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RESEARCH

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Public overconfidence in understanding food date labeling undermines our efforts to reduce food waste

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Abstract

Given the profound social, economic, and environmental consequences of food waste, identifying effective and timely strategies to mitigate this issue is imperative. While prior research has explored the connection between consumers' misunderstanding of food date labeling (FDL) and food waste, questions remain regarding both the discrepancy between consumers' subjective (self-reported) and objective (test-based) knowledge of FDL, and how subjective knowledge influences the efficacy of information interventions on a global scale. Using online survey data ($N = 7830$) from China, we measured consumers' subjective and objective FDL knowledge separately and constructed a knowledge deviation index. Our analysis reveals that 57.78% of consumers exhibit "knowledge overconfidence"—overestimating their understanding of FDL, and a significant correlation between knowledge deviation and food waste. Although the randomized information intervention experiment and difference-in-differences (DID) model results demonstrate the effectiveness of specific label information in enhancing consumers' objective FDL knowledge and reducing food waste willingness, the subsequent fixed-effects model results indicate that subjective FDL knowledge significantly hinders the beneficial effects of the intervention on both knowledge correction and the reduction in willingness to waste food. These findings offer novel insights for policymakers and stakeholders working toward United Nations Sustainable Development Goal 12.3 "halve food waste by 2030" by highlighting the critical role of addressing knowledge overconfidence in reducing food waste.

Keywords: Food waste, Knowledge deviation, Difference-in-differences (DID), Experimental economics, Sustainable food systems

Introduction

The global food supply is undergoing a significant transformation, characterized by the increasing prevalence of highly processed and prepackaged foods driven by advancements in food science and technology. Prepackaged foods now constitute a dominant share of daily diets in both advanced and transition economies (Monteiro et al. 2013; Popkin et al., 2020). Food labeling serves as a critical component of these products, acting as the primary communication channel between manufacturers and consumers, influencing purchasing decisions and nutritional outcomes (Potter et al. 2023). However,

the effectiveness of food labels depends not only on consumers' ability to accurately understand the information presented (Grunert and Wills 2007) but also on whether they act upon the label instructions (Kavanaugh and Quinlan 2020). Nevertheless, the effectiveness of food labels is frequently compromised. Technical jargon, ambiguous terminology, and numeric data on food labels often prove too complex for the average consumer, leading to widespread misunderstanding (Bai et al. 2020) and undermining the labels' intended role in guiding informed consumption and health decisions.

Among various food labeling systems, consumer misunderstanding and confusion of food date labeling (FDL) presents a particularly acute challenge with severe consequences. Growing evidence indicates that misunderstanding of FDL significantly exacerbates the global food waste crisis (Aschemann-Witzel et al. 2021; Marouli 2024). In addition, the information overload caused by excessive label content creates significant cognitive burdens and confusion for consumers (Grunert et al. 2010). This confusion is also closely related to food waste. Households in advanced economies generate nearly half of all food waste (FUSIONS 2016), with a substantial portion (approximately 20%) directly attributable to consumer confusion regarding date labels (Waste and Resources Action Programme 2011). Alarming, surveys such as that conducted by the U.S. Food and Drug Administration (FDA 2019) reveal that a vast majority of consumers (over 90% of Americans) unnecessarily discard edible food primarily because they misinterpret date labels as indicators of safety expiration rather than quality. This misinterpretation contributes significantly to preventable waste. This pervasive misunderstanding of FDL and its direct link to wasteful behavior constitutes a critical problem demanding deeper investigation (Brennan et al. 2021).

This gap in knowledge prompts crucial theoretical and practical inquiries: Does the prevalent misunderstanding of FDL reflect a broader "knowledge deficit" as conceptualized in science communication literature (Brossard and Nisbet 2007)? More specifically, to what extent is this knowledge deficit related to consumers' food waste behaviors? The deficit model, which attributes public misunderstandings to insufficient scientific understanding, may provide a valuable framework for examining these questions, yet its application to FDL comprehension remains unexplored.

This study adopts Brucks' (1985) tripartite framework of consumer knowledge—comprising objective, subjective, and experiential knowledge—as its core theoretical lens. This framework conceptualizes consumer knowledge as multidimensional, encompassing not only factual understanding measured through standardized tests (objective knowledge, true or false) but also self-assessed knowledge levels (subjective knowledge) and insights accumulated from past experiences (experiential knowledge). This theoretical perspective provides crucial guidance for our research: (1) It necessitates the independent measurement of consumers' objective FDL knowledge (e.g., assessed via standardized tests evaluating correct understanding of concepts like "best before" dates) and subjective knowledge (self-reported understanding). (2) It highlights the prevalent discrepancy between subjective and objective knowledge, termed "knowledge overconfidence" (Griffin and Varey 1996; Yang and Jin 2022), a phenomenon well-documented across various domains including consumer understanding of genetically modified organisms, nuclear energy, and climate change (Rabb et al. 2019). Especially for the understanding of food labels, Sharf et al. (2012) found that while 43.9% of consumers

believed they understood nutritional labels well, only 27.2% actually demonstrated high comprehension through objective testing, indicating a significant 16.7% points gap between perceived and actual nutritional label understanding. (3) Crucially, the theory of planned behavior (Fishbein et al. 1980) posits that behavioral intentions are significantly shaped by perceived behavioral control, and perceived behavioral control (closely linked to subjective knowledge) is a more direct and powerful predictor of actual behavior (Fiske et al. 1994) rather than objective knowledge alone. Consequently, this study focuses on examining the discrepancy between objective and subjective knowledge—termed “knowledge deviation”—as the central mechanism linking FDL understanding to food waste.

Building on this framework, our study aims to investigate the interplay between consumers’ subjective and objective FDL knowledge and its causal impact on food waste behavior. Significantly, we introduce and empirically test the concept of “knowledge deviation”—the gap between perceived (subjective) and actual (objective) understanding—as a novel and potentially more powerful predictor of wasteful actions than either knowledge dimension alone. This focus addresses a key gap in the literature, as prior FDL research has primarily examined the link between objective knowledge and waste (Kosa et al. 2007; Kavanaugh and Quinlan 2020; Toma et al. 2020), largely overlooking the behavioral implications of the subjective–objective knowledge gap.

Furthermore, we seek to rigorously evaluate the causal efficacy of information-based interventions designed to clarify FDL meanings and reduce waste. While such interventions show promise (Cheng et al. 2025; Dai and Gong 2024), their effectiveness may be hindered by consumers’ subjective knowledge. Individuals with high subjective knowledge often perceive less need for information (Alba and Hutchinson 2000), potentially creating a barrier to knowledge updating and behavior change. Our research innovatively investigates whether subjective knowledge acts as such a barrier within FDL interventions, providing critical insights for optimizing intervention design.

Through this investigation, we make significant contributions. Theoretically, we advance the understanding of consumer food label knowledge by integrating multidimensional knowledge theory and introducing “knowledge deviation” as a key behavioral antecedent in the FDL context, moving beyond the limitations of the “knowledge deficit” model. Methodologically, we employ a robust multi-method approach (combining OLS regression, difference-in-differences design, and fixed-effects model) to rigorously establish the empirical relationship between knowledge deviation and food waste and evaluate the causal effect of information interventions on consumers’ objective FDL knowledge and food waste reduction willingness. Practically, our findings on the role of subjective knowledge as a barrier to changes in objective FDL knowledge and food waste reduction willingness provide actionable insights for designing more effective, evidence-based information campaigns to reduce food waste, directly contributing to achieving UN Sustainable Development Goal 12.3 (“Halve food waste at the retail and consumer levels by 2030”).

Literature review and critical gaps

FDL has emerged as a critical focus within food waste research, yet significant knowledge gaps persist (Neubig and Roosen 2024; Wilson and Miao 2025; Brennan et al. 2021). Empirical studies consistently demonstrate that consumer confusion regarding date labels (e.g., conflating “best before” with “use by”) is a major driver of unnecessary household food waste (Aschemann-Witzel et al. 2021; Waste and Resources Action Programme 2011; FDA 2019). This phenomenon has been widely documented as a pervasive issue (Neff et al. 2019; Shamim et al. 2022).

Research on consumer knowledge related to labeling, including FDL, increasingly recognizes its multidimensional nature. Brucks’ (1985) tripartite framework distinguishing objective, subjective, and experiential knowledge provides a valuable lens. In the FDL context, objective knowledge refers to consumers’ accurate understanding of label meanings, typically measured through standardized tests; lower levels are operationally defined as “misunderstanding” (Kavanaugh and Quinlan 2020; Toma et al. 2020). Subjective knowledge reflects consumers’ self-assessed confidence in their understanding, while experiential knowledge stems from accumulated product use. A critical phenomenon observed across domains, including food labeling (Sharf et al. 2012), is the frequent discrepancy between subjective and objective knowledge—often manifesting as “knowledge overconfidence” (Griffin and Varey 1996; Yang and Jin 2022; Rabb et al. 2019). This gap represents a potential failure in information transmission.

The perceived behavioral control (closely linked to subjective knowledge) is often a more direct predictor of behavior than objective knowledge (Fiske et al. 1994). However, existing FDL research has predominantly focused on establishing links between objective knowledge and food waste behaviors (Kosa et al. 2007; Kavanaugh and Quinlan 2020; Toma et al. 2020). Critically, the potential behavioral consequences of the discrepancy itself—the gap between what consumers believe they know (subjective) and what they actually know (objective) about FDL—remain largely unexplored and constitute a major theoretical gap.

Concurrently, research on mitigating food waste has explored various intervention strategies. Information-based interventions have demonstrated efficacy in reducing waste (Aschemann-Witzel et al. 2019; Giesen and Hooge 2019; Reynolds et al. 2019; Zamri et al. 2020; Dai and Gong 2024). However, current interventions often rely on moral persuasion (e.g., “reduce waste” slogans in dining establishments or on promoting planned grocery shopping in supermarkets), while the recently published research has made significant strides by validating the efficacy of specific information dissemination about FDL meanings in waste reduction (Cheng et al. 2025). This establishes a crucial foundation for our work. However, research on the specific mechanisms and barriers influencing FDL intervention effectiveness remains limited. A significant potential barrier, suggested by consumer behavior literature (Alba and Hutchinson 2000), is that consumers with high subjective knowledge may exhibit lower receptivity to corrective information, believing they already possess sufficient understanding. Whether this “subjective knowledge barrier” impedes the effectiveness of FDL-specific educational interventions aimed at reducing waste is unknown and represents a crucial practical gap.

In summary, while the problem of FDL misunderstanding is well-recognized and linked to waste, and while consumer knowledge is understood as multidimensional,

prior research exhibits two key limitations: Specifically, it has largely neglected the behavioral impact of the discrepancy (knowledge deviation) between subjective and objective FDL knowledge on food waste behavior and has not empirically investigated the potential role of subjective knowledge as a barrier to the effectiveness of corrective FDL information interventions. Our study directly addresses these interconnected gaps.

Methodology

Given the breadth of content covered in this section, we first provide an overview of its organization. We begin by outlining the sampling strategy and sample characteristics, followed by a detailed presentation of the study design. This includes the framework and implementation of our information intervention experiment, as well as the conceptualization and measurement of key variables: knowledge (both subjective and objective), composite index construction, and food waste assessment. We conclude by specifying the empirical models and robustness test methods used in our analysis.

Sampling strategy

To address the potential variability in consumers' understandings of FDL across different food types (perishable and non-perishable) (Toma et al. 2020), we select two representative food categories: pure milk (perishable) and cookies (non-perishable). These products were chosen based on three key criteria: (1) Packaging and shelf life: Both are prepackaged, shelf-stable products (typical shelf life ≥ 3 months) widely consumed in Chinese households; (2) Research relevance: Dairy products like pure milk are well-documented in food waste literature due to their perishability and high waste rates (Blondin et al. 2017; Connors and Schuelke 2022); (3) Regulatory context: In China, only prepackaged foods (uniformly packaged and labeled) are required to display FDL, unlike bulk foods. Regarding the two selected food products, pure milk produced using ultra-high temperature pasteurization can be stored at room temperature for 3–6 months in sterile packaging. Cookies, as a non-perishable staple with stable physicochemical properties, serve as a control for perishability effects. This dual-product ensures robustness by capturing FDL interpretation differences tied to perishability while controlling for packaging uniformity and consumer familiarity.

We determine the survey sample areas by obtaining 5-year per capita milk consumption data (2016–2020) by province (including municipalities directly under the central government and administrative regions, hereafter abbreviated as “province”) from *China Statistical Yearbook* (National Bureau of Statistics of China, 2016, 2017, 2018, 2019, 2020) and classify provinces into tertiles (low/medium/high consumption) according to the numerical value divided into equal tertiles. Then, we select two provinces from each stratum based on per capita GDP (economic representativeness) and geographic distribution (eastern/central/western China), and finally, we select six provincial capital cities of the six selected provinces as the survey areas (see Table 1 for details) to capture socio-economic and regional diversity while maintaining focus on milk consumption patterns.

We employ a randomized controlled design with the following key features: (1) Sampling approach: random sampling of adults (18 years or older) with one-time participation restriction, stratified by food type (milk vs. cookies) with random assignment, excluding participants from the pre-tested study ($n=307$). (2) Questionnaire structure:

Table 1 Sample distribution

Region	Eastern China				Central China				Western China			
	Total samples: 1355				Total samples: 1286				Total samples: 1274			
City	Beijing		Guangzhou		Hefei		Changchun		Chengdu		Xining	
<i>The intervention group (Total samples: 2075; M samples: 1086; C samples: 989)</i>												
Food type	M	C	M	C	M	C	M	C	M	C	M	C
Samples	190	171	191	169	179	165	178	162	178	157	170	165
<i>The control group (Total samples: 1840; M samples: 934; C samples: 906)</i>												
Food type	M	C	M	C	M	C	M	C	M	C	M	C
Samples	164	148	161	161	153	155	151	143	153	152	152	147

Product codes: M milk, C cookies

Regional classification follows China's National Bureau of Statistics standards: Eastern region (11 provinces): Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan. Central region (8 provinces): Heilongjiang, Jilin, Henan, Shanxi, Anhui, Jiangxi, Hubei, Hunan. Western region: All other provincial-level administrative units

streamlined to maintain attention (single product focus per participant), four core modules (demographic and household characteristics, label knowledge assessment, food waste behaviors, and intervention experiment). (3) Quality control: pre-tested with 307 participants to refine questions. No advance notification or training provided. Intervention and control groups received identical questionnaires except for the experimental treatment phase. This approach ensured data quality while minimizing participant burden and selection bias.

Data collection and sample characteristics

We collected data through *Questionnaire Star* (<https://www.wjx.cn>), a leading Chinese online survey platform comparable to Synata. The platform maintains over 6.2 million registered users (including 3 million active users), nationwide coverage across 31 provincial divisions (excluding Hong Kong, Macao, and Taiwan), and a diverse participant pool across age, education, and income levels (Lin and Guan 2021). The survey company uses an integrity score system for participant screening and a mobile-optimized interface for accessibility, consistently providing qualified survey services. To ensure the effectiveness of the information intervention further, we excluded extreme response durations (< 12 min or > 2 h; mean = 22.5 min), removed non-consumers of target foods ($n = 306$) to focus on relevant populations, yielding a valid sample from 3915 participants from six geographically balanced cities across China's eastern, central, and western regions with two-period panel data ($N = 7830$). Sample demographics and the covariates employed in the econometric model are presented in Table 2, which summarizes the demographic profile of our sample. Key characteristics include: 44% female, mean age of 29.99 years (similar to China's typical internet users), 68.38% bachelor's degree holders, and per capita disposable income of 4783 CNY/month. The sample reflects China's urban online population—skewed toward younger, educated females—while maintaining reasonable representativeness.

Table 2 Variable description

Variables	Meanings and expressions	Mean	Std	Min	Max
<i>Demographic variables</i>					
Age	Years old	29.99	7.19	18	71
Gender	Female = 0; male = 1	0.44	0.50	0	1
Education	Below bachelor degree = 1; Bachelor degree = 2; Above bachelor degree = 3	1.90	0.55	1	3
Health	Whether all living family members are healthy (including participants)? (No = 0; Yes = 1)	0.77	0.42	0	1
Risk attitude	Risk aversion = -1; Neutral = 0; Risk preference = 1	-0.43	0.87	-1	1
Resources awareness	Do you believe resources are infinite? (7 Likert scale: Strongly disagree = 1; Strongly agree = 7)	2.70	2.14	1	7
<i>Family variables</i>					
Family size	The number of living family members	2.95	1.30	1	8
Old member	The number of elderly living family members (over 65 years old)	0.26	0.61	0	5
Disposable income	Per capita household disposable income, Yuan (CNY, Chinese monetary unit) per month	4783	3795	333	20,000
<i>Label attitude variables</i>					
Meaningful	FDL is meaningful. (7 Likert scale: Strongly disagree = 1; Strongly agree = 7)	6.10	0.97	1	7
Dependence	I judge whether the food is still edible by myself, not relying on the FDL. (7 Likert scale: Strongly disagree = 1; Strongly agree = 7)	2.36	1.33	1	7
<i>Food consumption habit variables</i>					
Planned	I always have a plan when purchasing food. (Likert scale: Strongly disagree = 1; Strongly agree = 7)	5.63	1.06	1	7
Freshness	According to the FDL, the freshness requirements for food when purchasing. (0–3 continuous integer variable, no requirement = 0; the highest requirement = 3)	1.98	1.01	0	3
Number of observations		3915			

All control variables in the table are collected during the pre-intervention survey phase. Following the established methodology of Lv et al. (2021), we operationalize consumers' risk attitudes through a validated behavioral economics measure: "For the supermarket lottery, what is your choice?" Option a: Participate in a lottery with 50% chance to win ¥100 and 50% chance to receive nothing (coded as 1); Option b: Indifferent between participating or not (coded as 0); Option c: Decline the lottery and receive ¥50 guaranteed (coded as -1)

Study design and definitions

Information intervention experiment

The study employed a randomized controlled design with intervention and control groups. Participants accessed the questionnaire anonymously via mobile devices, tablets, or computers with completely anonymous and voluntary. The experimental procedure is shown in Fig. 1. It should be noted that these three phases are completed within a single survey session. Specifically, the information intervention is administered immediately after collecting Phase 1 data, followed instantaneously by the collection of post-intervention data. According to time-monitoring data from the survey, participants completed the entire three-phase process within two hours.

Measurement of objective knowledge

This study examines consumers' objective knowledge of China's most prevalent food date label—the "quality guaranteed date label" (from the literal translation, analogous to the "best before date label" in international standards), which is a general term for various

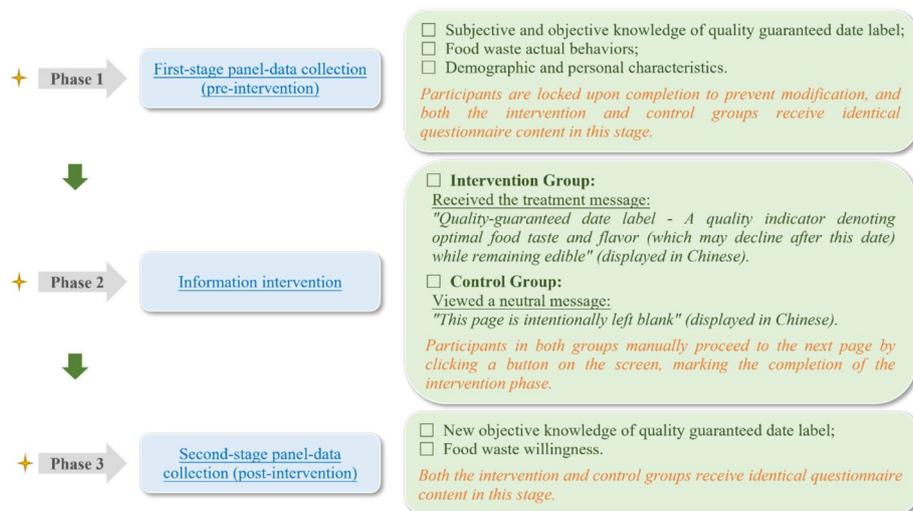


Fig. 1 Experimental procedure

Table 3 Objective and subjective knowledge assessment before the intervention

Items	Coding	Number	Proportion
<i>Objective knowledge</i>			
Answer incorrectly	0	3169	80.95%
Answer correctly	1	746	19.05%
Overall		3915	100.00%
<i>Subjective knowledge</i>			
Confused	0	1124	28.71%
Not confused	1	2791	71.29%
Overall		3915	100.00%

The assessment of objective knowledge level is the result of the investigator’s objective evaluation after the participant’s answer, while the subjective knowledge level is the original answer reported by the participant themselves, which is not affected by the investigators. The evaluation subjects are different

food date labels. Following Yang and Jin’s (2022) methodology, we operationalize objective knowledge as accurate understanding of the label’s official meaning: “The quality guaranteed date label indicates optimal food quality (not safety).”¹ The estimation results show that only 19.05% of participants correctly identify the label’s meaning (Table 3), which confirms widespread misunderstanding (low objective knowledge) among Chinese consumers and underscore significant knowledge gaps in FDL comprehension.

Measurement of subjective knowledge

Subjective knowledge reflects a consumer’s self-assessed understanding of a particular subject (Brucks 1985). Following the measurement approach of Buratto and Lotti (2023), we operationalize subjective knowledge by measuring participants’ self-assessment of the knowledge level of the FDL, specifically, whether they feel confused about

¹ <http://www.nhc.gov.cn/wjw/aqbz/201106/a054a6affd0e489da150cf2b51a971a7/files/e84256474d1445919246b4a41a87f172.pdf>

the meaning of the quality guaranteed date label. The results are presented in Table 3. To better distinguish between subjective and objective knowledge, we adopt the term “subjective knowledge” instead of “confusion” as used in prior research (Neff et al. 2019; Shamim et al. 2022). Notably, while 80.95% of participants incorrectly answered the factual meaning of the label, only 28.71% reported feeling confused about its meaning. This discrepancy suggests a significant divergence between subjective and objective knowledge, with consumers appearing to overestimate their actual understanding of FDL. This finding aligns with prior research on consumer overconfidence in nutritional labeling (Sharf et al. 2012) but extends it to the FDL domain. Interestingly, the overestimation of knowledge appears more pronounced for date labels than for nutritional information, highlighting a critical gap in consumer awareness. To evaluate intervention effects on objective knowledge, we construct two-phase panel data and the data results before and after the information intervention are shown in Table 4.

The knowledge deviation index

To quantitatively assess the discrepancy between consumers’ subjective and objective knowledge of FDL before the intervention, we adopt the measurement approach proposed by Buratto and Lotti (2023). Specifically, we compute the knowledge deviation index as the difference between subjective and objective knowledge scores, as formalized in Eq. (1):

$$I_{\text{knowledge deviation}} = (I_{\text{subjective knowledge}} - I_{\text{objective knowledge}}) \in [-1, 1] \tag{1}$$

$I_{\text{subjective knowledge}}$ represents the subjective knowledge level, $I_{\text{objective knowledge}}$ denotes the objective knowledge level, $I_{\text{knowledge deviation}}$ measures the relative magnitude of subjective and objective knowledge (see Table 5 for statistical results). The degree of deviation between subjective and objective knowledge is represented by the distance from the value “0”. However, in this study, we prefer this index to represent the relative degree of subjective knowledge over objective knowledge rather than the absolute degree of deviation. When $I_{\text{knowledge deviation}} < 0$ indicates that the participant’s subjective knowledge is lower than objective knowledge (underestimated subjective

Table 4 Descriptive statistics of changes in label objective knowledge and food waste behavior and willingness before and after the information intervention

All sample Variables	Before		After		Mean difference	
	Obs	Mean	Obs	Mean	Mean	t-value
<i>The intervention group</i>						
Objective knowledge	2075	0.204	2075	0.647	- 0.443***	32.348
Food waste	2075	- 0.157	2075	1.333	- 1.491***	- 14.619
<i>The control group</i>						
Objective knowledge	1840	0.176	1840	0.154	0.021*	1.733
Food waste	1840	- 0.077	1840	- 0.069	- 0.008	- 0.078

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The significance of the paired samples t-test here represents the significance of changes in both objective knowledge and food waste behavior before and after information intervention. “Obs.” denotes the number of observations in each analysis. Before the information intervention, the “Food waste” data in the table represents the actual food waste dates reported by participants, while after the intervention, the “Food waste” data reflect participants’ expected food waste dates (measuring behavioral willingness)

Table 5 Knowledge deviation contingency table

Subjective	Objective		
	0	1	Overall
0	907	217	1124
1	2262	529	2791
Overall	3169	746	3915
Scores	Categories	Number	Proportion
− 1	Knowledge underconfidence	217	5.54%
0	Neutral (subjective knowledge equals objective knowledge)	1436	36.68%
1	Knowledge overconfidence	2262	57.78%
Overall		3915	100.00%

The bold area, where $I > 0$, indicates knowledge overconfidence

knowledge); $I_{\text{knowledge deviation}} = 0$ reflects no knowledge deviation and includes two real situations: when subjective knowledge and objective knowledge are high or low at the same time (perfect alignment); $I_{\text{knowledge deviation}} > 0$ signifies that the participant's subjective knowledge exceeds their objective knowledge, which we define as "knowledge overconfidence." Notably, 57.78% of participants exhibited overconfidence (Table 5), and this phenomenon may stem from consumers' literal understanding of FDL. In our survey, we collected data on information channels by asking participants to report how they acquired the meaning of FDL and identified the main sources after collating the responses: literal understanding, popular science publicity, internet search, parents/family telling, and class learning. The channel analysis reveals that "literal understanding" (29.13% prevalence) dominates Chinese consumers' FDL comprehension, surpassing other sources.

Definition and measurement of food waste behavior and willingness

Building on the work of FAO (2011), we employ a similar definition of food waste from Cheng et al. (2025) that primarily concerns the discarding of edible food. In China, where the "quality guaranteed date" label is equivalent to the meaning of "best before date" (indicating food remains edible), discarding food near this date constitutes food waste behavior. We first use the first stage questionnaire (pre-intervention) to measure the baseline food waste behavior by asking participants to indicate the last consumption date for milk/cookies relative to the quality guaranteed date—the day before or after the quality guaranteed date, after which the food would be discarded. Response options spanned 16 consecutive days: − 5 to − 1 days (before expiration), 0 (on expiration date), and + 1 to + 10 days (after expiration). This design, adapted from Gong et al. (2022) and Li et al. (2024), captures consumers' tolerance window for near-expiration food. Further, we use the second stage questionnaire (post-intervention) to measure food waste willingness immediately following information intervention. Considering the information intervention happens immediately and the behavior after the intervention has not happen yet, we ask the participants to report their expected last consumption date to serves as a proxy for willingness to waste food. By comparing the actual food waste date (pre-intervention) and the expected food waste date (post-intervention), we interpret an

increase in this number (a later discard date) as indicating a prolonged intended food duration, meaning that more purchased food will be consumed rather than discarded, thus representing reduced food waste, which aligns with the definition established by Cheng et al. (2025). Using two-phase panel data, we evaluate intervention effects on waste willingness (results are shown in Table 4), we find that prior to the information intervention, both the intervention and control groups exhibit negative average food waste dates (mean < 0), indicating that most participants typically discard food before the quality guaranteed date. After the intervention, there was a significant change in the discard date in the intervention group, while no statistically significant difference in the control group. This preliminary finding suggests that the informational nudge effectively delays participants' intended food waste timelines.

Model specification and robustness tests

Analysis using first-phase cross-sectional data

Our empirical analysis comprises three key components. First, we examine the association between knowledge deviation (i.e., the discrepancy between subjective and objective knowledge) and actual food waste behavior. Since this analysis utilizes cross-sectional data from the pre-intervention baseline survey (Phase 1), we employ ordinary least squares (OLS) regression for estimation. The regression model is specified as follows:

$$FW_i = \beta_0 + \beta_1 I_{\text{knowledge deviation}_i} + \beta_2 X_i + \varepsilon_i \quad (2)$$

where $I_{\text{knowledge deviation}_i}$ represents individual i 's knowledge deviation index, calculated using Eq. (1); FW_i denotes participant's actual food waste date (pre-intervention); X_i is a vector of control variables including: participant's demographic variables, household variables, attitudes toward food date label, and food consumption habits (consistent with the variables in Table 2). Considering the limited empirical studies in the field of knowledge deviation, we refer to the studies of Yang and Jin (2022) and Buratto and Lotti (2023) to include the basic control variables. Further, considering that food waste is a resources issue, we added the resource perception to account for potential environmental consciousness effects on food waste behavior. Risk attitude accounts for the possibility that food waste may stem from risk avoidance tendencies. Since our study is based on FDL, consumers' dependence on FDL and their evaluation of its usefulness on FDL may have potential impacts. Considering food consumption habits are important predictors of food waste, we also include the food planning and freshness requirement in this study. ε_i is the error term.

To ensure the reliability of OLS regression findings, we conduct robustness tests through three approaches: (1) Sample restriction test. Recognizing potential heterogeneity in food consumption patterns, we retain the samples that do not consume milk or cookies and conduct regression based on the total sample of 4221 to exclude the influence of our choice of food types on the results. (2) Alternative variable changing test. To address potential nonlinearity in food waste behavior (the change in the date of consumer food waste may not be linear), which means the marginal effect of any two consecutive days may be different, we implement a threshold specification by transforming our dependent variable into a binary indicator. "0" if food was wasted on or before the

quality guaranteed date, and “1” if wasted after the quality guaranteed date to provide a more conservative test of consumer behavior. (3) Propensity Score Matching (PSM) analysis. PSM is a suitable method for reducing bias and controlling the effect of observable variables, thereby producing a quasi-random trial effect (Zhang et al. 2022). We constructed a dummy variable for knowledge overconfidence (indicating whether subjective knowledge exceeded objective knowledge) and the PSM method performing the nearest neighbor matching, caliper matching, and kernel matching to ensure balance between groups and address potential endogeneity concerns arising from selection bias.

Analysis using two-phase panel data

Second, to estimate the causal effect of our information intervention on consumers' objective knowledge and food waste willingness, we employ a difference-in-differences (DID) design. This quasi-experimental methodology, with roots tracing back to Snow's (1855) seminal study of London's cholera outbreak, has become the gold standard for policy evaluation in econometrics (Feng et al. 2021; Wang and Ge 2022). The DID framework treats our information intervention as a natural experiment, where the treatment assignment is plausibly exogenous to the outcome variables (Chen and Wu 2015). This approach offers two key advantages for our study: it accounts for time-invariant differences between the treatment and control groups, and controls for common temporal trends affecting both groups. Our identification strategy relies on two key sources of variation: within-group variation (pre- vs. post-intervention changes) and between-group variation (intervention vs. control group differences). The DID estimator effectively isolates the intervention's net effect by differencing out baseline differences between groups and eliminating contemporaneous shocks affecting all participants (Marianne et al. 2004; Wang and Ge 2022). The empirical specification is as follows:

$$OK_{it} = \alpha_0 + \alpha_1 \text{treat}_i \times \text{post}_t + \alpha_2 X_i + \lambda_i + \nu_t + \varepsilon_{it} \quad (3)$$

$$FW_{it} = \delta_0 + \delta_1 \text{treat}_i \times \text{post}_t + \delta_2 X_i + \lambda_i + \nu_t + \varepsilon_{it} \quad (4)$$

where OK_{it} represents participant's objective knowledge (pre- and post-intervention); FW_{it} represents the participant's actual food waste behavior (pre-intervention) and the food waste willingness (post-intervention); the index $t=0$ and 1 identifies a time series of data; treat_i is a dummy variable representing the intervention extracted from the survey; post_t denotes a time dummy variable, which captures the time effect of the intervention period. $\text{treat}_i \times \text{post}_t$ represents the real effect of the intervention. Our key interest is the coefficient α_1 and δ_1 , which represents the net intervention effect on objective knowledge and food waste willingness, respectively. λ_i represents the individual fixed effect, and ν_t represents the time fixed effect.

Finally, building on the methodological approach of Jiang et al. (2023), we employ a fixed-effects model with interaction terms to conduct further mechanism analysis—examining how subjective knowledge (SK_i) moderates the intervention's impact. Our key interests are the coefficients γ_1 and η_1 , which estimates the effects of the subjective knowledge on the objective knowledge and captures the moderating effect on food waste willingness change, respectively. μ_i is the unknown intercept for each participant.

$$OK_{it} = \gamma_0 post_t + \gamma_1 SK_i \times post_t + \gamma_2 X_i \times post_t + \mu_i + \varepsilon_{it} \tag{5}$$

$$FW_{it} = \eta_0 post_t + \eta_1 SK_i \times post_t + \eta_2 X_i \times post_t + \mu_i + \varepsilon_{it} \tag{6}$$

Results

The relationship between knowledge deviation and food waste behavior

Baseline regression and robustness tests results

Using cross-sectional data from the first stage of our panel survey, we estimate an OLS regression to examine how knowledge deviation influences food waste behavior. The results, presented in Column (a) of Table 6, indicate that a one-unit increase in the knowledge deviation index—reflecting every unit that subjective knowledge is higher than objective knowledge—is accompanied by an advancement of the food waste date (0.496 days earlier), reflected in reduced numerical values as defined in Sect. "Definition and measurement of food waste behavior and willingness", which indicate more food waste.

To ensure the reliability of our findings, we conduct robustness tests through three approaches: (1) Sample restriction test. Results presented in Column (b) of Table 6 demonstrate consistent effects, confirming the stability of our findings across different consumption patterns. (2) Alternative variable changing test. These regression results, shown in Column (c) of Table 6, yield qualitatively similar results while providing a more conservative test of consumer behavior. (3) PSM analysis. The common support condition is satisfied across all matching methods, as illustrated in Fig. 2a, c, e. Post-matching balance tests (Fig. 2b, d, f) demonstrate that the standardized bias for each covariate approaches zero, confirming the effectiveness of our matching procedure (Deng et al.

Table 6 Regression results of the relationship between knowledge deviation and food waste behavior

Variables	(a) FW ₁	(b) FW ₁	(c) FW ₂	(d) FW _{1-N}	(e) FW _{1-C}	(f) FW _{1-K}
<i>Deviation index₁</i>	- 0.496*** (0.085)	- 0.492*** (0.081)	- 0.048*** (0.013)			
<i>Deviation index₂</i>				- 0.473*** (0.114)	- 0.518*** (0.098)	- 0.520*** (0.098)
Control variables	YES	YES	YES	YES	YES	YES
Constant	- 0.256 (0.648)	- 0.268 (0.627)	0.283*** (0.099)	0.012 (0.687)	- 0.119 (0.644)	- 0.209 (0.649)
ATT	/	/	/	- 3.28	- 5.00	- 4.98
R-squared	0.077	0.080	0.045	0.067	0.074	0.075
Observations	3915	4221	3915	3299	3912	3913

Robust standard errors in parentheses. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. To ensure the robustness of our benchmark regression results, we conducted the following diagnostic tests and alternative specifications: (1) Multicollinearity test. The mean variance inflation factor (VIF) is 1.28 in baseline regression, with a maximum VIF of 1.68, confirming no severe multicollinearity concerns. (2) Regression specifications. Column (a): baseline OLS regression, Column (b): robust regression (full sample), Column (c): robust regression with a binary-transformed dependent variable. (3) PSM robustness Checks. Column (d): Nearest-neighbor matching (N), Column (e): Caliper matching (C), Column (f): Kernel matching (K). The control variables are consistent with those in Table 2

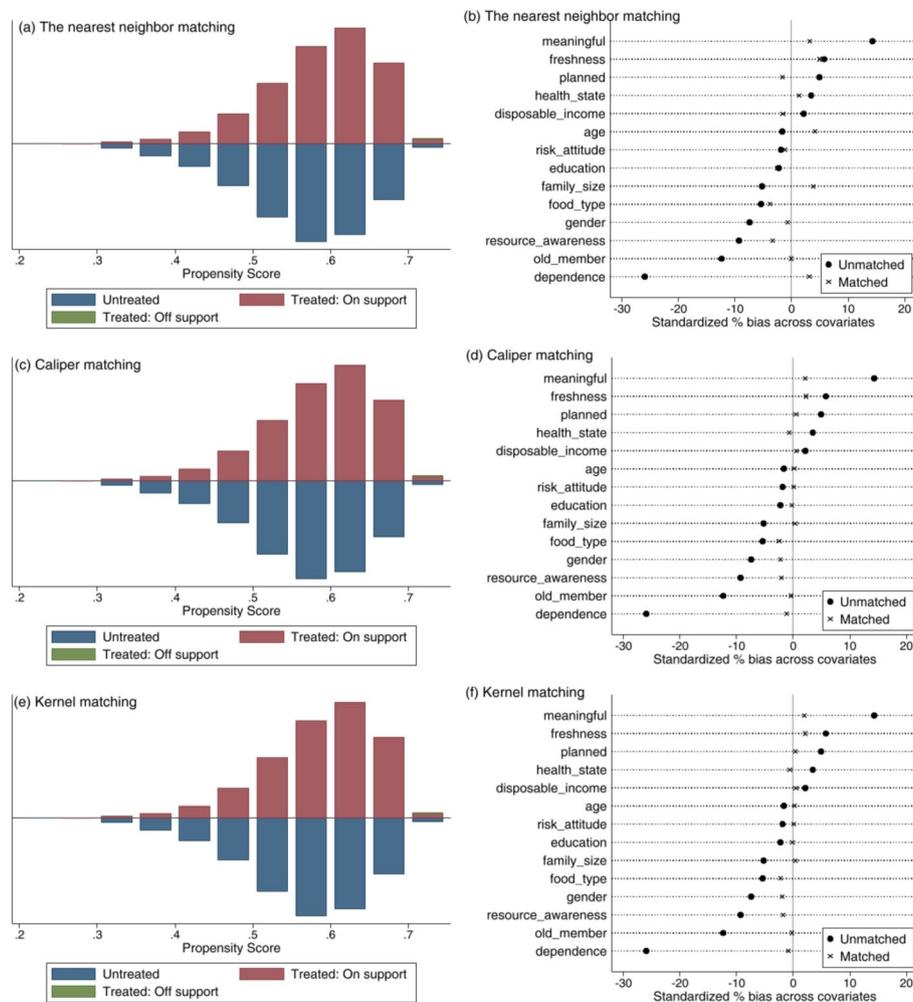


Fig. 2 Common support domains (a, c, e) and matching results (b, d, f)

2024). Subsequent regression analyses using the matched samples (Table 6, columns (d–f)) yield consistent results, further validating the robustness of our findings.

Heterogeneity analysis

We further explore the potential heterogeneity of this relationship between knowledge deviation and food waste across different population groups. Our investigation focuses on three dimensions. (1) *Regional differences*. Existing research has suggested that consumers in different countries exhibit varying knowledge of FDL due to differing national regulations (Neff et al. 2019; Cheng et al. 2025). This inspired us to explore—given China’s vast geographical and cultural diversity—whether regional differences also exist in the relationship between knowledge deviation and waste under the same FDL definition nationwide. By dividing the regions, we conduct new regressions, and results (columns (1–3) in the Table S1) show that this relationship is statistically significant across all three regions, indicating that the association between knowledge deviation and food waste is a widespread problem throughout China, underscoring its severity. (2) *Education levels*. Given that existing research has established a correlation between higher education

levels and better knowledge of food labels (Machín et al. 2018; Packer et al. 2021), we examine whether the relationship between knowledge deviation and food waste varies by education level. We categorize participants' education levels into a binary variable based on whether they have obtained a bachelor's degree or higher and conduct separate regressions. The results reveal that this phenomenon exists in both education groups and has a stronger impact among higher educated individuals, possibly due to their greater tendency toward knowledge overconfidence. (3) *Gender*. Given that Van Boxssteel et al. (2014) found no significant gender differences in objective FDL knowledge, we further examine how knowledge deviation affects the relationship between knowledge deviation and waste from the perspective of gender heterogeneity. Through conducting subgroup analyses stratified by gender, the regression results demonstrate that the relationship is also consistently significant in both genders.

Effects of the information intervention experiment

Building on empirical evidence of knowledge overconfidence's negative impact on food waste, we implement an information intervention experiment to recalibrate consumers' understanding of the quality guaranteed date label. The intervention significantly enhances consumers' objective knowledge of the quality guaranteed date label and extends the intended food retention duration, demonstrating its potential as a food waste mitigation strategy. (1) *Objective knowledge improvement*. Accuracy in understanding quality guaranteed date label rises from 20.39% to 64.77% in the intervention group, and the DID analysis confirms a net intervention effect of 0.465 on objective knowledge (Table 7, column (a)), empirically validating the intervention's efficacy. (2) *Behavioral impact*. The proportion of food waste on and before the quality guaranteed date decrease from 68.24 to 56.10%, and the DID model estimates demonstrate that the intervention significantly extends the anticipated food waste date by 1.483 days (reflected in increased numerical values of waste willingness as defined in Sect. "Definition and measurement of food waste behavior and willingness"), indicating a reduction in food waste willingness (Table 7, column (b)), which offers empirical support for global food waste interventions. These findings, originally published in Cheng et al.

Table 7 The regression result of the DID and fixed effect models

Variables	(a)	(b)	(c)	(d)	(e)	(f)
	OK	FW ₁	OK	FW ₁	OK	FW ₁
<i>did</i>	0.465*** (0.018)	1.483*** (0.141)	/	/	/	/
<i>post</i>	/	/	0.444*** (0.013)	1.491*** (0.074)	0.186 (0.181)	-0.981 (1.001)
<i>Subjective knowledge*post</i>	/	/	/	/	-0.051* (0.030)	-0.401** (0.175)
Constant	-0.088 (0.065)	-1.046** (0.499)	0.204*** (0.007)	-0.158*** (0.037)	0.204*** (0.006)	-0.158*** (0.037)
Control variables	YES	YES	YES	YES	YES	YES
<i>R</i> -squared	0.221	0.095	0.353	0.163	0.391	0.183
Observations	7830	7830	4150	4150	4150	4150

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. "OK" is short for "objective knowledge"

(2025), are summarized here due to their foundational relevance to our study. We omit further robustness or heterogeneity tests, and full methodological and analytical details are available in the cited work.

The hindering effect of subjective knowledge

Baseline regression results and robustness tests

Building on our team's prior research, we further examine the role of subjective knowledge in the intervention experiment. Our results reveal that subjective knowledge significantly undermines the effectiveness of information intervention—a finding that warrants greater attention in food waste reduction strategies. To assess how consumers' subjective knowledge influences their objective knowledge and food waste willingness, we employ a fixed-effects model. Baseline regression results (Table 7, column (c–d)) establish the intervention's initial effects, while models incorporating interaction terms (Table 7, column (e–f)) demonstrate the hindering role of subjective knowledge. Specifically, subjective knowledge weakens the intervention's impact on improving objective knowledge and similarly reduces the intervention's effect on lowering food waste willingness. To avoid bias in the results caused by the selection of food types, we validated the robustness of this finding in a larger sample using the same method as the sample restriction test in Sect. "[Baseline regression and robustness tests results](#)", and the results are presented in Table S2.

Heterogeneity analysis

Consistent with the analytical approach in Sect. "[Heterogeneity analysis](#)", we examine potential heterogeneity in the results across populations by investigating three dimensions below. (1) *Regional differences*. The subjective knowledge of consumers in western regions significantly hinders the impact of information on their label objective knowledge (as shown in Table S3). This not only helps us identify the most critical area, but also indicates that it could be prioritized as a pilot region for addressing this issue. (2) *Education levels*. Here, we find that the hindering effect of consumers' subjective knowledge on both label objective knowledge modification and food waste willingness reduction is more pronounced among highly educated groups (as shown in Table S4–S5). Contrary to the conventional assumption that individuals with higher education levels possess greater knowledge (Vera Cruz et al. 2024), our results highlight the severity of this issue among such populations, revealing a counterintuitive phenomenon that underscores the need for targeted interventions. (3) *Gender differences*. Although the association between knowledge deviation and food waste behavior is significant in both genders, the results presented here (see Table S4–S5) demonstrate that females' subjective knowledge exerts a more significant hindering effect on both label objective knowledge modification and food waste willingness reduction. This finding provides actionable insights for developing targeted and cost-effective interventions.

Discussion

This study provides a comprehensive investigation into how consumer knowledge deviation regarding FDL—specifically, subjective knowledge exceeding objective knowledge—exacerbates food waste behavior. We further evaluate the effectiveness of an information

intervention designed to address this issue and uncover the significant hindering role of subjective knowledge on intervention outcomes. Integrating our key findings with the existing literature, this discussion highlights the theoretical contributions and practical implications of our research.

Further exploration of the results

Knowledge deviation and food waste: pervasiveness and heterogeneity

Our core finding establishes a significant positive relationship between FDL knowledge deviation and increased food waste behavior (Table 6). Consumers who overestimate their FDL knowledge are more likely to discard food prematurely based on misplaced confidence, leading to waste. This finding introduces a crucial psychological driver into food waste research, complementing prior studies focused on objective knowledge in food waste (Kosa et al. 2007; Kavanaugh and Quinlan 2020). Notably, this relationship holds across all regions in China (East, Central, West; Table S1), demonstrating its pervasiveness as a nationwide challenge rather than a localized issue. Although studies by Neff et al. (2019) and Aschemann-Witzel et al. (2019) in a single country context reveal differences in objective knowledge of FDL knowledge, our study uniquely reveals the widespread impact of knowledge deviation on waste within a single country under uniform regulations.

Heterogeneity analysis reveals nuanced patterns: Despite the established correlation between higher education levels and better objective label knowledge (Machín et al. 2018; Packer et al. 2021), the negative impact of knowledge deviation on waste was significantly stronger among highly educated individuals (Table S1). This counterintuitive finding suggests that greater cognitive resources may paradoxically foster stronger knowledge overconfidence and thus increase susceptibility to biased judgments and subsequent waste, consistent with research on the overconfidence trap among high-ability individuals (Ehrlinger et al. 2008). Furthermore, although Van Boxtael et al. (2014) found no significant gender difference in objective FDL knowledge, our results confirm that knowledge deviation significantly drives food waste behavior in both males and females (Table S1), emphasizing the critical role of subjective knowledge in understanding behavioral outcomes.

The hindering effect of subjective knowledge: a key intervention challenge

Another critical and novel finding is the significant hindering effect of consumers' subjective knowledge on the intervention's success (Table 7(c–f)). Consumers with high pre-existing subjective knowledge show significantly smaller improvements in objective knowledge and weaker reductions in waste willingness following the intervention compared to those with lower subjective knowledge. This indicates that strong prior beliefs create a barrier, hindering the effective absorption and application of information, which is similar to the findings of studies based on the public's factual misunderstandings about politics (Nyhan and Reifler 2010).

Heterogeneity analysis offers deeper insights: The hindering effect of subjective knowledge on objective knowledge modification is particularly pronounced among consumers in western regions (Table S3), highlighting this region as a priority for intervention. Mirroring the pattern seen with knowledge deviation's impact, the hindering effect is

also significantly stronger among highly educated consumers (Tables S4–S5). This reinforces the “double-edged sword” nature of education in this context. While associated with greater knowledge resources (Vera Cruz et al. 2024), the accompanying strong subjective knowledge creates a significant barrier to knowledge updating, demanding targeted strategies to overcome overconfidence. An important gender difference emerged: Although knowledge deviation affected both genders equally, females’ subjective knowledge exerted a significantly stronger hindering effect on both knowledge updating and behavioral change (Tables S4–S5). This may stem from women’s often more central role in household food management (Daniel 2016), potentially reinforcing confidence in their food-related knowledge. Interventions targeting women may thus require greater emphasis on correcting misunderstanding.

Theoretical and practical implications

Our findings systematically reveal FDL knowledge deviation as a key psychological driver of household food waste, validate the effectiveness of targeted information interventions in improving knowledge and reducing waste willingness, and crucially identify subjective knowledge as a major barrier to intervention success. This offers significant theoretical and practical contributions. Theoretically, these findings empirically validate Yang and Jin’s (2022) theoretical framework of consumer resistance to scientific knowledge through three advancements: First, we demonstrate that knowledge overconfidence predicts reduced receptivity to corrective information. Second, we quantify how this cognitive bias significantly impairs the effectiveness of science communication. Third, we establish these findings in the critical context of food waste reduction. These insights suggest that current intervention designs require fundamental adaptation to account for and overcome this documented resistance mechanism.

Practically, given the critical role of the information intervention in reshaping consumer label knowledge and reducing food waste, timely and effective science popularizing is urgently needed to correct misunderstandings and mitigate overconfidence in understanding the food date label. The key challenge lies not only in capturing consumer attention but also in devising engaging ways to disseminate this knowledge—particularly among those who assume they already understand the meaning of the date label and thus dismiss further engagement. A crucial first step may be to make consumers aware of potential gaps in their label knowledge with some communication campaigns to enhance the effectiveness of outreach efforts. Our study, conducted in China, a representative transition economy, reveals that, like advanced economies, such nations must also address the significant food waste stemming from food date label misunderstanding. When formulating food date labeling policies, it is essential to not only draw on the established frameworks and experience of advanced economies but also to assess domestic consumers’ cognitive status/biases and implement targeted measures to prevent misunderstandings and subsequent food waste.

Limitations and future directions

Our study has several limitations that warrant discussion. First, while we examine the food date label using the general term “quality guaranteed date” prevalent in the Chinese market, this approach does not account for potential variations in consumer

understanding across different food date label expressions and types (e.g., “best before” vs. “use by”). Future research could focus on comparative studies of consumers’ subjective and objective knowledge situations regarding various expressions or types of other food date labels, as well as knowledge deviation patterns. Second, like most research in this field, we use self-reporting methods to assess the food waste behavior. However, it has been pointed out that the weaknesses of self-report measures of food waste may be accompanied by measurement errors (results lower than the actual value) (Talwar et al. 2022). Given the constraints of human resources, financial resources, and logistical difficulty, we chose the more operable online survey with a larger sample size, representing a necessary trade-off between scale and measurement precision. Further offline investigation in the future can improve the accuracy of the research results and obtain the actual waste behavior based on the direct waste measurements rather than memory-based value or willingness. Third, the urban focus of our sampling frame limits generalizability to rural populations, where Internet usage frequency and consumption patterns may differ substantially. In the future, research based on samples from rural areas is another direction. Last but not least, while we identify these key intervention effects, the mechanisms underlying information effectiveness likely involve multiple unexplored factors. For instance, the influence of factors such as consumers’ habitual food consumption patterns and their food date labels dependence throughout the process of label understanding, intention and actual behavior modifications warrants further in-depth investigation. Finally, given the habitual nature of consumers’ food management behaviors (Jabs and Devine 2006), the long-term effects of interventions on food waste actual behaviors warrant further investigation. Future research could track the long-term persistence of intervention effects and explore ways to translate knowledge gains into sustained habits, possibly using reminders, incentives, or convenience measures. Also, the psychological mechanisms underlying the moderating effect (e.g., information processing, trust) also merit deeper investigation.

Conclusions

Our study reveals a deviation between consumers’ subjective and objective knowledge of the most common and unified expression “quality guaranteed date” in China and examines its influence on food waste. By quantifying the net effect of the information intervention, we demonstrate how subjective knowledge may counteract global food waste reduction efforts. The main findings are as follows: There is widespread overconfidence in food date label knowledge. 57.78% of consumers overestimated their understanding of the label (“knowledge overconfidence”), exacerbating food waste behaviors. Corrective information improves consumers’ objective knowledge and extends perceived food durability. Despite these benefits, consumers’ subjective knowledge weakens intervention effectiveness, posing a persistent barrier to food waste mitigation. Moreover, this hindering effect demonstrates significant heterogeneity across regions, educational levels, and gender groups, suggesting the necessity of developing targeted interventions to address this issue.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40100-025-00431-0>.

Supplementary Material 1

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Author Contribution

Cheng: Formal analysis; Data curation; Methodology; Writing—original draft; Writing—review & editing. Gu: Software; Writing—original draft; Writing—review & editing. Ren: Writing—review & editing; Funding acquisition. Jiang: Formal analysis; Writing—review & editing. Zhao: Writing—review & editing; Supervision; Funding acquisition; Project administration.

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Data availability

The data came from the survey conducted by the research team and will be made available upon request.

Declarations

Ethics approval

Approval was obtained from the ethics committee of Northwest A&F University. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent to participate

No identifying personal information was gathered about the participants, given the data was received anonymously from the research company organizing the consumer panels. Informed consent was obtained from all individual participants included in the study. Only adult participants were included.

Competing interest

The authors declare no competing interests.

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