 2 weeks for deli meat).

We ran the experiment in two locations (Auburn, AL and Ithaca, NY) to have a diverse participant pool. We avoided deception in the experiment by testing labels available on the products in stores in both locations. This approach proved challenging. Because of the two locations, we had to choose the same products with the same date labels in the two markets. We discovered that in the preparation of the experiment, products have a variety of date labels in one market with a different array of labels in another. After searching across various products in markets in the two locations, we settled on deli turkey meat and meatless spaghetti sauce. We were interested in meat and meatless products if we recruited persons with dietary restrictions.

In grocery stores, we found it difficult to find a group of products with the same posted date in the correct time frame as needed for the experiment. To avoid deception, we used products and reported dates within a range that would not mislead the participants with a more recent date. For example, if two products had dates of November 18, 2017, and November 20, 2017, we stated, "The posted date on the product is no earlier than Use by November 18, 2017," to cover products that may have slightly more distant dates.

To evaluate risk and loss aversion and to provide a "washout" period between solicitations of willingness to pay and premeditated waste, we used a series of games that followed the experiment series by Liu (2013) and Tanaka et al. (2010).[10] However, considering the various currencies used in the two studies (Vietnamese dong in Tanaka et al. (2010) and Chinese yuan in Liu (2013)) and our budget limit, we did not follow the exact nominal payment amount in the series of the two studies. An additional departure from Liu (2013) and Tanaka et al. (2010), who focused on economic decisions and risks, the decision problems in our study involve not only economic risk and losses, such as losing food but also non-economic risk and loss related to food consumption such as losing health. However, it is quite challenging, if not impossible, to elicit participants' risk and loss preferences toward health using binding games. Therefore, we approximated participants' risk and loss preferences toward health using their risk and loss preferences toward economic returns.[11]

The game series used in the present study are presented in Appendix D in the Supporting Information, with payoffs ranging from losing \$10 to gaining \$280. A participant chooses between Option A and Option B for each row in each game series. Each participant's risk and loss aversion parameters and the probability weighting parameter are then recovered based on their choices. Appendix E in the Supporting Information discusses the procedure to recover these parameters based on participants' choices. We refer readers to Liu (2013) and Tanaka et al. (2010) for a detailed description of the solicitation methods and the approaches to recover risk and loss aversion parameters.

Although each participant took part in both the BDM auction and risk preference solicitation, participants, through random assignment, received their final payout from either the auction or the risk preference solicitation. Participants did not know their payout group assignment until they submitted all the bids and responses to risk and loss preference solicitation. For participants assigned to the auction for the payout, we used the BDM mechanism to determine the sale of products. We randomly selected the product, date label, and "market price" for the product with the date label for incentive compatibility. If participants' bids were higher than or equal to the "market price," then the participants would purchase the product at the "market price." On the other hand, if the bids were lower than the "market price," no purchases would occur.

For the participants assigned to the risk solicitation for the final payout, we randomly selected a row among all the preference solicitation series and then a numbered ball to determine the payout. For instance, if (i) a selected row was "Option A: get \$20 if balls 1–90, \$15 if balls 91–100; Option B: get \$28 if balls 1–70, \$2.5 if balls 71–100" and the selected ball is numbered "45"; and (ii) a participant chose Option A, then the participant will get \$20.

For participants in Auburn, AL, the initial participation payout was \$20 per person. For participants in Ithaca, New York, the initial participation payout was \$30 per person per the Lab for Experimental Economics and Decision Research (LEEDR) requirement at Cornell University. For those in the auction, the average market price of the products was \$4.00. Therefore, on average, participants in Alabama in the auction final payout received \$20 in cash if no purchase occurred or \$16 and a food product if a purchase occurred (in New York \$30 or \$26). For participants in the risk preference final payout, the expected total payment was \$31 in Alabama (\$41 in New York), which was the sum of the initial payment (\$20 in Alabama and \$30 in New York) and the expected payment from the risk and loss preference solicitation games (\$11).

EMPIRICAL MODEL

In the BDM auction, each participant provided six bids for their willingness to pay and six percentage values (between 0 and 100) of expected consumption for the three date label scenarios (no date label (base), "Best by," and "Use by") and two foods (deli meat and spaghetti sauce).[12] These values serve as the outcome measures for the statistical models. Equation (5) presents a general model covering a few specifications for our empirical analysis.

$$\begin{aligned} Y_{ijk} = {} & \beta_0 + \beta_1 \text{Treatment}_1 + \beta_2 \text{Treatment}_2 + \beta_3 \text{Food} + \beta_4 \text{Treatment}_1 \times \text{Food} \\ & + \beta_5 \text{Treatment}_2 \times \text{Food} + \sum_{m=1}^{3} \beta_{5+m} A_{im} + \sum_{m=1}^{3} \beta_{8+m} (\text{Treatment}_1 \times A_{im}) \\ & + \sum_{m=1}^{3} \beta_{11+m} (\text{Treatment}_2 \times A_{im}) + e_{ijk}, \end{aligned} \tag{5}$$

where Y_{ijk} is the willingness to pay or premeditated waste for participant $i \in \{1, ..., 200\}$ under date label scenario $j \in \{0, 1, 2\}$ and *Food* $k \in \{\text{deli meat, spaghetti sauce}\}$. The β's are coefficients to be estimated, Treatment_1 equals 1 if the date label is "Best by" and 0 (no date label) otherwise, Treatment_2 equals 1 if the date label is "Use by" and 0 otherwise. Food is a dummy variable with value 0 for deli meat and 1 for spaghetti sauce. A_{im}, $m=1,2,3$, stands for risk aversion, loss aversion, and probability weighting; and e is the error term.

We begin with the base model and increase complexity. We first estimate a fixed-effects model (Equation 5) to evaluate the two treatments (i.e., "Best by" and "Use by") relative to the base (i.e., only the date but no date label) interacted with food item without considering any behavioral variables (i.e., risk and loss aversion as well as probability weighting parameter or demographic variables). We use Deli Meat (Food = 0) as the base relative to Spaghetti Sauce (Food = 1). We further estimate random effects models to include the behavioral parameters and their interaction terms with date labels.

Moreover, to capture the individual heterogeneity of participants in sessions by experimental round and food, we also estimate a set of mixed effects models. Doing so will yield "statistically efficient, robust, and consistent parameter estimates" (Liu, 2016, p. 62). In the mixed-effects models, we estimated three-level hierarchical models with a random slope and intercept for the ith participant in the nth experimental session ($n = 1, \ldots, 16$) and random intercepts for food k. Given the hierarchical structure of the experiment (200 participants in 16 sessions) and random differences across the foods, the mixed-effects models captured fixed components, $\boldsymbol{W}$, (treatment, food, treatment and food interactions, and socioeconomic variables) and random, $\boldsymbol{Z}$, (individuals in sessions over food products) components in Equation (6). Additionally, the model adjusted the errors for heteroskedasticity based on the three randomized experimental rounds ($q=1, 2, 3$).

The mixed model is a linear model with random parameters, which can be written as:

$$Y=\boldsymbol{W}\beta+\boldsymbol{Z}\gamma+e,\ e\sim N(0,\boldsymbol{R}), \tag{6}$$

where $\boldsymbol{W}$ and $\boldsymbol{Z}$ are known matrices, β is a vector of fixed effects; γ is a vector of random effects; and e is the error term. We further assume that $E(\gamma)=0$, $\text{Var}(\gamma)=\boldsymbol{D}, \text{Cov}(\gamma,e)=\mathbf{0}$, and $\gamma\sim N(O,\boldsymbol{D})$ (Christensen, 2019, pp. 162–167). The $\boldsymbol{D}$ variance–covariance matrix is for the random effects of the between-subject variations. The $\boldsymbol{R}$ matrix is the block-diagonal matrix of the variance of the residual of the fixed effects, which permits within-group variation (Kyureghian et al., 2013). Specifically, the mixed-effects model can be written as follows:

$$\begin{aligned} Y_{ijk} = {} & \beta_0+\beta_1\text{Treatment}_1+\beta_2\text{Treatment}_2+\beta_3\text{Food}+\beta_4\,\text{Treatment}_1\times\text{Food} \\ & +\beta_5\,\text{Treatment}_2\times\text{Food}+\sum_{m=1}^{3}\beta_{5+m}A_{im}+\sum_{m=1}^{3}\beta_{8+m}(\text{Treatment}_1\times A_{im}) \\ & +\sum_{m=1}^{3}\beta_{11+m}(\text{Treatment}_2\times A_{im})+\sum_{p=1}^{12}\beta_{14+p}X_i+\gamma_{0i}+\gamma_1\text{Food}+\sum_{n=1}^{3}\gamma_{n+1}\text{Round}_n+e_{ijk}, \end{aligned} \tag{7}$$

where the β coefficients are the fixed-effects parameters. The γ coefficients are the random-effects parameters. $\boldsymbol{X}$ is a vector of socioeconomic variables including race (non-white or white), gender (male or female), age, age squared, income tercile (low, middle, or high-income groups), site of the experiment (Alabama or New York), number of children under 18 years old, marital status (married/domestic partner or single), and educational attainment (college degree or not) (see Table 1 for summary statistics of these variables). Equation (7) also includes the risk, loss,

TABLE 1 Summary statistics (number of observations: 200).

	Mean/Percent	Standard deviation	Min	Max
Income groups				
Low income	33.43		0	1
Middle income	43.17		0	1
High income	22.40		0	1
Gender				
Female	70.56		0	1
Male	29.44		0	1
Race				
White	66.50		0	1
Other races	33.50		0	1
State				
Alabama	48.50		0	1
New York	51.50		0	1
Education				
No college degree	14.50		0	1
College degree	85.50		0	1
Marital status				
Single	36.27		0	1
Married/Partnered	63.73		0	1
Number of kids <18 years	0.510	0.869	0	4
Willingness to pay	2.463	1.674	0	8.00
Premeditated waste	23.283	33.206	0	100
Risk aversion	0.536	0.344	−0.820	0.890
Loss aversion	2.084	1.966	0.120	9.960
Probability weighting	0.615	0.307	0.030	1.715

and probability-weighting parameters (A_m) and their interactions with the treatments. The variable Round$_n$ is continuous—a time trend—representing knowledge gained over the experiment rounds.

RESULTS

Pairwise comparisons

Figure 2a,b provide the willingness to pay and premeditated waste for products for each date label condition, assuming unconditional normality. Bootstrapping the means and pairwise t-tests of the willingness to pay indicates statistical differences in deli meat under no date label (mean = 2.642) relative to "Best by" (mean = 2.339, $p < 0.001$) and "Use by" (mean = 2.291,

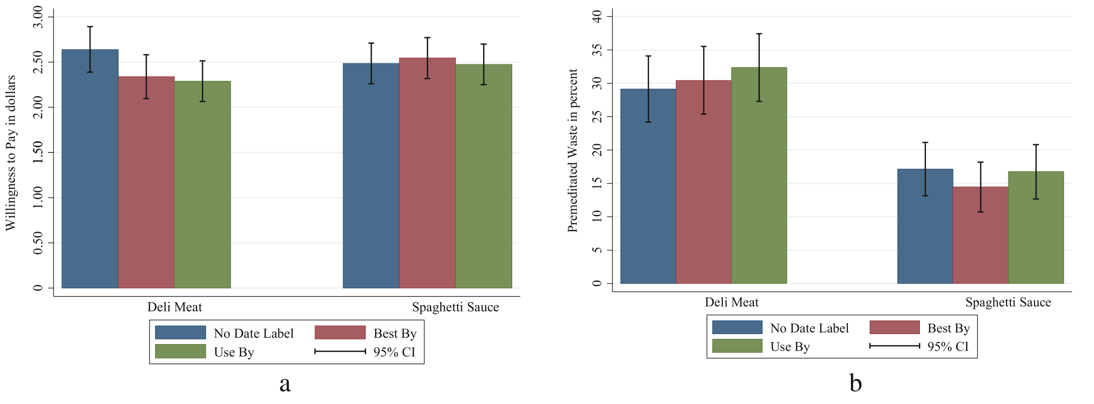

FIGURE 2 Willingness to pay and premeditated by date label and product (number of observations: 200). (a) Willingness to pay (WTP). (b) Premeditated waste (PW).

$p < 0.001$). Thus, the presence of date labels lowers the willingness to pay for deli meat. In this pairwise comparison, the mean willingness to pay for deli meat under "Best by" relative to "Use by" is not statistically different ($p = 0.207$). The spaghetti sauce willingness to pay values are not statistically different for the no date label (mean $= 2.486$) relative to "Best by" (mean $= 2.546$, $p = 0.192$) nor to "Use by" (mean $= 2.475$, $p = 0.848$). Comparing the mean willingness to pay for spaghetti sauce under "Best by" relative to "Use by" is not statistically different ($p = 0.189$).

For deli meat, the premeditated waste under no date label (mean $= 29.13$) is not statistically different from that under "Best by" (mean $= 30.45$, $p = 0.127$), but it is different for "Use by" (mean $= 32.375$, $p = 0.002$). This difference suggests greater premeditated waste for deli meat under "Use by" relative to no date label. Comparing the mean premeditated waste for deli meat under "Best by" relative to "Use by" is statistically different ($p = 0.018$). Thus, "Best by" yields less premeditated waste than "Use by." Pairwise testing of the premeditated waste indicate statistical differences in spaghetti sauce under no date label (mean $= 17.145$) relative to "Best by" (mean $= 14.45$, $p = 0.036$) but not "Use by" (mean $= 16.75$, $p = 0.800$). The mean premeditated waste for spaghetti sauce under "Best by" and "Use by" is statistically different ($p = 0.038$), with "Best by" producing less premeditated waste than "Use by."

Econometric results: Base model

Table 2 presents the estimation results for the base models where we only focus on key variables of the analysis. The base models of the willingness to pay (Model 1) and the premeditated waste (Model 2) reveal the impact of the treatments by foods with fixed effects on the individual and round by product with standard errors clustered by the individual. The round (time fixed-effects) represents the experiment's six solicitations (three rounds for two products), given the order in which we displayed the foods and the order of the date labels.

For the willingness to pay (Model 1), the estimated coefficients for date labels for "Best by" and "Use by" are -0.303 ($p = 0.000$) and -0.350 ($p = 0.000$), which are not different from each other ($p = 0.232$), partially supporting our hypotheses. The coefficient on spaghetti sauce is not statistically significant at the typical thresholds. The interaction terms "Best by × Spaghetti

TABLE 2 Fixed effects and random effects model for willingness to pay (WTP) and premeditated waste (PW).

	Model 1 WTP Fixed effects model	Model 2 PW Fixed effects model	Model 3 WTP Random effects model	Model 4 PW Random effects model
	Coef./SE	**Coef./SE**	**Coef./SE**	**Coef./SE**
Treatment (Base: No Date Label)				
Best By	−0.303***	1.32	−0.372**	7.746***
	0.054	0.858	0.15	2.673
Use By	−0.350***	3.245***	−0.426**	12.179***
	0.052	1.048	0.18	3.434
Food (Base: Deli Meat)				
Spaghetti sauce	−0.156	−11.985***	−0.144	−12.276***
	0.106	2.587	0.107	2.646
Treatment × Food				
Best By × Spaghetti sauce	0.363***	−4.015***	0.366***	−4.056***
	0.073	1.507	0.074	1.543
Use By × Spaghetti sauce	0.340***	−3.640**	0.344***	−3.740**
	0.072	1.775	0.074	1.817
Risk aversion			−0.525	−4.912
			0.495	6.472
Treatment × Risk aversion				
Best By × Risk aversion			0.104	−2.155
			0.125	2.481
Use By × Risk aversion			0.132	−4.306
			0.153	3.261
Loss aversion			−0.073	2.245*
			0.067	1.172
Treatment × Loss aversion				
Best By × Loss aversion			0.002	−0.651**
			0.016	0.315
Use By × Loss aversion			0.014	−1.033**
			0.023	0.447
Probability weighting			0.047	3.276
			0.329	6.879
Treatment × Probability weighting				
Best By × Probability weighting			0.003	−6.337**
			0.126	2.996
Use By × Probability weighting			−0.055	−7.205*
			0.158	3.74

TABLE 2 (Continued)

	Model 1 WTP Fixed effects model Coef./SE	Model 2 PW Fixed effects model Coef./SE	Model 3 WTP Random effects model Coef./SE	Model 4 PW Random effects model Coef./SE
Constant	2.642***	29.130***	3.007***	25.641***
	0.058	1.318	0.41	7.573
R^2	0.005	0.049	0.023	0.066
F-test/Wald test	9.93	9.28	64.84	75.99
p-Value	0.000	0.000	0.000	0.000
Number of observations	1200	1200	1176	1176

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Sauce" and "Use by × Spaghetti Sauce" reflect food's moderation of the treatment on willingness to pay. The coefficients are 0.363 ($p = 0.000$) for "Best by × Spaghetti Sauce" and 0.340 ($p = 0.000$) for "Use by × Spaghetti Sauce," showing that the food product moderates the influence of the date label.

For premeditated waste, the coefficient of "Best by" is 1.32 ($p = 0.125$), and for "Use by," the effect is 3.245 ($p = 0.002$). These values represent increases in the percent of premeditated waste over the no date label condition for deli meat, supporting our hypotheses. The treatment coefficients statistically differ from each other ($p = 0.017$) as hypothesized. Spaghetti sauce has a coefficient of −11.985 ($p = 0.000$), indicating that this long-shelf-life food item has considerably lower premeditated waste than deli meat. The coefficients of the treatment interacted with food are −4.015 ($p = 0.008$) for "Best by × Spaghetti Sauce" and 3.640 ($p = 0.042$) for "Use by × Spaghetti Sauce," suggesting a moderation effect of food and the date label, supporting our hypotheses.

Econometric results: Risk, loss, and probability weighting parameters and contrast margins

While the base models provide evidence of the effects of date labels, the models that include the three behavioral parameters (risk, loss, and probability weighting) reveal the heterogeneity of treatment effects (see Models 3 and 4 in Table 2). In Models 3 and 4, we see the coefficients of the treatment variables (including interaction terms) are qualitatively the same as and quantitatively close to those in corresponding Models 1 and 2, except that in Model 4, the coefficients of "Best By" and "Use By" are considerably larger than the corresponding coefficients in Model 2. Specifically, in Model 4, the "Best by" coefficient is 7.746 ($p = 0.004$). For "Use by," the coefficient is 12.179 ($p < 0.0001$). The estimated coefficients for "Best by" and "Use by" are nearly six and four times the value of the estimates for the models without the risk and loss preference parameters (Models 2 vs. 4).

For the willingness to pay in the model (Table 2, Model 3), the coefficients of the behavioral factors are statistically insignificant, failing to support our hypotheses. However, the loss

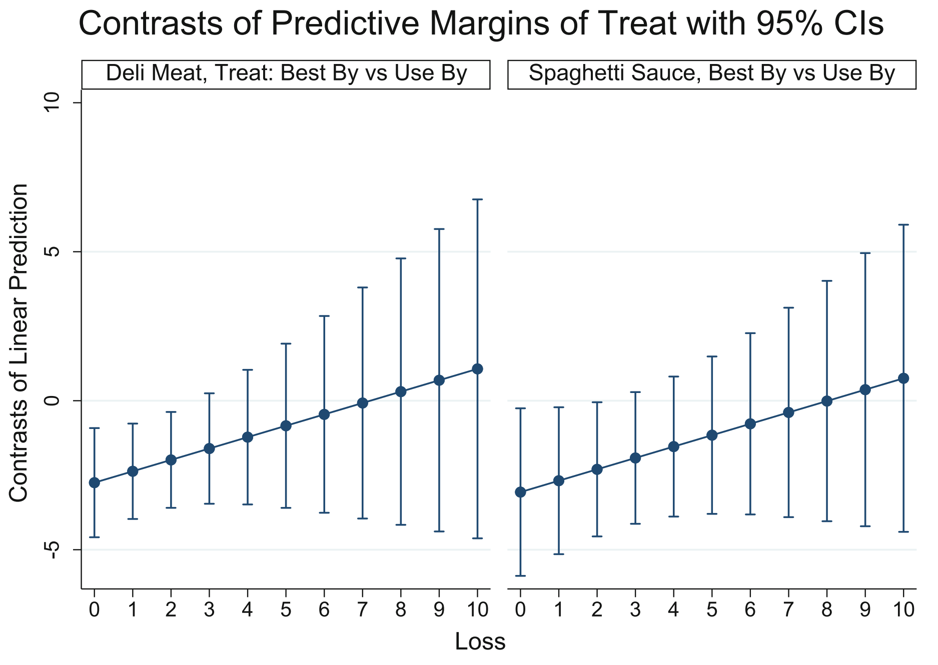

FIGURE 3 Contrast margins of predicted premeditated waste ("Best by" less "Use by") from the random effects model.

aversion coefficient for premeditated waste is 2.245 ($p = 0.055$). Thus, more loss averse participants tend to have higher rates of premeditated food waste. The coefficient of the interaction of loss aversion and "Best by" ("Use by") is −0.651 ($p = 0.039$) (−1.033, $p = 0.021$). The negative sign suggests that more loss averse participants have a diminished treatment effect of the date labels relative to no date label. Figure 3 illustrates that loss seeking (<1), loss neutral (=1), and low loss averse (>1) participants have higher premeditated waste for "Use by" relative to "Best by" as indicated by the negative value of the contrasts.[13] However, for participants who are more loss averse (>2), the difference between the "Use by" and "Best by" is not statistically different from zero ($p > 0.05$). Appendix F in the Supporting Information shows histograms of the risk, loss, and probability weighting parameters.

While the risk aversion and the probability-weighting parameters are statistically insignificant, the interaction of the probability-weighting parameter and "Best by" ("Use by") is −6.337 ($p = 0.034$) (−7.205, $p = 0.054$). These results indicate the moderation of the treatments by consumers' loss aversion and the probability weighting function. None of the estimated coefficients for risk and loss parameters (Risk Aversion, Loss Aversion, or Probability Weighting) for the willingness to pay are statistically significant (Table 2, Model 4). The largely undetermined impact of risk aversion on the willingness to pay and premeditated waste from the theoretical analysis may explain why, in most cases, the coefficients of the risk aversion parameter in our empirical analyses are statistically insignificant (see Tables 2 and 4).

From the estimates from the random effects (Models 3 and 4 in Table 2), we estimate the marginal differences between the treatments by bootstrapping the standard errors with 1000 replications (see Table 3). For deli meat, the presence of the date label lowers the willingness to pay for "Best by" ($p < 0.001$) and "Use by" ($p < 0.001$) relative to no date label. Yet, the willingness to pay is not statistically different by date labels for spaghetti sauce. For deli meat,

TABLE 3 Estimated marginal effects of "Best by" and "Use by" relative to no date label and each other on willingness to pay (dollars) and premeditated waste (percentage points) from random effects with risk and loss parameters.

Date labels	WTP (*p*-value)	PW (*p*-value)
Deli Meat		
No Date Label-Best by	0.311***	−1.342
	(0.000)	(0.126)
No Date Label-Use by	0.360***	−3.296***
	(0.000)	(0.002)
Best by-Use by	0.049	−1.954**
	(0.250)	(0.017)
Spaghetti Sauce		
No Date Label-Best by	−0.055	2.714**
	(0.251)	(0.035)
No Date Label-Use by	0.016	0.444
	(0.780)	(0.776)
Best by-Use by	0.071	−2.270**
	(0.162)	(0.0451)

Note: Bootstrapped standard error with 1000 replications.
$^{**}p < 0.05$; $^{***}p < 0.01$.

premeditated waste is larger for "Use by" relative to no date label ($p = 0.002$) and "Best by" ($p = 0.017$), though "Best by" is not different than no date label.

For spaghetti sauce, the premeditated waste is lower for "Best by" than for no date label ($p = 0.035$) and "Use by" ($p = 0.045$); however, "Use by" is not different than no date label. Appendix G in the Supporting Information includes additional results of models with interaction terms between food products and risk preference parameters[14] and the inclusion of participant beliefs about the meaning of date labels.[15] The results do not fundamentally change.

Econometric results: Mixed effects model with socioeconomic variables

While the previous results are the key models, we also evaluate the adjusted models by including participant characteristics in addition to their risk and loss parameters. The socioeconomic variables reflect participant-specific variations in the willingness to pay and premeditated waste. We estimate these models with mixed-effects regressions. Table 4 shows that the key coefficients on the treatment variables do not change substantially with the inclusion of the socioeconomic variables and the mixed effects modeling. The Income Tercile variables are statistically significant and negative for the willingness to pay models. The findings suggest that participants from the higher two income groups ($85,000 to $115,000 and greater than $115,000) were less willing to pay than participants from the lowest income group (less than $85,000). The *State* variable (base: Alabama), indicating the location of the experiment, is negative and statistically significant. Despite their higher average payout, the New York participants had a $0.92 to $0.97 lower average willingness to pay than the Alabama participants. A potential explanation for the differences in the willingness to pay is the number of zero bids by state. New York participants

TABLE 4 Mixed effects model of willingness to pay (WTP) and premeditated waste (PW).

	Model 5 WTP Adjusted base model	Model 6 PW Adjusted base model	Model 7 WTP Adjusted full model	Model 8 PW Adjusted full model
	Coef./SE	Coef./SE	Coef./SE	Coef./SE
Treatment (Base: No Date Label)				
Best By	−0.269***	3.050*	−0.324**	9.130***
	0.071	1.7	0.134	3.079
Use By	−0.335***	5.378***	−0.415***	13.516***
	0.069	1.67	0.128	3.059
Food (Base: Deli Meat)				
Spaghetti sauce	−0.135	−12.349***	−0.123	−12.616***
	0.113	3.088	0.113	3.124
Treatment × Food				
Best By × Spaghetti sauce	0.308***	−3.674**	0.312***	−3.672**
	0.076	1.732	0.076	1.737
Use By × Spaghetti sauce	0.340***	−4.389**	0.346***	−4.485**
	0.076	1.748	0.076	1.755
Risk aversion			−0.758**	−1.600
			0.327	5.826
Treatment × Risk aversion				
Best By × Risk			0.112	−2.053
			0.111	2.559
Use By × Risk			0.161	−4.431*
			0.111	2.557
Loss aversion			−0.052	2.014**
			0.053	0.954
Treatment × Loss aversion				
Best By × Loss			−0.007	−0.579
			0.019	0.442
Use By × Loss			0.002	−0.839*
			0.019	0.437
Probability weighting			−0.226	4.926
			0.349	6.227
Best By × Probability			0.023	−6.320**
			0.124	2.828
Use By × Probability			−0.005	−6.647**
			0.123	2.86

TABLE 4 (Continued)

	Model 5 WTP Adjusted base model	Model 6 PW Adjusted base model	Model 7 WTP Adjusted full model	Model 8 PW Adjusted full model
	Coef./SE	Coef./SE	Coef./SE	Coef./SE
Round	−0.009	−1.217*	−0.018	−1.160*
	0.032	0.682	0.032	0.696
Income Tercile (Base: Low Income)				
Middle income	−0.416*	−4.083	−0.478**	−4.186
	0.243	4.103	0.242	4.18
High income	−0.585**	4.925	−0.550*	5.006
	0.296	5.002	0.293	5.055
Gender (Base: Male)				
Female	−0.129	8.492**	−0.133	9.503**
	0.235	3.978	0.233	4.017
Age	0.013	0.031	0.046	0.015
	0.056	0.944	0.056	0.967
Age × Age	0.000	0.000	−0.001	0.000
	0.001	0.011	0.001	0.011
Race/Ethnicity (Base: People of Color)				
White	−0.333	−4.644	−0.152	−5.462
	0.248	4.189	0.252	4.353
State of Experiment (Base: Alabama)				
New York	−0.974***	6.286	−0.918***	4.91
	0.232	3.92	0.230	3.979
Education (Base: No College Degree)				
College Degree Holder	−0.513*	8.271	−0.508	7.245
	0.308	5.21	0.311	5.368
Relationship Status (Base: Single)				
Married/Partner	−0.187	−3.632	−0.248	−2.67
	0.284	4.795	0.285	4.928
Number of children <18 years old	0.223	−14.707***	0.174	−13.507***
	0.285	4.817	−0.248	−2.67
Married/Partner × Number of children	−0.154	11.580**	−0.127	10.482*
	0.321	5.424	0.324	5.589
Constant	4.018***	22.281	3.958***	17.688
	1.136	19.237	1.15	19.964

(Continues)

TABLE 4 (Continued)

	Model 5 WTP Adjusted base model	Model 6 PW Adjusted base model	Model 7 WTP Adjusted full model	Model 8 PW Adjusted full model
	Coef./SE	Coef./SE	Coef./SE	Coef./SE
Random-effects parameters				
Individuals nested in sessions	0.168**	2.612***	0.139*	2.590***
	0.072	0.179	0.073	0.189
Foods	−0.117**	3.234***	−0.134**	3.240***
	0.058	0.056	0.059	0.057
Residual Heteroskadasticity Adjustment				
Round 1	−0.554***	2.626***	−0.561***	2.617***
	0.048	0.046	0.048	0.047
Round 2	−0.442***	−0.270***	−0.444***	−0.257***
	0.101	0.071	0.102	0.072
Round 3	−0.195***	−0.667***	−0.203***	−0.651***
	0.075	0.117	0.076	0.118
Wald test	0.000	0.000	0.000	0.000
Number of observations	1050	1050	1032	1032

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

reported a willingness to pay $0.00 at a rate of 18.90% of deli meat, while the Alabama participants reported $0.00 for 10.36% of deli meat ($p = 0.0032$). The share of $0.00 willingness to pay did not differ significantly for spaghetti sauce. For non-zero bids, participants in Alabama had a higher willingness to pay for both products than those in New York, with a difference of $0.55 ($p < 0.001$) for deli meat and $1.08 ($p < 0.001$) for spaghetti sauce.

For the Waste models, the *Gender* variable is statistically significant and positive, suggesting that women have a premeditated waste higher than men. The coefficient of the *Number of Children below 18 years old* is negative and statistically significant. The interaction with the *Marital Status* reveals that married/partnered status moderates the negative effect on premeditated waste, given the presence of children.

Econometric results: Robustness check with the conditional mixed-process model (CMP) of willingness to pay and premeditated waste

As a robustness check, we estimate the models of willingness to pay and premeditated waste jointly with the conditional mixed-process model documented by Roodman (2011). The errors of previous models may be correlated as participants choose their willingness to pay and consumption percentage jointly. Researchers have used the CMP model to estimate two or more nonlinear models as a seemingly unrelated regression (SUR) (Arslan et al., 2017; Chege et al., 2015; Chiputwa & Qaim, 2016; Dong et al., 2016; Kalenkoski & Hamrick, 2013; Vellema et al., 2015). Further, researchers use conditional mixed-process models for estimating SUR of multi-level or hierarchical models, as the models in this paper (Addison & Teixeira, 2019). Thus, we estimate the conditional mixed-process model given the mixed-effect estimation. The estimates are similar in direction and magnitude (see Appendix I in the Supporting Information). The benefit of the SUR is the greater efficiency of the model, which increases the statistical significance, for example, the loss aversion for willingness to pay and loss aversion interactions with the date labels for premeditated waste. However, we lose the statistical significance of risk aversion for willingness to pay and probability weighting interactions in the premeditated waste models—nevertheless, the central findings of the analysis hold.

DISCUSSION

In our experiment, participants adjusted their willingness to pay and premeditated waste under the date label treatments ("Best by" and "Use by"). For the willingness to pay, both date labels relative to no date label lowered the valuations of deli meat, but they did not affect spaghetti sauce. The date labels had differential effects on the premeditated waste: "Best by" lowered the premeditated waste for spaghetti sauce, whereas "Use by" increased the premeditated waste for deli meat. However, "Best by" had no statistically significant effect on deli meat waste, and neither did "Use by" affect spaghetti sauce waste. The "Best by" date label caused less premeditated waste than the "Use by" date label for both products. The statistically significant coefficients of the date label and loss parameter interactions imply heterogeneity in response to the date labels. As suggested by the differential response to date labels readily seen on foods, these results confirm that consumers experience confusion about the meaning of date labels. However, changing date labels may not lower food waste compared to those without a label.

One of the key findings of this study is that moving deli meat from a quality label "Best by" to a safety label "Use by" could increase premeditated waste. While improper handling of deli meat and expired meat can pose a health hazard, participants in the experiment assessed deli meat at least 2 weeks before the expiration date. Thus, a change to the safety label alone promoted participants to predict greater waste, in contrast to Li et al. (2020), who found that a date label before the expiry date promoted less waste than the presence of the date alone. The reduction in premeditated waste for the spaghetti sauce with the introduction of the date labels is similar to the finding by Li et al. (2020) for yogurt. Further, switching from the safety label to the quality label may reduce premeditated waste for spaghetti sauce, which is consistent with current policy efforts. The concordance of these results may follow lines of perishability and possible illness from products. These results suggest the heterogeneity of responses to adjusting date labels.

Additionally, more loss averse participants tend to have greater premeditated waste. For participants with loss loving or low loss aversion preferences, "Use by" leads to more premeditated waste for deli meat than "Best by." For participants with higher loss aversion preferences, however, premeditated waste under "Use by" is not statistically different from "Best by." We find that participants who are more loss averse tend to waste more to avoid or mitigate losses in health. For participants with larger loss aversion parameters, food waste may be less of a concern when compared with the potential loss of health caused by deteriorated food. As a result, the participants did not respond differently to the date labels and anticipated wasting more than other participants.

The role of probability weighting further supports the importance of loss aversion. Participants who overweight small probabilities have a higher premeditated waste for deli meat under both date labels, perhaps because the perceived loss caused by the date labels for these participants is more substantial than others. However, risk aversion does not moderate the treatment effects. Thus, the heterogeneity of the responses to date labels suggests that a two-label solution may not address food waste adequately.

These heterogenous results follow the diverse literature on nutrition labels and healthy food choices (Braga et al., 2023a, 2023b; Campos et al., 2011; Cawley, 2016; Donini et al., 2022; Egnell et al., 2019; Elshiewy & Boztug, 2018; Finkelstein et al., 2018; Krasovskaia et al., 2024). While researchers have found evidence that labels can influence food choice and behavior, these effects may be heterogeneous by person (Campos et al., 2011) and over products (Braga et al., 2023a, 2023b). Donini et al. (2022) argued that the complexity of nutrition is hard to capture in a single front-of-the-pack label. Moving beyond date labels alone accords with the newer literature that questions the power of date labels. D'Amato et al. (2023) found that the date label had little effect on waste relative to the expiry date. They argued that the size of the label was small, which may not help participant awareness. Badiger et al. (2023, p. 234) reported inattentiveness to date labels relative to the posted date, and they concluded that we should move "beyond just standardization of label phrases and focusing food waste prevention efforts on the date."

This study has some limitations that need consideration. While the proposed regulation is of "Use by" and "Best if Used by," our study evaluated "Use by" and "Best by." As this study began before the suggested policy changes, we did not anticipate the choice to use "Best if Used by" as the quality label. Further, to avoid deception, we needed the same labels on both products in both locations. Only "Best by" and "Use by" appeared on spaghetti sauce and deli meat in both study sites. Thus, we are cautious in our interpretation of our findings to current market conditions.

The choice of spaghetti sauce and deli meat was to reflect deferential perishability. However, we acknowledge that we aligned the differential perishability by product type: vegetable (meatless sauce) and animal (deli meat). Participants who avoid animal-based products may have a lower valuation and a greater premeditated waste of deli meat relative to spaghetti sauce. Any product we consider will have multiple attributes that may shape participant response. However, we acknowledge this limitation but assert that two experimental products provide further information than studies examining only one product.

While the crossover over parallel design has the benefit of making participants their control, the potential of carryover of effects between treatments may dampen treatment effects if the washout period is inadequate. Nevertheless, we assert that the benefit of the crossover design outweighs the costs of potential carryover effects. We acknowledge that our sample size may not be large enough given our post-hoc power calculation. Further, we acknowledge as a limitation that other auction methods may offer greater reliability of results. Nevertheless, our two-site location, crossover design, and consistent results across locations lend credulity to our findings.

POLICY IMPLICATIONS

The Food and Drug Administration (FDA), in a letter to the food industry, wrote that the FDA "strongly supports industry's voluntary industry-wide efforts to use the "Best if Used By" introductory phrase when choosing to include a quality-based date label to indicate when a product will be at its best flavor and quality" (Yiannas, 2019). However, the FDA did not comment on using the "Use by" label. Despite these efforts, Leib et al. (2019) argued that while the industry efforts of voluntary standardization are beneficial, federal legislation is needed because of contradictory state laws and unguaranteed food industry compliance. Subsequently, Blumenthal and Pingree introduced the Food Date Labeling Act of 2021 in December of that year, with subsequent re-introduction in 2023. If passed, the law would require food manufacturers to label foods of quality with "Best if Used by" or "BB" and for safety, "Use by" or "UB." The recent passage of AB 660 in California offers hope that at least at the state-level simplification and standardization of date labels are possible (Irwin, 2024). Our findings suggest that these proposed changes may yield disparate impacts on waste associated with different foods. Thus, policymakers may find that changing date labels will not resolve food waste. While simplifying the labels may mitigate confusion about the multiple labels, consumers may respond differently to the labels depending on the food, their level of loss aversion, and their probability weighting.

Earlier food safety literature acknowledged the importance of understanding the heterogeneity of people to develop communications that help them manage food risks. The present paper noted that identifying people's unique characteristics as they navigate food risk concerns is an initial step to creating effective risk communication specific to the hazards. Date labels can be a part of risk communication. Still, they are not responsive to the unique characteristics of the person nor the food beyond the conflated concepts of safety and quality (Miles & Frewer, 2001). A single signal of quality or safety is unlikely to be the only solution to mitigating food waste at the product level or in its entirety. As FDA Deputy Commissioner Frank Yiannis (2019) noted, "While standardizing the use of date labels for quality reasons is encouraged as a best practice, we know that labeling is not enough."

Useful food waste interventions will help consumers understand the safety or quality risks to the products. These policies need to address the heterogeneity in the public so that more loss averse consumers can have enough information to adjust their subjective probabilities. Behavioral nudges that counter the bias will have a role when information fails. Generic labels for large swaths of products will not address the differential response. The date labels used currently may have little benefit for many consumers. As mentioned in the bills before Congress, new technologies, such as sensors indicating microbial count or temperature fluctuations, may lead to more accurate food use. Weis et al. (2021) and Rickard et al. (2023) noted that a freshness indicator was useful in helping consumers better manage product discard with date labels about quality or safety. Thus, regulations that require censors could prove helpful to mitigate food waste.

CONCLUDING REMARKS

Consumers adjust their food waste behavior by date labels. Different date labels can appear on food packages; these labels may lead to confusion and encourage waste. In this experimental auction, participants gave bids for deli meat and spaghetti sauce under no date label, "Best by," and "Use by" labels. The participants also indicated the share of products they expected their family to consume under the three labeling conditions. Additionally, participants revealed their preferences in terms of loss and risk aversion.

The treatment effects of the date labels were differential by product and heterogeneous by loss aversion. For deli meat, participants were less willing to pay under both date labels, while the date labels did not affect the willingness to pay for spaghetti sauce. For waste prediction, participants anticipated lower waste for spaghetti sauce under "Best by" and higher waste for "Use by" for deli meat. Loss aversion moderates these results, suggesting stronger responses for loss averse participants. This paper's findings challenge the idea that implementing quality and safety labels will adequately address food waste. Depending on the type of food in question, participants anticipate wasting more or less food under different date labels than food waste under the no-date-label scenario. Thus, date labels matter to food waste, but more foundational interventions that address behavioral biases may substantially affect food waste.

ENDNOTES

[1] Rep. Pingree and Senator Blumenthal have introduced versions of their bills in 2021 (Blumenthal, 2021; Pingree, 2021). The bills included the simplification of date labeling, prevention of mandatory discards after the discard date (expiry date), consumer education, and the permission of other labels such as time and temperature-sensitive labels (Rep. Pingree, 2023; Sen. Blumenthal, 2023). On September 28, 2024, Governor Gavin Newsome of California signed into law AB 660: Food and beverage products: labeling: quality dates, safety dates, and sell-by dates (Irwin, 2024). The law is similar to the bill that has been in the Congress.

[2] We refer readers to Barberis (2013) for a comprehensive review of prospect theory.

[3] To avoid deception in the experiment, we chose to use "Best by" and "Use by" because we found these date labels on the products in the markets in both locations of the experiments. The "Best if used by" label was unavailable for both goods in both locations, reflecting the labeling environment's heterogeneity.

[4] Note that unless the consumer suffers from sunk-cost fallacy, the food item price is not a component of τ because the price has been paid regardless of whether the food is wasted. We are indebted to a referee for the interpretation of τ.

[5] The empirical models of Weis et al. (2021) and Rickard et al. (2023) follow a similar pattern.

[6] We followed the IRB protocols approved to collect and analyze the data.

[7] For instance, we excluded data from one participant who reported a willingness to pay $80 or more. We assume that this was a key entry error. The inclusion of this entry did not fundamentally change the results.

[8] In this experimental design, researchers provide participants with at least two treatments (A and B). Between the treatments, the participants experienced a "washout" period to allow the effect of the treatment to dissipate. Researchers randomize participants into arms where the order of the treatments varies (AB or BA).

[9] The control round of no date label was always first, but the subsequent rounds' order, risk aversion, loss aversion, and probability weighting solicitation were randomized by session.

[10] In the experiment, we also conducted a game to evaluate ambiguity aversion, which is not included in the present paper.

[11] Lusk and Coble (2005) used a similar approach when assessing the impact of risk preferences on consumers' food choices, although their analysis was based on expected utility theory instead of prospect theory. Further, their risk-preference elicitation is focused on the gain domain even though their risk of concern (health risk of consuming genetically modified food) is in the loss domain. Our study avoids such inconsistency by elicitating participants' risk preferences in both gain and loss domains.

[12] Premeditated waste (PW) is one hundred minus the percentage value of expected consumption.

[13] We bootstrap the standard errors with 1000 replications.

[14] We see differences by product and date labels with moderation by loss aversion. Particularly, we see that deli meat has greater premeditated waste than spaghetti sauce for both date labels, but the difference by food disappears for more loss averse participants.

[15] The inclusion of beliefs about the date labels suggests that participants may not understand the labels and, in some instances, "getting the label correct" is associated with more waste (see Appendix H in the Supporting Information for a discussion and model results). We thank the reviewers and editor for these suggestions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Wilson, Norbert Lance Weston, and Ruiqing Miao. 2025. "Food Waste, Date Labels, and Risk Preferences: An Experimental Exploration." *Applied Economic Perspectives and Policy* 47(3): 1029–57. https://doi.org/10.1002/aepp.13507