Food Policy 114 (2023) 102381

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

True to type? EU-style date marking and the valuation of perishable food

Alessio D'Amato [a], Timo Goeschl [b,c,d], Luisa Lorè [e,*], Mariangela Zoli [a]

[a] University of Rome "Tor Vergata" and SEEDS, Italy
[b] Alfred Weber Institute of Economics and Heidelberg Center for the Environment, Heidelberg University, Germany
[c] Leibniz Center for European Economic Research - ZEW, Mannheim, Germany
[d] RWI Research Network, Essen, Germany
[e] Department of Economics, University of Innsbruck, Austria

ARTICLE INFO

JEL classification:
D12
C93
Q53
Q18

Keywords:
Date marking
Food waste
Consumer valuation
Information-based policies
Multiple price list experiment
In-store experiment

ABSTRACT

Date marking is intended to help consumers make informed food safety and quality choices when confronted with perishable food products. We provide causal in-store evidence on how EU-style date marking (best before and use by) influences consumers' valuation of perishable food around the expiry date. In a preparatory survey (n = 100), we first identify perishable food items amenable to experimental manipulation. A modified multiple price list (MPL) experiment (n = 200) then tests shoppers' valuation of perishable food with expiry dates in the future and the past. We vary date mark type (use-by versus best-before) and information status (with and without education) while preventing free disposal censoring. We find that expiry dates affect consumer valuation. Variation in date mark type has little practical relevance. Educating consumers about the meaning of date mark types reduces willingness to pay for potentially unsafe food, but does not increase it for more durable items. An attentiveness experiment (n = 160) finds that inattention and consumers' native understanding of current date marks can explain the evidence from the modified MPL experiment. Jointly, these results help explaining existing observational evidence and assessing the prospects of consumer education campaigns.

1. Introduction

Perishable goods make up a substantial share of final goods traded in the economy, particularly in the food sector. There, consumers use physical properties of food items, such as appearance or smell, as visual and olfactory cues for inferring whether a food item can be consumed, could be stored for later consumption, or should be discarded (van Boxstael et al., 2014). Packaging of food restricts consumers' ability to use such sensory cues. To help consumers make informed decisions when food is packaged, most countries have introduced date marking as a specific form of product labeling. The European Union (EU), the world's largest integrated market with over 450 million consumers, is no exception. There, date marking is attached to all packaged food products and takes one of two types. One type, *best before* (BB) is attached to relatively durable food items. It shows the calendar date with the intention to communicate the time horizon over which the item maintains its highest quality and after which it remains safe to consume for some time.[1] The other type, *use by* (UB) is attached to food items that spoil quickly. It shows the calendar date with the intention to communicate the date until which the food item is safe to consume and after which it should be considered unsafe.[2] The presence of two date mark types, as observed in the EU, illustrates a wider pattern in date marking schemes, namely an attempt to serve both resource efficiency and food safety objectives. When safe, food of acceptable quality should be consumed, thus minimizing waste (*BB* label). If unsafe, food should not be consumed, but discarded (*UB* label). Yet, both date marks are typically referred to as the *expiry date* of the product, despite the different messages that the date mark intends to convey.

* Corresponding author.
E-mail addresses: damato@economia.uniroma2.it (A. D'Amato), timo.goeschl@awi.uni-heidelberg.de (T. Goeschl), luisa.lore@uibk.ac.at (L. Lorè), zoli@uniroma2.it (M. Zoli).

[1] The legal definition in the European Union is that the best-before date is "the date until which the food retains its specific properties" (EU Regulation No. 1169/2011, p. 26).

[2] After that date, "food shall be deemed to be unsafe" (EU Regulation 1169/2011, p. 35).

https://doi.org/10.1016/j.foodpol.2022.102381
Received 7 February 2022; Received in revised form 25 August 2022; Accepted 15 November 2022
Available online 6 December 2022

In this paper, we provide *causal* experimental evidence on how date marks such as those used in the EU influence consumers' valuation of perishable food around the expiry date. In its focus on valuation, the paper follows recent literature (see review below) that deliberately studies observable choice behavior under varying incentives (Wilson et al., 2017; Collart and Interis, 2018; Sapci and Sapci, 2020). This literature relates consumers' valuations of food items, derived from observed choice, to food consumption and waste behavior that is itself unobservable by the researcher. Its approach complements a rich body of earlier research built on an alternative methodology, namely surveys of consumers who self-report the food consumption and waste behavior that the researcher cannot observe directly (Van der Werf et al., 2018; Garrone et al., 2014). This earlier literature has provided the basis for concluding that date marks appear to struggle to induce intended consumer behavior, leading to health risks if products with UB labels are consumed after the expiration date[3] and to unnecessary food waste if consumers discard products with BB labels at the expiry date despite being safe to consume.[4] The benefit of studying observable choice behavior for our purposes is that it can provide causal evidence on how variations in the date marking of a food item drive consumers' *valuation* of the product and whether educating consumers about date mark meaning has an impact. Understanding the date mark — valuation link is critical for understanding the observational evidence and for assessing the assumptions underlying initiatives aimed at improving consumers' native knowledge through education. This is where our study comes in.

Our experimental study finds that without further consumer education, a change in the expiry *date* drives a change in consumers' native valuation of a food item at and around that date. The average consumer, in other words, takes perishability into account when they assess the value of a packaged food product, also in the absence of education. A change in the date mark *type*, however, does not affect consumers' native valuation: The BB and the UB labels induce statistically indistinguishable valuation profiles of food items around the expiry date. Educating consumers at the point of sale about the date mark has an asymmetric effect: Consumers' valuation only responds to the safety aspects implicit in the UB label type, leading to a significant drop in the value of a perished item. Educating consumers does not increase their valuation of BB-labeled products around the expiry date, however, thus frustrating improvements in resource efficiency through education. A follow-up experiment traces these causal patterns to consumers' cognitive inattention to label type at the point of sale and asymmetric native knowledge.

Experiments that systematically vary date marks in the field are rare. The resulting lack of causal evidence is the result of particular empirical challenges that researchers encounter in a food labeling context as soon as they move beyond surveys and university laboratories. Ideally, the researcher would be able to manipulate subjects' beliefs and knowledge about and awareness of existing information-based policies. In practice, subjects may hold strong beliefs or possess hard knowledge about the existing policy such that the researcher's experimental treatment fails to induce a different set of beliefs or knowledge. The researcher would also want to manipulate the type of date marks and the calendar dates stamped on otherwise identical food products. Such external manipulation is important in order to disentangle factors associated with specific foods from the role of the date mark. In practice, unless expertly done, subjects may recognize the mismatch between product type and date label type or detect the manipulation. The researcher will also want to create food management decision contexts that allow issues of acquiring, keeping, and consuming or discarding food items to affect consumers' valuation in a consequential way.[5] Any manipulation, finally, needs to adhere strictly to research ethics and food safety: Consumers may not be needlessly deceived or exposed to additional food risks as a result of experimental manipulation. This is particularly true if the research involves food items at or beyond their labeled expiry date.

Our experimental approach addresses the empirical challenges to causal inference through a sequence of three steps. First, on subjects' knowledge and beliefs, our experiment is informed by a preparatory survey ($n = 100$) in which subjects disclose their beliefs about date marking of different grocery products and their confidence that their beliefs are accurate. We find a widespread lack of confidence and considerable heterogeneity in the accuracy of shoppers' beliefs about the applicable date mark across grocery items. For some items, shoppers are no better than a coin toss in guessing the correct date mark, have low confidence in their guess, and only a quarter or less of subjects express confidence in their guess. This informs our second step, a modified in-store multiple price list (MPL) experiment. There, we employ a food item (eggs) for which beliefs on date marking turn out to be demonstrably weak. The choice of product, time, and country setting (eggs, 2019, Germany) are conducive to date mark manipulation that is credible and non-detectable: In contrast to other countries, date-marking of individual eggs was unfamiliar to German consumers in 2019. The date-mark were instead attached to the outside of egg cartons and could be replaced by the experimenter with acceptable effort, skill, and suitable equipment for producing industry-grade date mark labels. Third, storage, consumption and discarding are relevant features of consumers valuing eggs: Eggs are not consumed on the spot, but are perishable[6] and easily disposed of. Finally, the setting is conducive to maintaining ethics and food safety: Eggs are, by law, date-marked *best-before*. By forward-dating expiry dates on egg cartons and by affixing a *use-by* date mark, subjects face the same or lower risk in all experimental conditions than they do in the marketplace.

We recruit 200 grocery shoppers in a suburban grocery store for the MPL experiment by inviting them individually to participate in an initial survey about food shopping habits in exchange for a combination of monetary (€2) and in-kind (a box of six organic eggs) rewards. After receiving the reward, subjects are randomly assigned to one of four treatment conditions. One condition varies the date mark type (*BB* or *UB*). The other varies the information status of the subjects, either relying on subjects' *native* knowledge or *educating* subjects prior to taking consequential choices. In this two-by-two design, all subjects then make MPL choices over cartons of eggs with expiry dates manipulated by the experimenter. The modification of the standard MPL experiment consists of adding a specific terminal buy-back mechanism at the end of the experiment. This methodological contribution of the paper allows the researcher to overcome free-disposal censoring in cases in which theory supports both positive and negative valuations for a product and overcomes a possible upwards bias. This terminal buy-back mechanism has applications beyond food (waste) to areas such as products that are potentially noisome or dangerous to all or a subgroup of consumers, for example allergenic or repugnant products. The modified MPL experiment delivers for each of the four treatment conditions willingness-to-pay (WTP) data of 50 individuals for eggs with an expiry date seven days after, one day after, on the day, and the day before the subject participates.

[3] The World Health Organization estimates that a significant share of the 600 million food illness episodes can be linked back to pathogens (such as Salmonella and Listeria) present in packaged foods (Havelaar et al., 2015).

[4] In the EU, 10% of the 88 million tons of food waste have been linked directly to date marking, with an estimated cost of €14 billion (https://ec.europa.eu/food/safety/food_waste/eu_actions/date_marking_en). In the US, more than 80 percent of consumers report that they discard food before the expiry date (Leib et al., 2016).

[5] Typical food items used in experiments, such as chocolate bars (Davis and Millner (2005)), lend themselves to impulse consumption and are typically consumed well within the product lifetime. The issue of discarding food therefore fails to arise.

[6] In addition, eggs' shelf life cannot be extended through freezing.

The final step in our approach is an experiment that tests whether the treatment effects that we establish in the modified MPL experiment are consistent with the nature of consumers' information about date marks. We recruit 160 shoppers in two treatment conditions that provide incentives to subjects to reveal their native knowledge about date marks and the attention that they pay to the information that policy-makers attach to packaged food products.

Individually and jointly, the three research steps provide answers for the empirical challenges that beset field experimental research on date marking. They allow the researcher to safely manipulate the relevant date mark features while holding the product constant and therefore draw causal conclusions about how variations in the date mark affect consumers' valuation. This furthers our understanding of how consumers value perishable goods with different expiry dates and different date mark types. Expiry dates clearly impact on consumers' valuation of perishable goods and are therefore a promising target of future policy changes. Date mark types, on the other hand, exhibit inattention problems in the absence of educational campaigns and can give rise to asymmetric effects of consumer education. This should be of interest to both governments and retailers interested in balancing food safety and food waste.

2. Related literature

Date marking has attracted considerable interest among researchers in OECD countries, in particular in the context of understanding food waste (EU-Council, 2016; Hall et al., 2009). This has led to a number of surveys in which consumers repeatedly report that they are aware, understand, and act upon date marks on food product (e.g. Eurobarometer, 2015) while researchers consistently find the opposite (Neff et al., 2015, 2019). Evidence suggests that the intended effect of date-marking policies may be limited or can even backfire: Thompson et al. (2018) find in an online survey of 548 Scottish consumers that consumers report no difference in willingness to consume 'expired' food items between use-by and best-before labels. Wilson et al. (2018) show that consumers make unwarranted inferences about food items based on date labels beyond safety and quality, and Roe et al. (2018) find in a lab survey that date marking itself leads to increased discarding of otherwise unobjectionable food items.[7] Jointly, these and other results from surveys and studies with consumers cast doubt on the usefulness of date marking perishable food for guiding consumer's purchase, consumption, and discarding decisions. European evidence supports this conclusion: Around one quarter of respondents from countries in the EU misinterpreted the *BB* label in a survey as implying that the food is no longer safe after the corresponding date. Such misinterpretation is likely to result in underestimating the true value of food products. At the same time, 28% of respondents exhibit an inaccurate understanding of *UB* date marks (Eurobarometer, 2015). If this leads to households overestimating the true value of unsafe food after its expiry date, there could also be over-consumption of certain food items and too little discarding.

While survey evidence, such as cited above, is informative, it cannot shed light on the causal relationship between date marks and consumers' valuation of food items. There is a small number of experimental studies that provide causal evidence. Collart and Interis (2018) conduct a laboratory experiment ($n = 150$) with general population subjects that can use a $35 endowment to acquire food items of varying shelf life and different perishability, including expired items, in an on-screen choice experiment. Their treatment conditions vary information and expiry dates, but not the label type. Education on date mark meaning does not impact on consumer choice in their experiment, while information relating product choice to food waste and its environmental consequences does. Closer in spirit to our study is a paper by Wilson et al. (2017). They conduct a laboratory experiment ($n = 200$) with non-student subjects under four different date labels conditions ("Best by", "Fresh by", "Use by" or "Sell by"), remaining shelf life, package size, and three types of food. An auction is used to elicit both participants' willingness to pay and expected amount of food waste in order to calculate a measure of willingness to waste (WTW), on the basis of the idea that date labels may have an impact on WTW by affecting both WTP and the expected amount of waste. More specifically, the closer the expiry date, the lower the WTP and the larger the expected waste, leading to a larger WTW. The auction results suggest that WTW is larger for labels that imply, in the consumers' perception, a safety concern, namely *UB*. In our paper, we also study the WTP for products of different labels and expiry dates. Differently from Wilson et al. (2017), however, we do not aim at establishing any explicit relationship between consumers' evaluation and waste choices. This clearly does not exclude that there is an intuitive mapping between such valuation and food waste. Low consumer's valuation of an item close to the due date may lead it not to be sold and thus to spoil. Even when bought, misconception of the label may reduce the consumer's perceived value of the food item which is then more likely to be wasted. Also related is an experimental auction study conducted in a lab setting using student subjects ($n = 159$) by Sapci and Sapci (2020). Like our study, the experiment elicits willingness to pay for food items under two date marks popular in the US context, "sell by" and "expires on". Other differences are that consumer education is always provided, procedures involve multiple sequential auctions using pen-and-paper and within-subject comparisons, and valuation of products is not examined close to the expiry date. They find that consumers are willing to pay more when the same product is labeled with the "expires on" date mark type and interpret this as a willingness to avoid the ambiguity implicit in the "sell by" label.

We contribute to previous studies in three ways: First, we move the experiment to an in-store setting that gets the experimenter closer to the average consumer. Second, our design involves directly manipulating date marks on products handled by consumers and tested for being amenable to manipulation, thus establishing a clean treatment effect. Third, we adopt a modified MPL experiment as the elicitation mechanism, overcoming some of the challenges implicit in negatively valued consumption goods.

3. Theoretical considerations and design

The objective of our experimental design is to establish how date mark type and the information level causally affect consumers' WTP for perishable food with different expiry dates, including the possibility of expired food and negative WTP. The guidance provided by the theoretical literature for design and hypothesis development is surprisingly limited.[8] In a much-cited empirical paper, Tsiros and Heilman (2005) provide a review of the literature up to 2005 and conclude that while there is a considerable theoretical literature on supply-side aspects of perishability in the retail sector, the demand side is largely unexplored in applied economic theory. As a result, the authors qualitatively sketch the outlines of a theoretical framework that, fifteen years later, remains little improved upon.[9] We build on these outlines

[7] In sessions with 88 consumers that could inspect and smell opened milk containers, subjects reported a stronger intention to discard the milk if the container had a date mark compared to containers that did not bear a date mark.

[8] One exception is an early paper on optimal household inventory management with perishable products (Reinhardt et al., 1973). The focus of the paper's deterministic model is on the implications of product lifetime for shopping frequency, however, rather than the valuation questions explored here.

[9] There is a handful of papers that test psychological theories in the context of perishable food, such as the theory of planned behavior (Siddique, 2012) or value-belief-norm theory (Farr-Wharton et al., 2014).

to inform our experimental design and the formulation of four testable hypotheses on date mark type, information, and expiry date.

Perishability is synonymous with a fixed time horizon over which a good provides positive benefits. Arguing intuitively, Tsiros and Heilman (2005) posit that the instantaneous consumption value (the expected immediate satisfaction derived from consuming the product) is decreasing over time as the good degrades. A slightly richer characterization of the consumer's problem is to consider that the owner of a perishable item faces a trade off between the instantaneous consumption value[10] and the option value, i.e. the value of postponing consumption to a later point. For most food items, both values are directly connected with the expiry date. Distance to the expiry date, i.e. remaining shelf life, weakly increases the perceived quality of the food item and hence the expected consumption value. Likewise, remaining shelf life increases the option value because there is more time left for postponing consumption. Perfectly intuitively, therefore, WTP tends to decrease as a perishable product approaches its expiry date.[11] The evolution of the WTP is captured in its day-to-day changes, or *intertemporal* differentials, and these changes tend to increase in absolute terms as the good approaches (or exceeds) the end of its shelf-life.

Both date mark types target the formation and evolution of consumption and option values, but intend to affect them differently: If effective, a *best-before* mark induces a roughly constant expected consumption value up until the expiry date and a slow decline thereafter, thus giving rise to a positive option value beyond the expiry date and a smooth increase in the intertemporal differentials. A *use-by* date mark, on the other hand, is intended to induce an expected consumption value that is positive up until the expiry date and negative thereafter. If effective, the option value therefore collapses to zero at the expiry date, forcing a jump in the intertemporal WTP differential.

The intended difference between the two date mark types on the formation and evolution of WTP for perishable food constitutes the primary empirical target of the experiment. On theoretical grounds, it is smallest for distant expiry dates and largest at and just beyond the expiry date. Conditions for detecting a treatment effect of date mark type will therefore be favorable when the otherwise identical food items on offer are date-marked close to their expiry date. The secondary target of the experiment is the effect of consumer education. We reason that compared to consumers with native knowledge about date marking, consumers with additional education present more favorable targets for detecting the effects of different expiry dates and date mark types. This reflects our reading of the prior evidence, cited earlier, that members of the public frequently overlook or misinterpret the date mark.

In order to detect an effect of date mark type on WTP, we use a modified multiple price list experiment in which otherwise identical food items differ, within subjects, by expiry dates and, across subjects, by date mark type. Among the experimental methods commonly used to elicit individual valuations, we opt for an MPL approach. The reasons are that MPL experiments are easy to implement, induce truthful revelation by participants (Andersen et al., 2006, 2007), and have demonstrated feasibility and fidelity even in demanding field settings (Berry et al., 2020; Burchardi et al., 2021). As such, they appear apt for an application in an in-store setting with consumers as participants.

In an MPL experiment, participants are asked a sequence of "yes/no" decisions for a set of discrete prices: Would the participant want to pay for a certain outcome (such as receiving a good) should that price be drawn? Vis-á-vis the classic BDM, this implies a loss of point identification, giving only interval identification, but it is arguably more transparent and easier to understand: subjects take a sequence of consequential binary decisions with ordered bid prices such that the researcher can identify, with some precision, the switching point between the two choices. The researcher then selects one of the paired options at random, and the choice is implemented. As the selection is randomly drawn and participants are aware that their responses do not affect which of the binary decisions will be chosen, they are stimulated to answer truthfully in order to get their preferred choice. One, often unspoken, assumption in standard MPL experiments is that the choice outcomes have non-negative value to the subject. In the context of perishable food, this assumption needs not hold, in particular not in the context of food items close to or beyond the expiry date: Subjects may well prefer not to own food that is spoiled or about to spoil. There are two avenues open to the researcher: One is to ensure compliance with an experimental protocol in which food items chosen must eventually and verifiably be consumed by the subject. This is the solution used in the seminal paper by Coursey et al. (1987), in which experimental subjects who win an auction have to hold an unpleasant tasting substance in their mouths for a period of time. Similarly, in the papers by Shogren et al. (1994) and Hayes et al. (1995) subjects have to consume potentially unsafe meat sandwiches in order to collect their participation reward. Even if this approach survived a current ethics review, its feasibility is established only for lab experiments involving student subjects. The other avenue is to augment the design. Here, a simple extension of the MPL into negative price terrain will not suffice due to free disposal censoring. Free disposal means that experimental subjects can always dispose of products by throwing them away at no cost to themselves. This option means that any positive payment in exchange for receiving the unwanted product will be acceptable to subjects. This induces censoring at zero payments: Subjects who prefer to dispose of the good rather than consume it will not be induced to express truthfully their negative WTP even if the MPL includes negative prices. The presence of free disposal censoring can be detected, however, through a simple procedural change: The experimenter offers to buy the item back after the MPL experiment. This terminal buy-back mechanism provides subjects with zero or negative WTP a clear incentive to exchange the unwanted good for a positive reward.

Among the two approaches, our design opts for the terminal buy-back mechanism for three main reasons. One, in an in-store setting with general population subjects, strict protocol compliance is untested and suffers both from questionable ethicality and tenuous enforceability. Two, explaining such a protocol is also likely to have a chilling effect on recruitment of subjects. Three, the buy-back mechanism allows the option value of food products to establish itself: When protocol compliance forces subjects to consume the item on site (to prevent disposal), the option value could not enter WTP and its estimates would understate true WTP for acquiring the product. These three reasons underpin our choice of a modified MPL experiment for eliciting WTP in an in-store experiment for perishable food items.

4. Procedures

4.1. Preparatory survey

Strong beliefs among consumers, whether correct or incorrect, about which foods bear which date mark and high confidence in their beliefs are an obstacle to a successful experimental manipulation of date mark labels. Worse, subjects may be suspicious of labels affixed to the food item that conflict with their highly confident beliefs. In surveys, German subjects claim that they always (51%), often (25%) or at least sometimes (9%) check the expiry label on a product and understand its meaning (Eurobarometer, 2015). This makes German consumers potentially not amenable to experimental manipulation of date mark labels.

[10] On contrast to Tsiros and Heilman (2005), one need not require the instantaneous consumption value to decrease strictly with time. It can remain constant for long times, peak at certain times (for example for festive events with traditional food items) or change through time with changes in preferences (e.g. appetite) and external conditions (e.g. weather).

[11] Hypothesis 1 in Tsiros and Heilman (2005) states much the same, without taking the option value explicitly into account, however.

Table 1
Share of correct answers as to label type, median confidence level and share of strong beliefs, by food item.

Food product	Share of correct answers	Median confidence level	Confidence level > 7
Eggs	0.50	5	0.25
Table salt	0.66	6	0.33
Fresh fish	0.64	6	0.31
Sliced bread	0.65	6	0.27
Minced meat	0.66	7	0.42
Fruit juice	0.72	7	0.40
Yogurt	0.90	8	0.51

To test the viability of an in-store experiments in such a context, we conducted a preparatory survey with general population subjects (n = 100) at a grocery store in Germany in order to elicit beliefs, knowledge, and confidence among members of the target population about current date marking practices for a range of food items.[12] This survey was carried out from Sept. 4th to Sept. 6th, 2019 during morning, afternoon, and evening shopping hours. Subjects were invited to participate in a survey for a small symbolic reward unrelated to their answers. They were handed a tablet computer and were presented, for a selection of seven commonly purchased food products, with a choice of which of the two labels, BB or UB, they believed to be associated with that product. For each choice, subjects were asked to report their confidence in their choice on an 11-point Likert scale from 0 (not at all sure) to 10 (absolutely sure).[13] The survey was not incentivized, reflecting the unsettled debate about incentives in confidence tasks (Lebreton et al., 2018).

Table 1 reports the results of the survey by food category (first column), ranked by the share of correct answers (second column). For each category, it also reports the median confidence level among subjects (third column) and the share of subjects with a strong (> 7 on the Likert scale) belief (fourth column). The share of correct answers ranges from no better than flipping a coin (eggs) to 90% (yogurt). Median confidence across subjects closely tracks the share of correct answers across food items and so does the share of subjects with high confidence in their choice.[14] Among the food categories, eggs stand out as a food item that is a particularly suitable target for an experimental manipulation of date mark labels: Our sample of German shoppers had low median confidence in their guess of the correct date mark type and only a quarter of shoppers held a strong belief in their choice. This is consistent with the fact that only half the subjects picked BB as the correct date label type. These findings provide the basis on which eggs were chosen as the product whose date mark label would be experimentally manipulated in an in-store setting.

4.2. In-store experiment

The in-store experiment was run in a sub-urban grocery store of a medium-sized German city between Sept. 20th and Sept. 21st, 2019 during morning, afternoon, and evening shopping hours. This store belongs to the same chain of supermarkets as the store in which the preparatory survey was carried out, thus attracting the same customer segment. However, it is located 5 km away in a different part of the city, reducing overlap between the participant pools of the preliminary survey and the in-store experiment.

Table 2
Treatments, by treatment condition.

	Information status	
Label type	Best-before — native	Best-before — educated
	Use-by — native	Use-by — educated

To recruit subjects, we invited shoppers walking through the store lobby to participate in a survey in exchange for a reward. Participants were assigned to one of four treatment groups through a randomized assignment protocol.[15] Irrespective of assignment, they completed a survey on grocery shopping behavior and demographics on a tablet computer. The survey was uniform for all treatments and did not refer to date marks or the perishability of food items.[16] As compensation for their time, participants received two rewards at the end of the survey: One reward was €2.00 in coins.[17] The other reward was a carton of six organic eggs date-marked to industry standards with an expiry date always coinciding with the day of the experiment.

The treatment arms separated with the handing-over of the reward: Two of the four treatment groups, labeled *BB*, underwent the MPL experiment handling egg cartons exclusively bearing date marks that read *best before DD.MM.YY*. The other two groups, labeled *UB*, underwent the MPL experiment handling egg cartons exclusively bearing date marks that read *use by DD.MM.YY*. This variation in date mark *type* constitutes the first of two treatment dimensions of the MPL, as summarized in Table 2. The second dimension varied the information status of the shoppers. Two of the four groups, labeled *n* for *native*, proceeded to the MPL experiment without receiving additional information about the meaning of date marks attached to food items. The other two treatment groups, labeled *e* for *education*, underwent a three-step procedure to enhance their knowledge about date mark labeling: After being reminded or educated about the meanings of *BB* and *UB* labels through a tablet screen, they had to successfully complete a two-question, four-options multiple-choice quiz on date mark interpretation and had to correctly identify which of the two date mark label was present on the carton they had received. Only then were subjects in the *e*-treatments able to proceed to the MPL experiment.

All four treatment groups were administered the same MPL experiment, which consisted of a sequence of three screens. On each screen, the consumers made seven consecutive choices between a 'keep option' and an 'exchange option'. Choosing the former meant retaining the carton received as a reward and dated-marked with an expiry date on the day of the experiment. Choosing the latter meant exchanging it, for a financial transaction, against another, otherwise identical carton with a different expiry date. Table 3 shows the entries of the price list, with the keep option on the left and the exchange option on the right, ordered by size of payment. The upper bound of €1.00 was determined by reference to the fact that the product on offer could be purchased in the same store for a retail price between €2.19 to €2.69 with an expiry date typically 20 days ahead. The lower bound of receiving money in order to accept a carton of eggs with a longer shelf life acted as a basic check for the presence of status quo bias (Samuelson and Zeckhauser, 1988) and endowment effects (Kahneman et al., 1991). The number of days before the expiry date, x, moved from $x = 7$ on the first to $x = 1$ (written as 'tomorrow' in the MPL) on the second screen. For $x = -1$ (written as 'yesterday') on the third screen, the exchange option lists *receive* instead of *pay* and vice versa to account for the inversion of the remaining lifetime of the product.

[12] See Appendix B, Fig. B.1, for a flowchart of the survey.

[13] Other researchers choose a format in which subjects rate their confidence on a scale between 50% (no confidence = random choice) and 100% (absolute confidence) (Lebreton et al., 2018; Murad et al., 2016). While appropriate for highly educated student subjects, members of the general population with little familiarity of a quantitative approach are in our opinion likely to find this format challenging.

[14] At the individual level, there is only a weak statistical association (Kendall's τ) between the likelihood of correctly answering the question on the label type and the confidence that the subject expresses about her choice.

[15] See Appendix B, Fig. B.2, for a flowchart of the MPL experiment.

[16] See Appendix A for details on the survey questions.

[17] Consumers received one €1-coin plus one €0.50, two €0.20 and one €0.10 coin such that every subsequent transaction in the MPL could be immediately implemented.

Table 3
Price list, basic format.

Keep option	Exchange option
Carton dated today	Carton dated in x days and pay €1.00
Carton dated today	Carton dated in x days and pay €0.80
Carton dated today	Carton dated in x days and pay €0.60
Carton dated today	Carton dated in x days and pay €0.40
Carton dated today	Carton dated in x days and pay €0.20
Carton dated today	Carton dated in x days and pay nothing
Carton dated today	Carton dated in x days and receive €0.20

Table 4
Buy-back task.

Keep option	Exchange option
Keep carton	Return carton and receive €3.50
Keep carton	Return carton and receive €2.50
Keep carton	Return carton and receive €1.50
Keep carton	Return carton and receive €0.50
Keep carton	Return carton and receive nothing
Keep carton	Return carton and pay €0.50

To maintain incentive compatibility, one of the $7 \times 3 = 21$ choices were randomly implemented for each subject. Upon conclusion of the MPL, each subject therefore either held a pack of eggs expiring on the date of the experiment and €2.00 in coins; or a pack with a different expiration date and a cash balance in accordance with the implemented choice. Then, subjects proceeded to the last stage of the experiment, the buy-back task. This task was essentially another MPL experiment in which subjects had to select, within a list of six possible alternatives, whether to keep the pack of eggs or return it to the staff in exchange for a payment (see Table 4). Note that the range includes a zero payment and a negative payment. This ensures that the experimenter can observe whether participants have a negative WTP for the food item currently in their possession and interpret the evidence from the preceding MPL experiment accordingly without concerns about free disposal censoring.[18]

As in other MPL experiments, incentive compatibility is maintained by one of the choices being randomly selected for implementation. The experiment concluded with a brief questionnaire on demographic characteristics.

On the basis of the described experiment we have constructed a set of outcome variables: the willingness to pay (WTP) and the intertemporal WTP differentials. WTP is derived from the second buy-back MPL (as shown in Table 4) with the aim to calculate the consumer valuation for an eggs carton expiring today (i.e. on the day of the experiment); the WTP is therefore constructed on the basis of preferences revealed in the buy-back MPL by consumers that, after the implementation of the first MPL experiment, were left with a carton expiring on the day of the experiment. The WTP differentials are instead derived from the first MPL experiment, on the basis of the three series of choices made by consumers in the three consecutive screens (as shown in Table 3); this provided us with three different WTP differentials between an eggs carton expiring today and the ones expiring respectively in a week, tomorrow and yesterday.

Since the in-store experiments expose subjects to food items whose date marks have been manipulated by the experimenter, the researchers involved discussed two concerns. One was whether the procedures exposed subjects to increased health risk. We concluded that this was not the case: The sourcing of the eggs used was organized such that each and every manipulated date mark bore an expiry date *earlier* than that originally on the packaging.[19] The other concern was the use of deception in the in-store experiment. Deception can be harmful to subjects. Deception can also undermine the trust that the general public has in empirical research. The most severe forms of deception, in declining severity, are those that cause physical or physiological trauma, withholding of promised payments, leading subjects to purchase mislabeled products, and providing subjects with false information about their own or other subjects' performance (Colson et al., 2015; Rousu et al., 2015; Cason and Wu, 2019). Our procedures ensure that physical or physiological trauma to subjects can be excluded by design. The products used in the in-store experiment are not mislabeled in the sense that they are of worse quality than announced. All subjects receive products in the in-store experiment that are of equal or better quality than what the date mark conveys.

We conducted the experiment with a sample size of $n = 200$, evenly distributed across the four treatment cells based on a randomized assignment protocol. The size of the sample was determined on the basis of a power analysis performed to detect statistically significant differences between the current average price of an eggs pack (€2.40) and a discounted price, ranging from 25% to 50% discount. These price differentials have been chosen by considering the discount policies that grocery stores sometimes adopt to promote the purchase of perishable products approaching their expiry date. Using a price differential up to €0.60 (25% discount), as well as conventional levels of significance ($\alpha = 0.05$) and power ($\beta = 0.8$) the most pessimistic n per treatment cell is 45. We took a conservative stance and recruited 50 subjects per cell.

5. Hypotheses and results

5.1. Hypotheses

The experiment is designed to detect two treatment effects. The primary effect is the impact of date mark type (*BB* vs. *UB*) on consumers' consequential decisions about perishable food.

Hypothesis 1. Willingness to pay for perishable food is higher for products labeled best-before than for products labeled use-by.

Theory predicts that the strongest support for Hypothesis 1 will arise for expiry dates on the day of the experiment (see Section 3). The reliance of Hypothesis 1 on a comparison of WTP across date mark types re-emphasizes the usefulness of a buy-back experiment that generates WTP *level* data.

The same theoretical considerations predict that the date mark type will affect how consumers' valuation varies around the expiry date. The *UB* date mark, being associated with greater perishability than the *BB* mark, is predicted to lead to larger day-to-day WTP differentials around the expiry date: Consumers are expected to discount food more heavily as the items approach or exceed the end of their posted shelf-life. These *intertemporal* WTP differentials are recovered from subjects' choices in the MPL experiment and form the basis of Hypothesis 2.

Hypothesis 2. Intertemporal WTP differences for perishable food are lower for products labeled best-before than for products labeled use-by.

Both Hypotheses 1 and 2 therefore make statements about the impact of the date mark on WTP and measure these impacts around the expiry date. The difference is that Hypothesis 1 draws on WTP for products expiring exactly on the day of the experiment while Hypothesis 2 examines the changes around the expiry date, both before

[18] To detect free disposal despite the buy-back mechanism, we also monitored waste bins in the proximity of the store during the duration of the experiments. There was no evidence of cartons of eggs being disposed of close-by. Whether participants took eggs home to dispose of them is something that our design does not allow us to observe.

[19] It is also important to note that other than in the US, eggs are not sold refrigerated in the EU. European Commission Regulation No. 589/2008 prohibits this practice, reflecting diverging views on different risks posed by egg-borne food diseases on both sides of the Atlantic.

and after. Differently put, Hypothesis 1 tests for differences in levels while Hypothesis 2 tests for differences in slopes.

The secondary effect we expect to detect through the experiment is the impact of educating (or reminding) consumers about the meaning of date marks before they take their choices in the MPL experiment. In light of prior evidence (see Section 2), we expect a significant share of consumers to be confused or mistaken about date mark meaning in the baseline condition (*n*). Educated consumers understand that products labeled *UB* are more perishable. Since they are expected to constitute a greater share of consumers in treatment condition (*e*), average WTP is predicted to be lower compared to the native treatment condition (*n*) for *UB* products and vice versa for *BB* products.

Following the structure of Hypotheses 1 and 2, we examine this prediction both in terms of its effects on the WTP level and the intertemporal WTP differentials. For the WTP level, this leads to Hypothesis 3.

Hypothesis 3. Compared to native consumers, educated consumers have a higher WTP for perishable food labeled best-before and a lower WTP for perishable food labeled use-by.

Again, theoretical considerations favor detection around the expiry date. Consumers' understanding of how the passing of the expiry date affects food safety and quality is likely to have the greatest impact on product valuation. The same effect is expected to establish itself in intertemporal WTP differentials.

Hypothesis 4. Compared to native consumers, educated consumers exhibit greater intertemporal WTP differences for perishable food.

A final consideration for guiding the data analysis is that the two-by-two design allows the experiment to also speak to the combination of the primary effect of label type and the secondary effect of education. The effects are likely to be mutually supportive, giving rise to a positive interaction effect.

5.2. Main results

Our procedures recruited 50 subjects for each of the four treatment cell in a balanced design. All 200 subjects completed the modified MPL experiment, including the terminal buy-back mechanism. There were no drop-outs. Filters for eliminating subjects who declared themselves to be following a vegan diet or to have someone with an egg allergy in their household were present, but no subject triggered these filters in our sample.

Data from MPL experiments with general population subjects tends to be noisy and deviations from basic axioms of choice are common. A potential source of inconsistency comes from multiple switching behaviors, i.e. subjects can switch back and forth from one option to the other of each binary decision when they move down the price list. Differently from subjects that have a single switching point, or, in other terms, that maintain the same option up to their WTP and then switch to the other option, for multiple switchers their choices do not allow the researcher to infer their true WTP. Our in-store experiment is no exception with respect to potentially inconsistent preferences. For example, between 4% and 7% of subjects switch more than once in one of the ordered bid price lists, 15% in at least one of them. These shares are in line with or below those reported in other MPL experiments with general population subjects (Gaudecker et al., 2011). More importantly, the frequency of deviations is statistically unrelated either to treatment assignment or to expiry dates. We err on the conservative side and exclude subjects from the subsequent analysis of MPL data if they switched more than once on at least one screen, leaving us with complete MPL observations from 170 subjects. The MPL data used for hypothesis testing includes, however, the sizeable share of non-switching subjects. While subjects that have a single switching point always constitute the largest share, subjects exhibit considerable status quo bias.

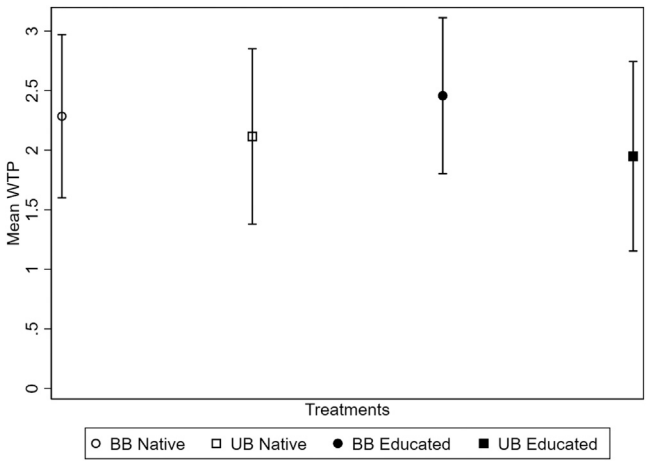

Fig. 1. Average WTP in € for an egg carton with expiry date on day of experiment, by treatment condition.

For the terminal buy-back mechanism, from where we draw the data for testing Hypotheses 1 and 3, we obtain 123 observations from subjects that were assigned an egg carton with an expiry date on the day of the experiment by the randomized incentive mechanism.[20] If we restrict the sample in the most conservative way by excluding all those subjects that switched multiple times at least once, this leaves us with exactly 100 subjects. These form the basis of the analysis below. Among the 100 subjects, 15 have a strictly non-positive WTP for a carton, highlighting the potential scale of free disposal censoring in the absence of a terminal buy-back mechanism. Unaccounted for, this censoring would bias WTP estimates upwards.[21]

Figs. 1 and 2 summarize and display the key statistics that form the basis of hypothesis testing. Fig. 1 reports, for each treatment condition, participants' average WTP for an egg carton with an expiry date on the day of the experiment. WTP measurements for this day are most favorable for detecting the treatment effects of both date mark type and education. A first observation is that the average WTP between €1.95 and €2.46 reported by subjects are reasonable in the context of an in-store retail price for the same carton of eggs between €2.19 and €2.69. While our analysis exclusively focuses on the treatment effects, these levels indicate that subjects were, on average, taking meaningful choices in the MPL experiment. A second observation is that the standard errors, represented by the error bars around the average WTP, are relatively large: Across subjects, there is considerable variation in WTP, which reaffirms earlier findings that general population subjects tend to return noisy WTP data in MPL experiments.

Fig. 2 displays, grouped by expiry day, the mean intertemporal WTP differential in all four treatment conditions. The WTP differentials are premiums, or discounts, relative to a carton of eggs expiring on the day of the experiment. The four leftmost estimates are the premiums for eggs with an expiry date one week after the experiment in the four treatment conditions, starting with *BB* and *UB* with native consumer information, followed by *BB* and *UB* after consumer education. In the middle are the premium estimates for eggs with an expiry date one day after the experiment, by treatment as above. The four rightmost

[20] The remaining 77 were randomly assigned cartons with a different expiry date.

[21] In the present data, failing to take non-positive WTP into account would have led to a positive bias of around 6%. This estimate comes from re-coding the MPL data as if the buy-back mechanism had not included zero or negative payments and re-computing the WTP.

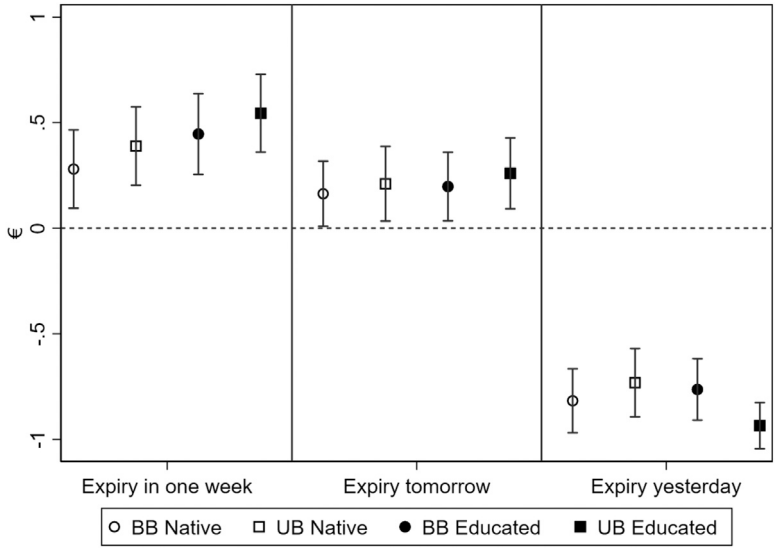

Fig. 2. WTP premium (discount) relative to carton with expiry date on day of experiment, in €, grouped by expiry date (in one week, on the next day, on the day before) and by treatment conditions. The average premium for an expiry date a week (a day) later is €0.42 (€0.21), equivalent to 20% (8%) of purchase price. The average discount for an expiry date one day before is €0.79, equivalent to 34% of purchase price. Variations in label type (best before or use by) and in information status (native or educated) have no significant impact on the WTP premium. The exception is a negative impact on WTP for expired food items labeled *UB* of educating consumers about label meaning.

estimates show the discounts (negative premiums) for eggs whose expiry date was one day before the experiment, again by treatment.

Like the level estimates, the intertemporal WTP differentials pass a visual plausibility test and accord with the basic economic intuition of Section 3: For eggs with an expiry date one week in the future, the premium of around €0.42 is equivalent to around 20% of the average purchase price of the egg carton. With an expiry date one day in the future, the WTP premium relative to eggs expiring today is about €0.21 or 8% of the purchase price. When the expiry date is one day in the past of the experiment, then participants demand a discount of around €0.79 or 34% off the price. The systematic decrease in the WTP differentials as the expiry date approaches and passes is not only in line with theory, but it is also empirically robust: The ordering of the estimated WTP differentials, pooled by expiry date, is statistically highly significant ($p < 0.001$ for each pairwise comparisons, one-sided t-test). At the same time, Fig. 2 shows that within each expiry date, the estimated WTP differentials associated with each of the four treatment variations cluster close together.

The first formal test is of Hypothesis 1, which posits that a *BB* label induces higher WTP than a *UB* label. Result 1 reports on testing this Hypothesis 1 using the WTP data from the buy-back experiment as reported in Fig. 1.

Result 1. *The date mark type has no statistically significant effect on willingness to pay for perishable food, irrespective of information status: Willingness to pay for egg cartons date-marked* ***best-before*** *and willingness to pay for egg cartons date-marked* ***use-by*** *are statistically indistinguishable, both for native information and after consumer education.*

For both conditions of the information status, a comparison of the mean WTP indicates a negative treatment effect of selling the same perishable good under a *UB* date mark rather than a *BB* date mark. This is in line with the prediction of Hypothesis 1. With native information (condition *n*), the difference between means of 2.28 (*BB*) and 2.11 (*UB*) is not significant, however ($p = 0.68$, M.W. Rank Sum Test). With educated consumers, the difference between means of 2.46 (*BB*) and 1.95 (*UB*) is larger, but still not significant ($p = 0.46$, M.W. Rank Sum Test). This indicates that given the heterogeneity among shoppers, the information-based policy induces some differences in consumer valuation of food, but not at a significant level. This is true even on the date of expiry, that is, in circumstances in which the information conveyed by the date mark type reaches its maximum consequentiality.

Hypothesis 2 postulated that a *UB* label induces higher intertemporal WTP differences than a *BB* label. The test of Hypothesis 2 is performed on the basis of subjects' choices in the MPL experiment and reported in Fig. 2.

Result 2. *There is a statistically significant impact of the date label on the intertemporal differences in WTP, but only for educated consumers valuing perishable products beyond the expiry date: Educated consumers have a greater WTP differential for products labeled* ***use-by*** *than for products labeled* ***best-before****.*

When consumers are educated, the difference between the mean WTP differential is only significant beyond the expiry date (−0.74 (*BB*) vs. −0.91 (*UB*), $p = 0.06$, M.W. Rank Sum Test). At all other expiry dates, the difference is not significant ($p > 0.37$ across all other dates, M.W. Rank Sum Test).

Hypothesis 3 concerns the effect of education returns on WTP. To test the hypothesis, we compare WTP level data (Fig. 1) separately for each date mark type in order to detect a treatment effect of education.

Result 3. *Education has no statistically significant effect on WTP: WTP of native and educated consumers are statistically indistinguishable, both for perishable food labeled* ***best-before*** *and for perishable food labeled* ***use by****.*

Under a *BB* label, mean WTP increases from €2.28 for consumers drawing on their native information to €2.46 for consumers that have undergone education about label meanings. Under a *UB* label, mean WTP decreases from €2.11 under native information to €1.95 following education. These effects are in the direction predicted by Hypothesis 3, but do not reach conventional levels of statistical significance ($p = 0.89$ and $p = 0.78$ for *BB* and *UB*, respectively, M.W. Rank Sum Test). Given the heterogeneity among shoppers, education induces the desired impact on valuation of perishable food, but even on the date of expiry not at a significant level.

Result 4. *Intertemporal WTP differences for perishable food differ between educated consumers and consumers drawing on native knowledge, but only for expired food products labeled* ***use-by****.*

When goods are labeled *UB* and consumers trade off an expiry date on the day of the experiment with an expiry date on the date before the experiment, the difference between the mean intertemporal WTP

Table 5
Dependent variable: WTP at expiry date. Baseline: Date mark *BB* at *n*ative information, no socio-demographic controls. Standard errors clustered at individual level. $^{*}p > 0.1$, $^{**}p > 0.05$, $^{***}p > 0.01$.

	OLS			Tobit		
	(1)	(2)	(3)	(4)	(5)	(6)
UB Label	−0.330	−0.170	0.0221	−0.418	−0.333	0.0376
	(−0.95)	(−0.35)	(0.04)	(−0.70)	(−0.39)	(0.05)
Education	0.00833	0.172	0.323	0.0515	0.138	0.436
	(0.02)	(0.37)	(0.62)	(0.09)	(0.17)	(0.54)
UB Label × Education		−0.339	−0.644		−0.178	−0.893
		(−0.49)	(−0.81)		(−0.15)	(−0.71)
Constant	2.357***	2.284***	2.179***	2.980***	2.941***	2.745***
	(8.04)	(6.81)	(3.45)	(5.57)	(4.75)	(2.89)
Socio-dem. controls	No	No	Yes	No	No	Yes
N	100	100	100	100	100	100

differential of native and educated consumers is significant (−0.67 (*n*) vs. −0.91 (*e*), $p = 0.03$, M.W. Rank Sum Test). For good labeled *BB* and at all other expiry dates, the difference is not significant ($p > 0.31$ across all other dates, M.W. Rank Sum Test).

5.3. Econometric evidence

We complete the analysis of the experiment by drawing on the additional data about subjects' demographic and shopping characteristics that the survey at the outset of the experiment collected. This econometric approach additionally serves as a robustness check on our main results and allows us to formally test for interaction effects.

Tables 5–7 report on the econometric results. Table 5 explains WTP for goods with an expiry date on the day of the experiments as a function of the treatment conditions and subjects' demographic characteristics, moving from very parsimonious (only treatment conditions) to increasingly richer specifications. We use two estimation methods: A basic OLS regression on the mid-points of the buy-back intervals and a tobit estimation. The baseline across all methods and specifications is the treatment condition *BB/native*.

Irrespective of method and specifications, the coefficient of the *UB* treatment does not attain statistical significance. Once socio-demographic controls are included (specifications (3) and (6)), the quantitative relevance of the *UB* mark decreases by an order of magnitude. The coefficient of the *e*ducation treatment has the predicted positive effect on WTP and becomes quantitatively more relevant by including socio-demographic controls, but not reaching statistical significance. Quantitatively, when sociodemographic controls are included, a tobit estimation, capable of accounting for the censored nature of our data, predicts an increase of €0.44 in WTP for goods labeled *BB* following education. In the same specification, we also recover a negative interaction effect between a *UB* label and education. The magnitude of the interaction effect more than offsets the education effect on WTP under a *BB* label alone. This provides indicative evidence that jointly, education and the *UB* mark decrease WTP, thus supporting the non-parametric tests of Hypotheses 1 and 3.

Table 6 explains the intertemporal WTP differentials measured in the experiment as a function of remaining shelf-life, treatment condition, and subjects' characteristics, again moving from very parsimonious to increasingly richer specifications. We again use two estimation methods: A basic OLS regression on the mid-points of the MPL intervals, and a tobit estimation. The baseline across all methods and specifications is the treatment condition *BB/native* with a remaining shelf-life of one week and no socio-demographic controls.

Across specifications, the coefficient estimates for the pooled data show that remaining shelf life consistently matters for WTP. Reducing remaining shelf life from one week to one day decreases WTP by €0.21 to €0.29. Expired food items are valued between €1.21 and €1.76 less. These effects are all statistically significant at the 1% level. But neither a *UB* date mark nor education have a statistically significant impact on the WTP differential. Likewise, the interaction effect between the *UB* and *e*ducation treatments is still negative, as observed in the non-parametric tests, but does not attain statistical significance, even when socio-demographic controls are included. This provides further evidence for the findings from testing Hypotheses 2 and 4 that label type and education have little detectable impact on the valuation of food items.

Restricting the pooled sample to observations where the intertemporal comparison only concerns food items just before and after expiry, Table 7 reports again no significant treatment effects of the *UB* label or education, but a significant and negative treatment effect for their interaction: For consumers educated about the meaning of date marks, WTP for food labeled *UB* is significantly lower. Adding socio-demographic controls attenuates the statistical significance of this result somewhat, but the results of the parametric analysis remain consistent with the non-parametric results. Taken together, they suggest that educating consumers about the meaning of date marks makes their valuation of food more responsive to the safety message of *use-by* labels. This provides a pathway through which education could lead to more unsafe food being discarded. At the same time, education does not make consumers' valuation more responsive to the quality message of *best-before* labels and therefore does not provide a pathway toward less food being discarded that is still of good quality.

6. Discussion and further experimental evidence

Results 1 through 4 and the econometric evidence demonstrate that consumers pay attention to the calendar *date* on the date mark. They raise doubts, however, about the ability of information-based policies to impact consumers' valuation of packaged food products through variations in the date mark *type*. While the general effects on the formation and evolution of WTP go in the desired direction, the treatment effects affect an insufficient share of subjects in their respective groups consistently enough to result in impacts of statistical or economic significance. Our sample size was chosen to detect effects comparable to price promotions conventionally employed by retailers to sell off items close to their expiry date. As the results make clear, the effect of variations in the date mark type on consumers' valuation is not as large as price promotions in the real world.

The results also indicate that educating consumers can produce asymmetric effects. The consistently negative impact on WTP levels of the interaction effect of labeling food with a *UB* date mark and educating consumers provides some evidence that educating consumers decreases consumers' valuation of unsafe food products. This makes it more likely that health-related discarding of food will increase. There is no evidence, however, that an education campaign can increase the valuation of *BB*-labeled products. This makes it less likely that education about date mark types has the potential to decrease food waste.

Table 6
Dependent variable: WTP differential. Baseline: Treatment condition *BB/native*, comparison with a remaining shelf-life of one week and no socio-demographic controls. Standard errors clustered at individual level. $^{*}p > 0.1$, $^{**}p > 0.05$, $^{***}p > 0.01$.

	OLS			Tobit		
	(1)	(2)	(3)	(4)	(5)	(6)
Expires tomorrow	−0.212***	−0.212***	−0.212***	−0.294***	−0.294***	−0.291***
	(−6.10)	(−6.10)	(−6.01)	(−5.83)	(−5.83)	(−5.81)
Expired yesterday	−1.205***	−1.205***	−1.205***	−1.761***	−1.762***	−1.748***
	(−21.04)	(−21.02)	(−20.71)	(−14.21)	(−14.21)	(−14.33)
UB label	0.0552	0.112	0.105	0.0663	0.171	0.163
	(0.99)	(1.42)	(1.39)	(0.78)	(1.44)	(1.45)
Education	0.0268	0.0813	0.0964	0.0361	0.138	0.160
	(0.48)	(1.07)	(1.29)	(0.42)	(1.18)	(1.44)
UB × Education		−0.110	−0.108		−0.206	−0.195
		(−0.99)	(−1.02)		(−1.22)	(−1.23)
Constant	0.378***	0.350***	0.367***	0.524***	0.472***	0.505***
	(6.57)	(5.65)	(3.75)	(5.83)	(4.93)	(3.37)
Socio-dem. controls	No	No	Yes	No	No	Yes
N	510	510	510	510	510	510

Table 7
Dependent variable: WTP differential between eggs expiring on day of experiment and expired eggs. Baseline: Date mark *BB* with *native* information, no socio-demographic controls. Standard errors clustered at individual level. $^{*}p > 0.1$, $^{**}p > 0.05$, $^{***}p > 0.01$.

	OLS			Tobit		
	(1)	(2)	(3)	(4)	(5)	(6)
UB label	−0.0185	0.144	0.150	−0.0632	0.334	0.367
	(−0.26)	(1.31)	(1.46)	(−0.35)	(1.32)	(1.61)
Education	−0.0831	0.0734	0.0806	−0.151	0.237	0.273
	(−1.16)	(0.72)	(0.80)	(−0.84)	(0.96)	(1.24)
UB × Education		−0.317**	−0.271*		−0.798**	−0.660*
		(−2.23)	(−1.88)		(−2.28)	(−1.96)
Constant	−0.734***	−0.814***	−0.930***	−1.231***	−1.424***	−1.478***
	(−11.58)	(−11.14)	(−7.75)	(−7.13)	(−7.01)	(−4.98)
Socio-dem. controls	No	No	Yes	No	No	Yes
N	170	170	170	170	170	170

To look for a possible explanation behind the results of the in-store experiment, we designed and conducted a follow-up experiment. The experiment builds on the hypothesis that information-based policies using date marks fail because shoppers pay little attention to the information conveyed through this vehicle. By design, it allows us to test whether shoppers notice differences in date mark type (*BB* versus *UB*) and expiry dates in a choice-relevant setting. We summarize its design and results before using its evidence to re-evaluate our main results.

The experiment was conducted in the same in-store setting as the MPL experiment. Shoppers passing through the store lobby were approached and asked whether they would participate in a tablet-based survey, with a carton of free-range eggs as a reward. Filter questions eliminated shoppers that do not purchase eggs for dietary reasons. Shoppers completed a survey on shopping habits and food preferences before being offered their reward. Experimental treatments began at this step in the procedures and differed with respect to the rewards on offer. Every participant was offered two cartons of free-range eggs, one of which they could pick as their reward. In one treatment condition, labeled *mark*, the two cartons differed by date mark (*BB* versus *UB*) and by brand (*A* vs. *B*),[22] randomly mixed. In the other treatment condition, labeled *date*, the two cartons differed by expiry date (*day of the experiment* vs. *day after the experiment*) and by brand (as above), randomly mixed. The associations between the two brands and the treatment dimensions were additionally randomized, resulting in two *combinations*, 1 and 2. Before selecting their preferred carton, the survey instrument asked shoppers about the criteria that they use when buying eggs in a supermarket and asked them to apply the same criteria to their choice in the experiment. After choosing, participants proceeded to a structured interview about the reasons for their choice. The structure was sequential: The interview progressed from open-ended to increasingly targeted questions about possible differences in the date mark attached to the two cartons and stopped as soon as a subject correctly pointed out the difference. This allowed subjects to be classified in one of four groups: Those who were attentive to the date mark and for whom it was choice relevant; those who were attentive, but for whom it was choice-irrelevant; those who could be guided to be attentive and were therefore theoretically reachable by a date mark; and finally those who remained inattentive to date marks even after guidance by the experimenter.[23] The interview concluded with participants being given the option of revising their choice.

A sample of 160 individuals was assigned to the two treatments (*mark* versus *date*) and, within each treatment, to one of the two

[22] We selected two brands of free-range eggs, REWE and Heitlinger, that retailed in the same price band in order to minimize strong brand-specific differences.

[23] Specifically, subjects who mentioned the difference between the date marks on the cartons without prompting by the experimenter were classified as 'choice relevant' if they mentioned the difference as the reason for their choice and 'choice irrelevant' if not. Subjects who recognized the difference after being guided to the date mark were classified as 'reachable', that is attentive after additional effort by the experimenter. All other subjects who concluded the guidance without noting the difference between the date marks were classified as 'inattentive' to date mark labels.

Table 8
Follow-up experiment — summary statistics.

	Mark		Date		Total
	Comb. 1	Comb. 2	Comb. 1	Comb. 2	
Number of subjects	40	40	40	40	160
Choice relevant	0	0	6	3	9
Choice irrelevant	0	0	6	2	8
Reachable	0	2	10	12	24
Inattentive	40	38	18	23	119
UB≠BB (share)	0.85	0.73	0.73	0.8	0.78
UB correct meaning (share)	0.55	0.43	0.6	0.38	0.49
BB correct meaning (share)	0.95	0.83	0.9	0.8	0.87
Choice revised	2	1	0	3	6

brand-treatment combinations (1 or 2). The assignment was based on a randomized assignment protocol that produced a balanced assignment of 80 in each treatment and 40 for each brand-treatment combination. Table 8 displays the results of the experiment.

The experimental evidence points to a number of observations that help interpret the results of the MPL experiment. First, as expected, brand-treatment combinations do not matter (combination 1 vs. combination 2 for mark and date treatments, $p > 0.81$, chi-square test). Second, pooling the data across brand-treatment combinations, shoppers are much more inattentive about the date mark type than about the expiry date (78 versus 41, $p < 0.01$, chi-square test). Third, irrespective of treatment, there is a significant difference between the *use-by* and *best-before* label: While 78% of subjects agree that the two labels have different and distinct meanings, only 49% correctly interpret the former as opposed to 87% for the latter ($p < 0.01$, chi-squared test).[24]

The evidence from the follow-up experiment suggests that some explanations for the results of the modified MPL experiment are more plausible than others. The ineffectiveness of date mark type manipulations on their own (Result 1) is likely a result of consumers' inattentiveness to what is a small visual change in the date mark. Choosing more salient visual cues could be a remedy for this inattentiveness. The information about expiry dates, which is also visually more prominent, has a larger impact and is therefore choice relevant, coherently with the intertemporal WTP differentials (Result 2). The most important insight from the follow-up experiment is about Result 3: Contrary to the assumptions behind some food waste policies (EU-Council, 2016), consumers are already relatively well informed about the meaning of *best-before* date marks. As a result, it is unsurprising that the education treatment causes no measurable change in willingness to pay in the *BB* condition. Education, however, does impact on WTP in the UB condition, since a substantial share of shoppers misinterprets the *use-by* date mark.

7. Policy implications

Our four core findings have immediate policy implications, both individually and jointly. Our first finding, namely that consumers typically care about and are attentive to expiry dates, is important: Expiry dates matter to consumers, and food labeling policies should reflect that. These policies also benefit from the experimental affirmation that a link exists between expiry date and food valuation. Date marks therefore constitute a valid entry point for policy intervention since consumers' choices demonstrably respond to variations in expiry dates. Any reform in date marking regulations should therefore be cognizant of expiry dates affecting how consumers value food items.

Policy-makers in the EU are especially concerned with the consequences of date mark *misinterpretation* on food waste production (EU-Council, 2016). Accordingly, the European Union's "Farm to Fork Strategy", part of the European Green Deal, foresees the development of new rules on date marking by the end of 2022 to reduce risks of misunderstanding and misuse of date labeling. Identifying new ways of presenting date labels is one key task included in the strategy.[25] This task should take account of our second finding, that inattention to the date mark *type* is widespread. Inattention and misinterpretation, while often leading to similar problems in choice outcomes, are different phenomena with different root causes. Any future evaluation of how date labels are presented should assess not only whether consumers correctly interpret them once made aware of their presence. It should also assess the extent to which the new design can overcome consumers' lack of attention to label *type* at the point of sale. Only those date label designs should be considered in the final round that demonstrably support consumers' attention to the presence of the date label and its type.

Policies aimed at consumer education about food labeling attempt to correct existing misinterpretations. Our third finding both supports and challenges such policies. We found that educating consumers about label meaning has asymmetric effects: Education about the *use-by* label affected consumers' valuation, reducing it. Education about the *best-before* label did not. Policy-makers' expectations about the effects of consumer education should include the possibility of such unanticipated outcomes. Education may further health and safety objectives of preventing the consumption of potentially unsafe food while achieving little in the way of reducing food waste. This policy objective likely requires different routes of intervention.[26]

8. Concluding remarks

Regulations that aim to inform consumers on important features and consequences of their purchase and management decisions about perishable goods are timely. Given the wider impacts of producing, harvesting, and delivering food to consumers' homes, helping consumers to avoid food waste while ensuring public health deserves policy-makers' attention. Date-marks are a plausible approach to providing this help, and initiatives to educate consumers about how to act based on date-marks merit careful assessment.

One challenge for coming to a better assessment of date-marking policies is the nature of the evidence base from which researchers and policy-makers can argue. Previous research has made substantial contributions towards building this evidence base through large-scale surveys, vignette experiments, and laboratory studies. Due to a number of empirical challenges, causal evidence has been more difficult to obtain in order to speak to the question of how date marks types and education causally affect consumers' valuation of perishable food. Our present paper is an attempt to provide such causal evidence for the academic and policy discussion.

In our mind, the evidence presented in this paper makes two contributions. One is the key finding that date mark types, as used at present, are not impactful for consumers' valuation of perishable food products and that educating consumers about their meaning is conducive to the health and safety objectives implicit in date marking food, but not to the objective of preventing food waste. Our follow-up experiment suggests that the explanation for this phenomenon lies in the existing asymmetry in consumers' understanding of the two date marks currently in use.

[24] More evidence for misinterpretation of the *UB* date mark comes from those individuals who accepted to revise their choice: Without exception, these consumers opted for a carton labeled *UB* in exchange for a carton labeled *BB*.

[25] This task is to involve consultations with the relevant stakeholders, an impact assessment procedure and a consumer research: https://ec.europa.eu/food/safety/food-waste/eu-actions-against-food-waste/date-marking-and-food-waste_en.

[26] Along these lines, our paper can also indirectly contribute to the literature on the design of policies to affect consumers' behavior in the direction of reducing food waste. See, among others, Hamilton and Richards (2019) and Yu and Jaenicke (2021).

The other contribution is the nature of the evidence that our paper presents. The evidence emerges from the combination of three interlinked building blocks. The first is a preliminary survey, which informs the choice of a perishable food item that lends itself to the experimental manipulation of date marks without compromising research ethics or the safety of participants. With the help of this choice, we believe that we overcome a core challenge for causal identification, namely varying the date mark without varying the underlying product. The second building block is a modified multiple price list experiment that exchanges the laboratory setting and its student subjects for an in-store setting with members of the general population. These procedural choices require an experimental interface that is accessible for a wide range of shoppers coming to the store. It also requires a new design approach in the form of a buy-back mechanism since we cannot rely on protocol compliance to overcome free disposal censoring. The third building block is a follow-up experiment that pursues the hypothesis that the treatment effects plausibly result from the nature of demand-side information. Jointly, these building blocks demonstrate that it is feasible to overcome at least some of the empirical challenges of generating causal evidence to understand information-based policies. Moreover, they demonstrate that the policy proposals are unlikely to accomplish their desired objectives. And they provide at least one explanation of why these proposals are likely to underperform, thus informing the development of policy alternatives.

The present paper provides conceptual and methodological points of departure for future research. Much of this paper hinges on the question of how well its evidence generalizes to other food categories. Future work will need to explore this as well as the question of how this approach could be extended to other categories of perishable products. This exploration should also consider the non-food domain, where issues of waste and (planned) obsolescence raise similar issues. While we believe that the in-store experiment takes important steps towards enhanced external validity of the findings, our attempts to conduct this research as a fully-fledged natural field experiment were unsuccessful. We remain hopeful that this avenue can be embarked upon in the future, while respecting the requirements of safety and ethics. Finally, the paper is limited to testing how current date marking practices perform. Clearly, we cannot rule out, and would in fact strongly suspect, that there exist alternative information-based policies that can make a significant contribution towards increasing consumers' valuation of perishable, but safe foods and reducing food waste. Identifying these alternatives remains a research priority.

CRediT authorship contribution statement

Alessio D'Amato: Conceptualization, Methodology, Writing – review & editing, Funding acquisition. **Timo Goeschl:** Methodology, Investigation, Validation, Resources, Writing – original draft, Supervision. **Luisa Lorè:** Methodology, Software, Formal analysis, Investigation, Data curation, Visualization. **Mariangela Zoli:** Conceptualization, Methodology, Formal analysis, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Authors would like to thank audience at EAERE2020, IAERE 2020 and NERI 2020 Conferences for insightful comments and suggestions. Funding from the University of Rome Tor Vergata - Mission: Sustainability projects (WDSC, number E81I18000760005) and from the Heidelberg Center for the Environment under its Small Grants Scheme are gratefully acknowledged.

Appendix A. Survey questions

General survey (pt. 1)

1. Do you regularly buy groceries?
   - Yes
   - No
   - I prefer not to answer
2. Would you saying that you are doing the most grocery shopping of your household?
   - Yes
   - No
   - I prefer not to answer
3. How many people, including yourself, live in your household?
   - 1
   - 2
   - 3
   - 4
   - 5 or more
   - I prefer not to answer
4. *If more than one person in the household:* Is someone in your household vegetarian?
   - Yes
   - No
   - I prefer not to answer
5. Are you vegetarian?
   - Yes
   - No
   - I prefer not to answer
6. *If more than one person in the household:* Is someone in your household vegan?
   - Yes
   - No
   - I prefer not to answer
7. Are you vegan?
   - Yes
   - No
   - I prefer not to answer
8. If we may ask: Could you assign yourself to one of the following age groups?
   - 18–25
   - 26–35
   - 36–45
   - 46–55
   - 56–65
   - 66 or more
   - I prefer not to answer
9. Do you have children?
   - Yes
   - No
   - I prefer not to answer
10. Which gender do you associate with?
    - Female

- Male
- Other
- I prefer not to answer

11. Which gender do you associate with?

- Female
- Male
- Other
- I prefer not to answer

12. What is the highest educational attainment you have achieved?

- *Kein Schulabschluss* - no High School Diploma.
- *Hauptschulabschluss* - Hauptschule Diploma, awarded after 9 years of Education.
- *Realschulabschluss* - Realschule Diploma, awarded after 10 years of Education.
- *Abitur* - High School Diploma, awarded after 12 years of Education and necessary prerequisite for University.
- *Berufsschulabschluss* - Apprenticeship, awarded after 3-years education cycle in which the student can learn a craft work from a trainer (an expert in the field) and attend a vocational school.
- *Hochschulabschluss* - University Degree, with no difference whether it is Bachelor or Master.
- *Promotion* - Ph.D.

13. You are currently...

- Studying/Training
- Self-employed
- Employed
- Retired
- Unemployed
- I prefer not to answer.

General survey (pt. 2)

N.B. The second part of the general survey is only administered to subjects in the modified MPL experiment.

1. What do you usually pay most attention to when you buy groceries at the grocery store:

- Produced in Germany
- Sustainable or environmentally friendly production
- Price
- Brand
- Other [please specify].

2. Do you or anyone else in your household like to eat eggs?

- Yes
- No

3. Do you or anyone else in your household have an egg allergy?

- Yes
- No

4. Is food sometimes thrown away in your household?

- Yes
- No

5. Who is typically responsible for discarding such food?

- Me
- Someone else

The questions for the Information test are as follows

1. *In shops, packaged groceries are sold with two labels indicating expiration dates. One is "Best Before", the other is "Use By". What do you think:*

- The two date marks have different messages for the consumer.
- The two date marks have the same meaning for the consumer.

2. *The "use by" date means:*

- The food will be safe to eat up to this date and should not be eaten past this date (UB)
- The food can be consumed after this date, but it may no longer be at its best quality (BB)
- The food can be used after this date only if the packaging is not damaged (CD1)
- The food will be safe to eat from this date on and should be eaten past this date (CD2)

3. *The "best before" date means:*

- The food will be safe to eat up to this date and should not be eaten past this date (UB)
- The food can be consumed after this date, but it may no longer be at its best quality (BB)
- The food can be used after this date only if the packaging is not damaged (CD1)
- The food will be safe to eat from this date on and should be eaten past this date (CD2)

The order of the two questions and the order of the possible options (equal in the two question for each individual in order to avoid possible confusion) is random across the subjects. The answers used in these two questions are the definition of the UB label and of the BB and two confounding definitions (CDs). The label definitions in English and in German are the official ones used in the (Eurobarometer, 2015).

Appendix B. Flowcharts of experimental designs

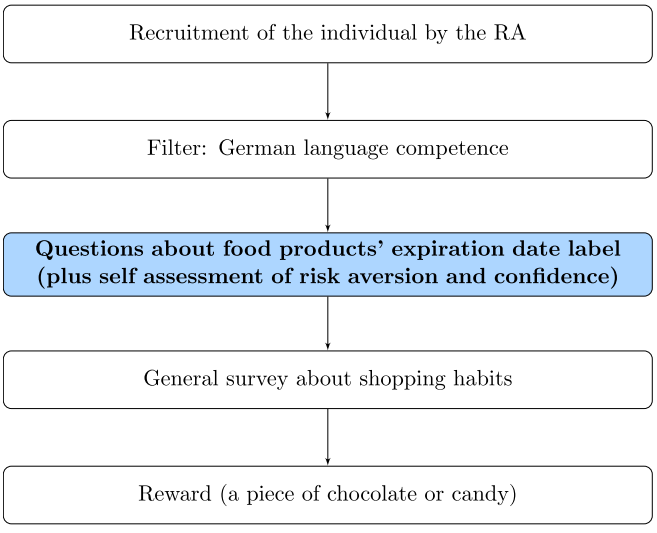

Fig. B.1. Flowchart of the preparatory survey.

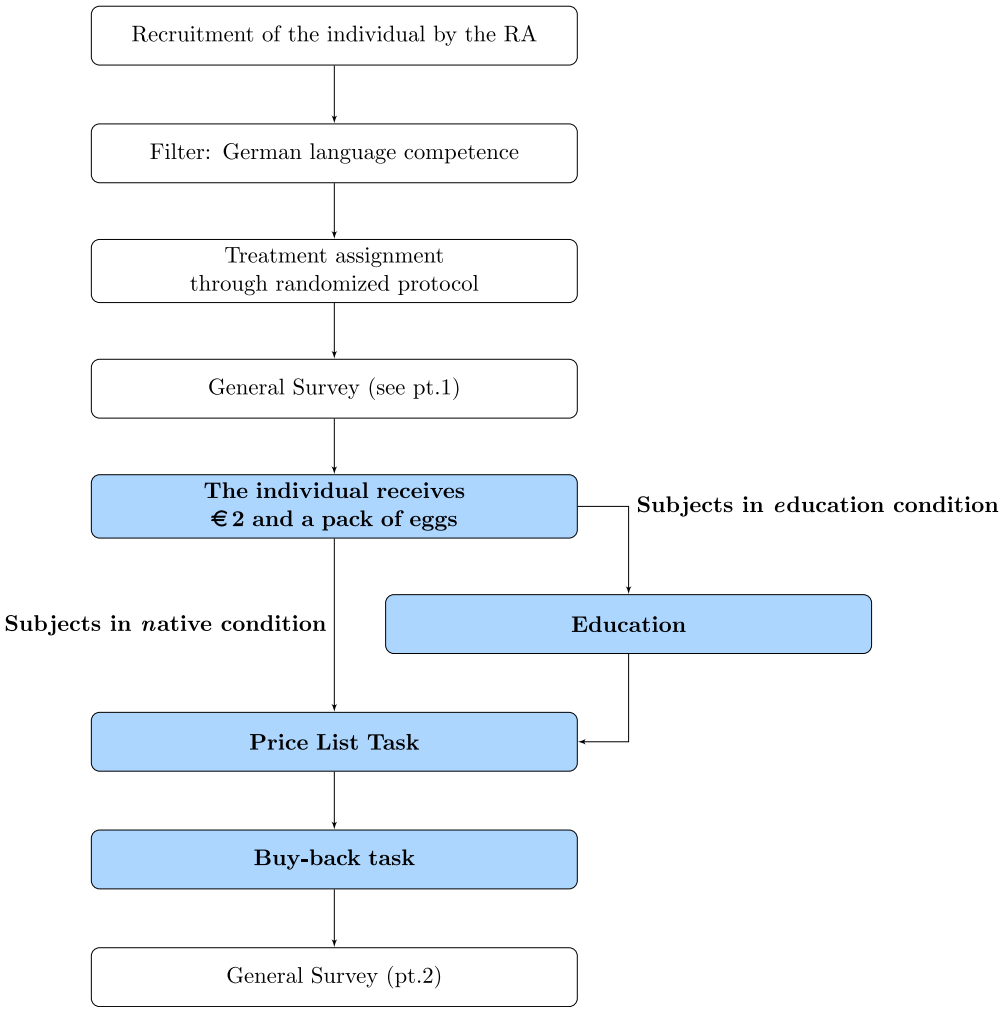

Fig. B.2. Flowchart of the modified MPL experiment.

References

Andersen, S., Harrison, G.W., Lau, M.I., Rutström, E.E., 2006. Elicitation using multiple price list formats. Exp. Econ. 9 (4), 383–405.

Andersen, S., Harrison, G.W., Lau, M.I., Rutström, E.E., 2007. Valuation using multiple price list formats. Appl. Econ. 39 (6), 675–682.

Berry, J., Fischer, G., Guiteras, R., 2020. Eliciting and utilizing willingness to pay: Evidence from field trials in Northern Ghana. Journal of Political Economy 128 (4), 1436–1473.

Burchardi, K.B., De Quidt, J., Gulesci, S., Lerva, B., Tripodi, S., 2021. Testing willingness to pay elicitation mechanisms in the field: Evidence from Uganda. Journal of Development Economics 152, 102701.

Cason, T.N., Wu, S.Y., 2019. Subject pools and deception in agricultural and resource economics experiments.. Environ. Resour. Econ. 73 (3), 743–758.

Collart, A., Interis, M., 2018. Consumer imperfect information in the market for expired and nearly expired foods and implications for reducing food waste. Sustainability 10 (11), 3835.

Colson, G., Corrigan, J., Grebitus, C., Loureiro, M., Rousu, M., 2015. Which deceptive practices, if any, should be allowed in experimental economics research? Results from surveys of applied experimental economists and students. Am. J. Agric. Econ. 98 (2), 610–621.

Coursey, D.L., Hovis, J.L., Schulze, W.D., 1987. The disparity between willingness to accept and willingness to pay measures of value. Q. J. Econ. 102 (3), 679–690.

Davis, D., Millner, E., 2005. Rebates, matches, and consumer behavior. South. Econ. J. 72, 410–421.

EU-Council, 2016. Council Conclusions on Food Losses and Food Waste, June 28, 2016. Technical Report, EU Council.

Eurobarometer, 2015. Flash Eurobarometer 425: Food Waste and Date Marking. Technical Report, European Commission.

Farr-Wharton, G., Foth, M., Choi, J.H.-J., 2014. Identifying factors that promote consumer behaviours causing expired domestic food waste. J. Consumer Behav. 13 (6), 393–402.

Garrone, P., Melacini, M., Perego, A., 2014. Opening the black box of food waste reduction. Food Policy 46, 129–139.

Gaudecker, H.-M.v., Soest, A.v., Wengstrom, E., 2011. Heterogeneity in risky choice behavior in a broad population. Amer. Econ. Rev. 101 (2), 664–694.

Hall, K.D., Guo, J., Dore, M., Chow, C.C., 2009. The progressive increase of food waste in America and its environmental impact. PLoS One 4 (11), e7940.

Hamilton, S.F., Richards, T.J., 2019. Food policy and household food waste.. Am. J. Agric. Econ. 101 (2), 600–614.

Havelaar, A.H., Kirk, M.D., Torgerson, P.R., Gibb, H.J., Hald, T., Lake, R.J., Praet, N., Bellinger, D.C., De Silva, N.R., Gargouri, N., et al., 2015. World health organization global estimates and regional comparisons of the burden of foodborne disease in 2010. PLoS Med. 12 (12), e1001923.

Hayes, D.J., Shogren, J.F., Shin, S.Y., Kliebenstein, J.B., 1995. Valuing food safety in experimental auction markets. Am. J. Agric. Econ. 77 (1), 40–53.

Kahneman, D., Knetsch, J.L., Thaler, R.H., 1991. Anomalies: The endowment effect, loss aversion, and status quo bias. J. Econ. Perspect. 5 (1), 193–206.

Lebreton, M., Langdon, S., Slieker, M., Nooitgedacht, J., Goudriaan, A., Denys, D., van Holst, R., Luigjes, J., 2018. Two sides of the same coin: Monetary incentives concurrently improve and bias confidence judgment. Sci. Adv. 4, eaaq0668.

Leib, E.B., Rice, C., Neff, R., Spiker, M., Schklair, A., Greenberg, S., 2016. Consumer perceptions of date labels: National survey. Safety 23 (54), 19.

Murad, Z., Sefton, M., Starmer, C., 2016. How do risk attitudes affect measured confidence? J. Risk Uncertain. 52 (1), 21–46.

Neff, R.A., Spiker, M., Rice, C., Schklair, A., Greenberg, S., Leib, E.B., 2019. Misunderstood food date labels and reported food discards: A survey of U.S. consumer attitudes and behaviors. Waste Manage. 86, 123–132.

Neff, R.A., Spiker, M.L., Truant, P.L., 2015. Wasted food: U.S. consumers' reported awareness, attitudes, and behaviors. PLoS One 10 (6), e0127881.

Reinhardt, P.G., et al., 1973. A theory of household grocery inventory holdings. Kyklos 26 (3), 497–511.

Roe, B.E., Phinney, D.M., Simons, C.T., Badiger, A.S., Bender, K.E., Heldman, D.R., 2018. Discard intentions are lower for milk presented in containers without date labels. Food Qual. Pref. 66, 13–18.

Rousu, M., Colson, G., Corrigan, J., Grebitus, C., Loureiro, M., 2015. Deception in experiments: towards guidelines on use in applied economics research. Appl. Econ. Perspect. Policy 37, 524–536.

Samuelson, W., Zeckhauser, R., 1988. Status quo bias in decision making. J. Risk Uncertain. 1 (1), 7–59.

Sapci, O., Sapci, A., 2020. Consumer perception of food expiration labels: "sell by" versus "expires on". East. Econ. J. 46 (4), 673–689.

Shogren, J.F., Shin, S.Y., Hayes, D.J., Kliebenstein, J.B., 1994. Resolving differences in willingness to pay and willingness to accept. Am. Econ. Rev. 255–270.

Siddique, M.A.M., 2012. Explaining the role of perceived risk, knowledge, price, and cost in dry fish consumption within the theory of planned behavior. J. Global Mark. 25 (4), 181–201.

Thompson, B., Toma, L., Barnes, A.P., Revoredo-Giha, C., 2018. The effect of date labels on willingness to consume dairy products: Implications for food waste reduction. Waste Manage. 78, 124–134.

Tsiros, M., Heilman, C.M., 2005. The effect of expiration dates and perceived risk on purchasing behavior in grocery store perishable categories. J. Mark. 69 (2), 114–129.

van Boxstael, S., Devlieghere, F., Berkvens, D., Vermeulen, A., Uyttendaele, M., 2014. Understanding and attitude regarding the shelf life labels and dates on pre-packed food products by Belgian consumers. Food Control 37, 85–92.

Van der Werf, P., Seabrook, J.A., Gilliland, J.A., 2018. The quantity of food waste in the garbage stream of southern Ontario, Canada households. PloS One 13 (6), e0198470.

Wilson, N.L., Miao, R., Weis, C., 2018. Seeing is not believing: Perceptions of date labels over food and attributes. J. Food Prod. Mark. 24 (5), 611–631.

Wilson, N.L., Rickard, B.J., Saputo, R., Ho, S.-T., 2017. Food waste: The role of date labels, package size, and product category. Food Qual. Pref. 55, 35–44.

Yu, Y., Jaenicke, E.C., 2021. The effect of sell-by dates on purchase volume and food waste. Food Policy 98, 101879.