



Expiration date label knowledge and food waste reduction: a synthesis and critical evaluation of policy recommendations

János Szenderák , Dániel Fróna ^{*}, Mónika Rákos

University of Debrecen Faculty of Economics and Business, Hungary

ARTICLE INFO

JEL classification:

Q01
Q18
Q53

Keywords:

Expiration date labels
Food waste
Consumer habits
Natural resources

ABSTRACT

Expiration date labels are fundamental policy tools; however, the information presented on these labels is often misinterpreted, resulting in the discarding of otherwise edible food. The confusion surrounding expiration date labels leads to unnecessary food waste and increases the pressure on natural resources. This research reviewed consumer understanding of expiration date labels and synthesized the policy recommendations. We found that consumers frequently experienced confusion about expiration date labels, and their interpretation was affected by contextual factors. Knowledge and understanding of expiration date labels varied considerably, while the range of policy proposals was relatively narrow, suggesting a restricted policy space. Consumer education and information campaigns were among the most common policy recommendations, despite their modest efficiency in altering consumer behavior. Standardizing expiration date labels and altering their physical appearance may enhance the efficiency of information transfer; however, the individual risk perception of different products must be taken into account. However, the limited scope of policy proposals can significantly hinder the effectiveness of resource management policies. Therefore, understanding real-life consumer habits and waste behavior when designing product- and region-specific policy responses is essential for enhancing sustainability efforts. Finally, we propose a simplified framework for possible policy interventions.

1. Introduction

Food consumption has increased dramatically in recent decades (Willett et al., 2019), with a considerable environmental impact (Searchinger et al., 2019). Food loss and waste have become major environmental issues, accounting for 8%–10% of global greenhouse gas emissions and taking up the equivalent of nearly 30% of global agricultural land. Approximately 1.05 billion tons of food were wasted globally in 2022 (132 kg/capita/year), representing 19% of the food available to consumers at the retail, food service, and household levels. Households were responsible for 60% of all food wasted (79 kg/capita/year) (UNEP, 2024). Food waste has been a key concern of the United Nations' Sustainable Development Goals (SDGs) (UN 2015), and interest in circularity principles in the food sector has been growing (Zhang et al., 2022). Global and European food policies aim to halve the per capita food waste by 2030, integrating food loss and waste policies in other European Union (EU) policies, in which misunderstandings and misuse of expiration dates play a prominent role (European Commission 2020). In the EU, 10% of annual food waste is attributed to expiration

date markings (European Commission 2018).

Expiration date labels are key policy tools for informing consumers and are present on virtually all food products worldwide. Most consumers use label information at least occasionally when deciding whether to buy or eat food (Turvey et al., 2021). Accessing more information about food products reduces information asymmetry, which arises because producers typically have more knowledge about food quality than consumers do. It was early recognized that this situation can easily create suboptimal resource allocation, which requires interventions (Akerlof, 1970; Zilberman et al., 2018). They are also widely used by food manufacturers (Kavanaugh and Quinlan, 2020) and are important in informed decision-making. However, consumers often misunderstand or are confused by expiration date labels (European Commission 2018; Turvey et al., 2021; D. Patra et al., 2022), which may result in discarding otherwise edible food (Neff et al., 2019). Providing label information serves various functions, from informing the consumer to preventing information overload or empowering the consumer by enabling them to express their value system through product choices (Asioli et al., 2020). However, considerable variation has been found in

* Corresponding author.

E-mail addresses: szenderak.janos@econ.unideb.hu (J. Szenderák), frona.daniel@econ.unideb.hu (D. Fróna), rakos.monika@econ.unideb.hu (M. Rákos).

date label practices, even within the EU, where identical products had different labels in different member states, ranging from exchanging “Best before” and “Use by” labels to varying storage and open life advice (European Commission 2018).

Achieving large-scale behavioral shifts is one of the most significant challenges of sustainability science (Schill et al., 2019); however, food waste-related behavior is not well understood, despite expiration date labels being an integral part of everyday consumption. Food waste reduction is socially, culturally, and technologically important (Santagata et al., 2021). It is considered a “win–win” solution due to its benefits for consumers, businesses, and the environment (Read and Muth, 2021). Although food waste is receiving growing attention, there are still areas with a generally low understanding, and policy tools to date have been largely ineffective in providing a viable solution. Food waste is a highly complex and multifaceted issue driven by different consumer behaviors (Schanes et al., 2018). Significant gaps in the data exist regarding food waste estimates, particularly in low- and middle-income countries (Hermanussen and Loy, 2024). Additionally, the food sector has high social and economic relevance and is more complex than other supply chains (Mehmood et al., 2021). Still, the costs and potential benefits of interventions to reduce food waste have not been fully understood (Read and Muth, 2021). Although informational interventions have dominated existing approaches (Jiang et al., 2024), it is important to analyze potential solutions rather than focusing on the current situation (Wang et al., 2021). Furthermore, no consensus exists regarding the association between sociodemographic variables and date label confusion (D. Patra et al., 2022). This study examines the relationship between consumer knowledge of expiration date labels and synthesizes literature-based policy recommendations. Our results suggest that consumers frequently misunderstand basic expiration date label information, albeit with considerable heterogeneity. The limited range of policy proposals suggests there is little policy space for maneuvering. These results also raise concerns about the effectiveness of adding more complex sustainability-related label information.

2. Methods

The Scopus and Web of Science (WoS) databases were systematically searched because they contain peer-reviewed research published in high-quality journals. The search yielded 186 studies (86 from Scopus and 100 from WoS). Only empirical studies focusing on date labels and food waste were included in the research. Gray literature, which is not peer-reviewed, was excluded from the search. The search criteria are illustrated in Table 1 and Fig. A.1.

General keywords were chosen to include all relevant studies. Different search strings may yield slightly different results, but more

Table 1
Search criteria.

Search Criteria	Web of Science (WoS)	Scopus
Keywords	food* AND wast* AND date AND label*	
Search type	All Fields	Article title, abstract, and keywords
Year	all available	
Languages	English	English
Inclusion criteria	Focus on the interaction of date labels, consumer understanding, and food waste. Studies published in peer-reviewed journals. Empirical studies.	
Exclusion criteria	No relevant empirical features. Conference papers, abstracts, and educational papers. Reviews and essay-type articles.	

Note: * denotes a wildcard. The search criteria were defined broadly to maximize inclusivity. Studies were included based on predefined inclusion criteria, while those that matched any exclusion criteria were excluded from further analysis.

Source: Authors’ own collection (2025).

specific keywords did not appear to extend the search results. Because several studies have proposed similar ideas and results, we present the conclusions that provide additional information. A similar approach was followed when synthesizing the policy recommendations. A transparent search and synthesis process was followed, allowing for comparison with different systematic review strategies as well. All three authors have participated in the inclusion and exclusion process, as well as the critical evaluation of the studies.

The R software was used to synthesize the literature and conduct an initial duplication check. The titles and the abstracts were reviewed and duplicates checked using the R package “revtools” (M.J. Westgate, 2019; M.J. Westgate, 2019). The first author performed the algorithmic search process and duplication removal, and then all authors screened and critically evaluated the remaining studies. During data cleaning, 41 duplicate studies were removed automatically, and 31 were removed manually. Additionally, five studies were unavailable, 53 were removed due to the topic choice, five were not available to the authors, four were literature reviews, and one was an unavailable book chapter. Finally, 51 studies were selected and synthesized.

3. Results and discussion

Most studies were conducted on samples from the United States (U. S.), while a significant proportion of the remaining studies focused on EU member states. Food waste is primarily concentrated in wealthier regions, resulting in more research from these regions. Unsurprisingly, the “Best Before” and “Use By” labels were the most frequently analyzed, as they are the most commonly seen on store shelves. Specific labels were also examined in some cases, but their presence was minimal. The analyzed studies focused predominantly on dairy products, eggs, fruit, and meat, which are items that could be the subject of policy interventions for various reasons. First, these products have relatively short shelf lives, making them more likely to be discarded early. Moreover, the spoilage of perishable products is easily detectable through sensory observation, which can pose significant health risks. While common themes were identified in the analyzed studies, particular observations may offer valuable policy insights (Table A.1. and Fig. A.2.). The main themes are discussed in greater detail in the following section.

3.1. (Mis)understanding of food labels

A frequent theme in the literature is the lack of understanding of label meanings, where consumers did not understand or were confused about the meaning of different labels. Most research has consistently found that consumers confuse quality indicators with food safety indicators (Kavanaugh and Quinlan, 2020; D. Patra et al., 2022; Shamim et al., 2022). In a few cases, consumers were highly confident in their incorrect impressions (Turvey et al., 2021), further aggravating the information bias.

Over 80 % of consumers in the U.S. used date labels, but only two-thirds correctly identified the definitions of “Expiration date” and “Sell-by date.” The labels “Best by” and “Use by” appeared to be confusing (Kavanaugh and Quinlan, 2020). Another U.S. research study found that over 98 % of respondents used these labels at least sometimes for decision-making, and most respondents also believed they knew how the labels should be interpreted. However, the general meaning of the “Best If Used By” and “Use By” labels was understood only by 64.0 % and 44.8 % of the respondents, respectively, and even fewer understood their specific meanings (Turvey et al., 2021). Additionally, 70 % of respondents agreed that discarding food after the package date has passed reduces the risk of foodborne illness. In comparison, nearly 60 % agreed that some food waste was necessary to ensure meals tasted fresh (Qi and Roe, 2016). Similarly, 84 % of U.S. consumers discarded food on a date near the package date. While label wording was generally correctly perceived by consumers, substantial confusion existed about federal label regulations, with more than half of the consumers being incorrect

or unsure (Neff et al., 2019). Other research in the U.S. supported these results. Furthermore, respondents felt that consuming foods after the expiration date indicated on the labels was unsafe (D. Patra et al., 2022). Among U.S. college students, milk labels also served primarily as indicators of safety. In most cases, the “freshness” theme dominated the labels’ description, and most respondents would discard expired milk (Connors and Schuelke, 2022). In the U.S., the “Use by” labels generated the most significant value of predicted waste, as it was suggestive of food safety concerns; however, waste behavior depended on the product (Wilson et al., 2017). Additionally, the expiration date label effect of food waste reduction was also heterogeneous across products (Rickard et al., 2022). In other regions, such as Peru and Brazil, leftover management practices were similar, with the expiration date being the primary factor in determining whether to consume or discard food items. However, Brazilian households also take the state of food preservation into account. It was shown that despite planning efforts, sales and promotions affected purchasing behavior (Cequea et al., 2021). In Australia, the perception of safe consumption after the “Best before” date was negatively associated with all food waste categories, and possible misconceptions about the “Best before” date labeling and quality preferences significantly contributed to household food waste. Additionally, behavioral tendencies, such as overprovisioning or a preference for consuming the freshest possible food, lead to greater food waste (Ananda et al., 2022). In India, despite not understanding the label information adequately, most consumers frequently used it, confusing quality and safety indicators (Shamim et al., 2022).

Food waste behavior in the EU was also associated with the frequency of checking and understanding the date labels. However, Western, Eastern, and Mediterranean Europe attached different degrees of importance to date labeling for consumption decisions (Toma et al., 2020). In Belgium, approximately 80 % of consumers were familiar with the labels “Use By” and “Best Before,” with 70 % indicating they understood the difference in meanings, while 30 % were unsure about the distinction (Van Boxstael et al., 2014). In Denmark, dairy products close to the “Best before” date were rejected by some consumer segments due to health concerns, low-quality perception, and an unappetizing appearance. These results contrast with other findings that the actual drivers of consumers’ willingness to purchase dairy products were their level of risk perception and food disgust sensitivity, not their level of knowledge (Melgaard et al., 2024). Research in Poland also found surrounding “Use by” and “Best before” labeling, with a strong product dependency and dissonance between consumer attitudes and behavior. Milk had the highest health risk when considering expired “Use by” dates, although 51 % of respondents still considered consuming it (Ankiel and Samotyja, 2020). Another study from Poland found that the respondents similarly interpreted the meaning of the “Best before” and “Use by” dates. Nearly 43 % of respondents believed that these indications mean the same thing, whereas 21 % were unsure. Nearly 40 % of respondents believed the term “Best before” meant the date when a product becomes unsafe for consumption or loses its quality (Bilska et al., 2020). Approximately 40 % of respondents in Greece misunderstood the meaning of food date labels, despite most reporting that they planned their food purchases. Most respondents considered waste prevention a significant issue, yet 40 % still discarded food after the “Best before” date (Abeliotis et al., 2014). In Lithuania, planning practices and knowledge of date labeling were found to be associated with less food waste. Greater food waste was linked to impulse buying, improper food preparation practices, nonconsumption of leftovers, indifference toward food waste, and concerns about food poisoning (Eičaitė et al., 2021). A Norwegian study found that most participants understood the difference between the “Best before” and “Use by” labels, while the date was “a trigger for food waste.” This implied that uncertainties about risk assessment often resulted in food waste. Respondents often implemented additional knowledge, such as using sight, smell, or taste to assess the products. Although this may reduce uncertainty about food risk and quality, it was weighed against nonperceptible (microbes and

pathogens) or hard-to-assess factors (Hebrok and Heidenström, 2019).

Sociodemographic factors and product types can affect how labels are interpreted. In the United Kingdom (UK), elderly (>60 years old) respondents were less overtly anxious about date labels. However, they were more careful with the “Use by” date in the case of specific food products (especially meat). This implied that so-called “common-sense” rules were applied frequently, often outweighing “expert” rules (Dickinson et al., 2014). In Italy, older people were also less likely to discard food that was labeled without “Best before” dates (Secondi, 2019). Additionally, age also affected the willingness to buy dairy products close to the expiration date and discard expired food (Melgaard et al., 2024; Thompson et al., 2018). In the U.S., the effects of education and age were also significant. Additionally, special groups, such as parents, may have different discard behavior because they are primarily concerned with nutrition and food safety (Wilson et al., 2018). Habitual behaviors related to discarding expired products were also observed in Scotland (Thompson et al., 2018), which was less emphasized in the literature but may have far-reaching consequences for policy effectiveness.

3.2. The role of sensory assessment

Most of the research indicates that consumers are cautious, often discarding food on a “just in case” basis, even if the food is perfectly edible. Plasil (Plasil, 2020) noted that the “date label is constantly consciously made into a cause for waste.” This is because the shelf life is typically shorter than in real life in a competitive market, due to the risk-avoidant strategies of producers or retailers. Consumers often rely more on label information than their senses, leading to the disposal of products after expiration. This also means that products are not consumed until the end of their natural life (Plasil, 2020).

In a U.S. field experiment, expiration dates indicated a quality standard for consumers and significantly influenced the perceived freshness of food. Interestingly, product quality was assumed to decrease monotonically as time passed when the expiration date was not visible. The product was initially perceived as more acceptable when an expiration date label was present. However that perception changed quickly once the expiration date had passed to levels more consistent with what they would perceive if the expiration date were not present (Li et al., 2020). In another U.S. experiment, subjects smelled milk in containers with and without a sell-by label date, and the intention to discard was higher in the case of milk with a sell-by date. This indicates an altered discard rate of milk compared to situations where consumers had to rely on their senses to determine product quality (Roe et al., 2018). Research in the UK found that consumers were heavily reliant on either expiration date or their senses when making decisions about food, which could be aided by including smart labels (Barone and Aschemann-Witzel, 2022). Another U.S. study found that labels served as indicators of quality and safety in the case of yogurt, while confusion about the labels increased food waste. Willingness to consume was not affected by the wording of the date labels after adjusting for quality and safety. Furthermore, the intention to eat a product increased significantly after informing consumers that the product had the proper color and was stored correctly. However, this does not imply that the policy should be to allow consumers to rely on their senses (Gong et al., 2022). In Belgium, judging the edibility of food products at home occurred mainly by checking visually and smelling (>80 %), followed by examining the shelf-life date (approximately 67 %) or tasting (approximately 50 %) (Van Boxstael et al., 2014). An Italian experiment with lettuce found that visible expiration dates dramatically affected consumers’ decisions to waste food. When lettuce was stored at 12 °C, only 12 % of the packages without expiration dates were estimated to be wasted; this increased to 27 % when the expiration date was visible. These percentages were lower when the expiration date was not reported (Alongi et al., 2019).

In Poland, consumer rejection of food products was significantly influenced by the date type (“Best before” vs. “Use by”), freshness

labeling, and food category as the product approached the expiration date. Interestingly, irrational consumer behavior was observed regarding edibility, which manifested in both the acceptance of potentially harmful food products and the rejection of edible foods (Samotyja and Sielicka-Różyńska, 2021). Another Polish research study evaluated the impact of “Best Before” dates on expected liking of food. Although “Best Before” dates were found to reduce consumer uncertainty regarding food edibility and maintain the consumers’ positive attitudes toward fresh products, they have also contributed to the waste of otherwise safe and edible food (Sielicka-Różyńska and Samotyja, 2023).

Research in the U.S. found that most participants (82 %) checked the expiration date when purchasing milk, and approximately 80 % always chose the date that was farthest out. However, this seems to be somewhat contradicted by the fact that consumers did not prefer fresh over milk that was close to the expiration date on blind tasting; neither did educational messages about code dates increase the consumer value of milk. This implies that even after a sensory experience and educational message, expiration dates were valued more than superior taste, and consumers responded to code dates even without properly understanding them (Paterson and Clark, 2020). In Pakistan, labeling dates and wrong package sizes were among the main reasons for food waste. In the case of processed food, the unawareness of respondents of expiration dates (50 %) was the leading reason behind waste (Khalid et al., 2019). A “refrigerator-based study” in the U.S. showed that utilization of refrigerated food was affected by food-related routines, such as refrigerator cleaning frequency, grocery shopping duration, and frequently checking nutrition labels. Physical and institutional signals of food safety and quality influenced the decisions to discard food, with unclear date labeling affecting the likelihood of a food item being fully utilized (Davenport et al., 2019) the most. In Germany, complex psychological and habitual elements affected the consumption of expired foods (Schmidt, 2019). Other research also confirmed that disposing of products past expiration dates had a strong habitual element (Thompson et al., 2020). Also, experimental methods have shown that food evaluation and ambivalence were affected by expiration date labels (Buttlar et al., 2021). Habitual elements were less prominent in the literature yet appear essential to understanding the full scale of the problem.

3.3. Physical qualities

Some researchers were also concerned with the physical qualities of the labels and food packages. In the U.S., date label standardization was among the most supported food waste solutions (Fan et al., 2022). However, eye movement experiments with milk labels in the U.S. found that expiration dates received significantly more attention than the labels themselves. This suggests that the decision to discard milk is closely tied to the actual expiration date rather than the wording on the label. This questions the effectiveness of label changes in altering discarding behavior (Badiger et al., 2023). Additionally, the expiration date communicated most of the meaning in the UK and the U.S., and consumers derived no additional meaning from the text on food safety or quality. Date labels more suggestive of food safety were associated with a higher percentage, while freshness indicators were associated with reduced food discard rates. Product heterogeneity was substantial, and protein products were more easily discarded, whereas processed food items were less likely to be discarded (Weis et al., 2021). In Germany, supporting results were found. Education about expiration dates did not affect consumer valuation of durable foods (D’Amato et al., 2023). In Poland, the younger generation was more concerned with interpretation, while the older generations experienced technical obstacles (such as font size, the presence of information, the label’s readability and accessibility) and misunderstanding the two date types based on food quality and safety concept (Samotyja, 2021). However, date label meanings can vary by product and across attributes (such as nutrition, quality, safety, and taste), affecting the expected response to a policy change. Simplifying date labels to only “Use by” and “Best by” may help

clarify the meaning of the date labels and decrease food waste. Additionally, it may be beneficial to remove “Use by” from products with a long shelf life (Wilson et al., 2018). In Czechia, changing the labels was considered to reduce the confusion caused by labels. Changing the “Best before” date to the date of the highest quality was widely accepted among all sociodemographic groups, although it did not have a clear connection to consumer preferences (Dordevic et al., 2020).

It is not clear how consumers would respond to not having labels. An Italian study analyzed the effect of removing “Best before” labels and found strong regional, age, and household size-related differences in responses. Older respondents who mainly resided in southern regions were more likely to use sensory assessment in a scenario in which the “Best before” label was missing (Secondi, 2019). In addition to product heterogeneity, these results highlight the important role of the senses in certain situations.

3.4. The consumption of suboptimal foods

The pricing of suboptimal food is indirectly linked to labeling issues, as pricing mechanisms are adjusted by the expiration dates; that is, food products close to expiration are offered at a reduced price. The two main factors in this case are the price discount and the willingness of consumers to engage in this practice.

Research in the U.S. found that preferences for expired food products were generally heterogeneous, and clarifying the meaning of date labels (“Best before”) was insufficient to change preferences for expired food. However, when a link was established between date labels, food waste, and its environmental impacts, participants’ willingness to purchase expired food increased, albeit with considerable product heterogeneity (Collart and Interis, 2018). In Taiwan, the perceived value of expired food depended on the degree of perishability and price discounts. This research also highlighted that familiarity with expiration date-based product practices enhanced the relationship between price discounts and perceived value (Chang and Su, 2022). In Northern Europe, consumers tended to purchase these products when they were sold at a discount. However, the purchase and consumption of suboptimal products depended on the type of suboptimality and whether the product had already been purchased. This implies that labels can have different meanings at home and in the supermarket (de Hooge et al., 2017). Another method involves reprocessing products close to the expiration date. For example, there was a willingness to pay for reprocessed fried chicken in Japan (Kawata and Kubota, 2018). A U.S.-based study found that QR code-based shelf-life labeling of milk had a wide consumer acceptance, as it effectively displayed and communicated “Best by” dates (Lau et al., 2022). Thus, novel technologies may contribute to developing dynamic pricing strategies and accepting suboptimal foods.

3.5. What does the literature recommend?

3.5.1. Education and consumer awareness

The most common policy proposals were related to informational approaches, such as education and raising consumer awareness. The cost effectiveness of consumer education campaigns is expected to be high (Read and Muth, 2021), and other research seems to support the positive benefits of education (Turvey et al., 2021). Most research suggested that more information should be provided to consumers through education, communication, and awareness-raising campaigns. It would be especially important to correct misunderstandings through education, because consumers frequently believed, incorrectly that they already understood the necessary information to interpret the label (Turvey et al., 2021; Neff et al., 2019; D. Patra et al., 2022; Cequea et al., 2021; Bilka et al., 2020; Abeliotis et al., 2014; Eičaitė et al., 2021; Secondi, 2019; Plasil, 2020; Roe et al., 2018; Gong et al., 2022; Alongi et al., 2019; Samotyja and Sielicka-Różyńska, 2021; Schmidt, 2019; D’Amato et al., 2023). Additionally, consumers must be educated about good

practices (Cequea et al., 2021; Aschemann-Witzel, 2018) and the nutrition losses associated with food waste (Khalid et al., 2019). Several studies stressed the importance of reaching particular consumer groups based on age, income, or gender (Neff et al., 2019; Qi and Roe, 2016; Melgaard et al., 2024; Aschemann-Witzel, 2018) or considering geographical (Secondi, 2019) and product-level variation (European Commission 2018; Ananda et al., 2022). These factors are also important when designing policy interventions (Ananda et al., 2022). Some research suggested that governmental campaigns should promote a better understanding of labels (Van Boxstael et al., 2014) and positive associations (Buttlar et al., 2021). Other suggestions emphasized the importance of targeting gaps in information about the link between date label confusion, food waste, and environmental impacts. Education should also go beyond simply clarifying food date labels or improving expiration date knowledge (Thompson et al., 2018; Collart and Interis, 2018). Similarly, designing effective policy solutions should consider consumer risk perceptions and trust in labels (Thompson et al., 2018). Consumers must be informed of the monetary value of wasted food and its impact, as well as the usability of food products after the “Best before” date via social awareness campaigns (Ankiel and Samotyja, 2020; Eičaitė et al., 2021). Furthermore, consumers must be informed of the physical signs of food safety and quality. Clarifying and strengthening the meaning of physical and institutional signals of food safety and quality must be prioritized (Davenport et al., 2019).

3.5.2. Standardization and physical qualities

General policy proposals about expiration date label standardization, harmonization, and other institutional changes were also frequent. The research highlighted that harmonizing labels (Neff et al., 2019; Wilson et al., 2017; Van Boxstael et al., 2014; Gong et al., 2022; Fan et al., 2022) and even changing specific labels entirely (Qi and Roe, 2016; Dordevic et al., 2020) could be beneficial. Standardizing labels and regulatory issues were among the common themes (Turvey et al., 2021; Neff et al., 2019; Wilson et al., 2017; Davenport et al., 2019; Weis et al., 2021). Changing label noticeability by the label size, location, and format would also be important (Connors and Schuelke, 2022). The specifics of label dates are critical to resolving label confusion. If expiration dates are set at the point when taste quality begins to deteriorate, consumers and producers may benefit. If, however, the policy is to set expiration dates when the food is no longer safe, public outcomes may improve, minimizing food waste (Li et al., 2020). However, the actual date received more attention than the phrasing in some experiments in the U.S., suggesting that altering the label wording may not effectively change behavior about discarding food (Badiger et al., 2023). The willingness to waste food was strongly product dependent (Wilson et al., 2017). In the U.S., similar conclusions were reached; it was shown that the potentially reduced environmental impact from standardizing labels alone may be small because it addresses the proportion of household waste resulting from discarding otherwise edible food too early. However, this is one of the cheapest options for a nationwide intervention (Read and Muth, 2021). Additionally, policies need to be compatible with incentives, particularly from a cost–benefit standpoint (Fan et al., 2022).

Some research has also highlighted the benefits of novel packaging methods, using freshness indicators (Weis et al., 2021), QR code-labeled products (Lau et al., 2022), using smart or innovative labels, using spoil prevention packaging (Read and Muth, 2021), or the effect of different framings (Song et al., 2021), where education and in-store demonstrations may be crucial (Roe et al., 2018; Barone and Aschemann-Witzel, 2022). Additional information on preserving food as a best practice is also suggested (Cequea et al., 2021). In the dairy industry, the shelf life of milk should be extended, and innovations to ensure milk freshness and positive dairy experiences should be explored (Paterson and Clark, 2020). Improving the visual presentation of messaging may also be beneficial (Turvey et al., 2021), as well as resizing packages and changing existing designs (Cequea et al., 2021; Hebrok and Heidenstrøm, 2019). Furthermore, cost-effectiveness analysis of

interventions, especially label standardization and packaging innovations, would be necessary (Read and Muth, 2021).

3.5.3. Other recommendations

A common theme among the remaining policy proposals was extending the use of expiration date-based pricing or increasing the acceptance of suboptimal food items. Reusing or reselling products at lower prices can reduce food waste (Plasil, 2020; Chang and Su, 2022; de Hooge et al., 2017), although it must be accompanied by appropriate policies and market strategies (Li et al., 2020). However, some research has found a lack of a positive impact of communication in promoting suboptimal food purchases. For instance, communicating different motives, such as saving money or avoiding food waste, did not affect the purchase of suboptimal foods. Additionally, expiration date-based pricing was expected to have a small impact in supermarkets. However, familiarity with the process may have positive benefits (Aschemann-Witzel, 2018).

Relatedly, some research proposed extending the consumption period by reprocessing the product (Kawata and Kubota, 2018). At the same time, other research found that expiration date-based pricing has no apparent effect. Instead of changing communication strategies, retailers should consistently and transparently apply the idea of reducing prices for suboptimal food (Aschemann-Witzel, 2018). The benefits of modern technology-based community interventions, such as a mobile phone app and social media (D. Patra et al., 2022), were also discussed.

Additionally, policymakers should differentiate between measures oriented toward purchasing behaviors at supermarkets or consumption behaviors at home, as they are likely to be driven by different factors (de Hooge et al., 2017). However, providing information will not necessarily inculcate safer practices. For example, for elderly consumers, health professionals could guide kitchen or food safety practices, taking an asset-based approach (Dickinson et al., 2014). A less discussed, potentially effective strategy would be to consider existing social practices and habits. For instance, discarding expired food was significantly influenced by habit (Thompson et al., 2018). Measures to reduce household food waste should also be implemented in conjunction with actual food handling practices. That is, these measures must be developed in context (Hebrok and Heidenstrøm, 2019).

4. Discussion

We identified the main problem areas in food expiration dates through the systematic literature review. These issues are related to limited understandings of the meaning of labels, the uncertain effectiveness of educational interventions, changes in the physical presentation of labels, the supportive role of technological innovations, and the influence of habitual elements and learned behaviors.

4.1. General (mis)understanding of expiration date labels

Misunderstanding and confusion about food quality and food safety indicators were a common theme in the literature. There appears to be a strong connection between label wording and consumers’ perceptions of risk, frequently resulting in food being thrown away “just in case.” This behavior is particularly prevalent in households with children and for certain products, such as meat and milk. These results are intuitive if we assume that households with children are more risk averse in terms of food that is near its expiration. Additionally, the expiration labels on specific food products, such as meat or milk, are much more visible, which may have a greater impact on consumers’ experiences. A frequent recommendation has been to enhance consumer understanding through education and awareness campaigns. These results suggest that how consumers interpret labels may vary based on their associations, highlighting the need for effective and targeted communication strategies.

Although consumer information can help reduce uncertainty, experimental evidence suggests that greater information may be

insufficient to encourage voluntary emissions reductions (Pace et al., 2025). Educational interventions, especially those aiming to change knowledge and attitudes, as opposed to human behaviors directly, may have only a short-term, ineffective impact (Kristal and Davidai, 2023). Investigating the role of habits and consumer heuristics during purchases is vital, as comparing products across different attributes is complex. While expiration date labels are relatively simple and widely used, other product features (such as GMO-free, organic, geographical, or environmental impact indicators) add additional layers of complexity. Past research highlighted the role of changing preferences, choice complexity, and information overload in human decision-making (DellaVigna, 2009; Murawski and Bossaerts, 2016), potentially serving as a guideline for policymakers. However, answering these questions would almost certainly require large-scale, costly experimental methods.

4.2. Changing the physical qualities and institutional settings of the labels

A frequent recommendation involved harmonizing labels to reduce consumer confusion. Altering the label's position, font type, font size, and color may enhance consumer understanding. In terms of socio-demographic dependencies, younger adults may have insufficient information and experience to correctly interpret labels, while older adults may have physical obstacles to reading the information. Several research studies suggested that label dates had a higher weight in the decision-making process than the label phrasing. We can assume this behavior is a way to reduce mental calculations when choosing food products, since label dates are easier to interpret and compare. Although the use of a "hard date" was raised by some authors that is, using the last possible date of safe consumption, this approach is not without drawbacks. If food products pass the highest quality points, retailers must sell inferior-quality products. These products may still be edible, but a negative association may be created with consumers, leading to reduced purchases. The new design may also contrast with regular marketing campaigns that strongly emphasize features such as freshness or intense colors. Removing specific labels is not feasible, as sensory assessments tend to be subjective and unreliable.

4.3. The supporting role of technological innovations

Technical innovations could enhance consumer understanding of expiration date labels or the associated environmental issues. The provided information could range from a simple color coding scheme to a QR code. Smart labels could improve people's understanding of the product characteristics, for example, by providing additional information about the product's ecological footprint. More advanced technological solutions, such as QR codes, demand greater digital skills. Furthermore, the additional R&D involved in these solutions may incur higher costs. This approach also implies that highly complex social or environmental issues can be represented through simple color or symbol codes. This research has not examined in detail the impact of packaging innovations, which are closely linked to expiration date labels. By enhancing product quality and extending shelf life, these innovations are expected to significantly contribute to reducing food waste. However, this remains an underresearched area with limited knowledge of consumer perceptions and acceptance (Brennan et al., 2021)

4.4. Habitual elements and the role of the social environment

Food demand is affected by habits and social structures, while environmentally significant behavior is a result of personal habits, household routines, and the surrounding infrastructure (Spurling et al., 2013; Klitkou et al., 2022). Meals consumption is relatively habitual and routine, following physical needs and social conventions (Spurling et al., 2013). Established behavioral patterns are one of the most significant obstacles to proenvironmental behavior (Kollmuss and Agyeman, 2002).

Therefore, policies must be integrated into everyday practices (Creutzig et al., 2018). For example, so-called food "nudges" have become a popular approach to changing the choice environment without restricting consumer freedom (Mertens et al., 2022). Nevertheless, scaling up nudge interventions may have its own challenges (DellaVigna and Linos, 2022). Additionally, because nudges work best in controlled environments, they may have limited reach in terms of food consumption and purchase (Lehner et al., 2016).

Suboptimal food pricing has emerged as a separate strategy, despite its close relationship with expiration date labels. Research also stressed that two important components of efficient strategies are the food discounts and familiarity with the practice of suboptimal food pricing. In this context, implementing suboptimal food pricing could be an effective complementary strategy alongside educational initiatives to reduce food waste. Adjusting the discount rate is relatively simple compared to other interventions, and the resulting change can be easily compared across different stores and products. This approach permits better control and monitoring. Furthermore, this strategy targets consumer behavior directly instead of attitudes and beliefs, as purchasing cheaper food results in economic savings. In this way, consumers can efficiently conduct a simple cost-benefit analysis of their available options while assessing purchases.

4.5. A simplified framework of intervention entry points

A simplified framework for identifying intervention entry points has been developed (Fig. 1). The potential areas for policy interventions can be categorized into two main sections: the prepurchase stage of the value chain and the postpurchase stage, where waste primarily occurs. A noteworthy difference is that home storage, consumption, and waste behaviors are not directly observable. These behaviors occur without direct external oversight, significantly undermining the effectiveness of policies directed toward waste management. We found that risk perception, heterogeneity, and food waste impacts are critical areas and direct policy entry points.

The issue of risk perception is significant in designing information strategies. The perception of risk varied considerably among different food products. Perishable products, such as meat or milk, were characterized by increased precaution, while the consumption of other products was characterized by a combination of institutional (label information) and personal (sensory) risk assessment. Consequently, informational interventions should be tailored to reflect the risk profiles of each product. The second intervention area addresses the significant variability at the product level, influenced by sociodemographic and geographical factors. Therefore, successful policy interventions must target product-level factors, particularly education and pricing.

Finally, the third area of intervention (impact) highlights that food loss presents ethical, economic, social, and environmental challenges with significant consequences across all these dimensions. Targeting these areas may reinforce behaviors aimed at reducing food waste. However, it can be argued that social and environmental impacts are more likely to be assessed through associations (such as "healthy" or "environmentally friendly") than actual knowledge. The average consumer often understands and experiences little about food's environmental and social impacts, which are commonly associated with incorrect beliefs or under- and over-estimations. Therefore, policy-making should address incorrect associations, beliefs, and habits directly instead of merely providing information.

Policy influences decisions through two primary channels: the choice environment and the choice process. The key difference between them is that modifying the choice environment affects the outcome of decisions without changing the underlying decision-making process. In contrast, the choice process itself involves altering the decision-making process. Intervention strategies can utilize a combination of both channels.

Technological advancements can enhance the product's shelf life through additives, storage, and packaging technology innovations.

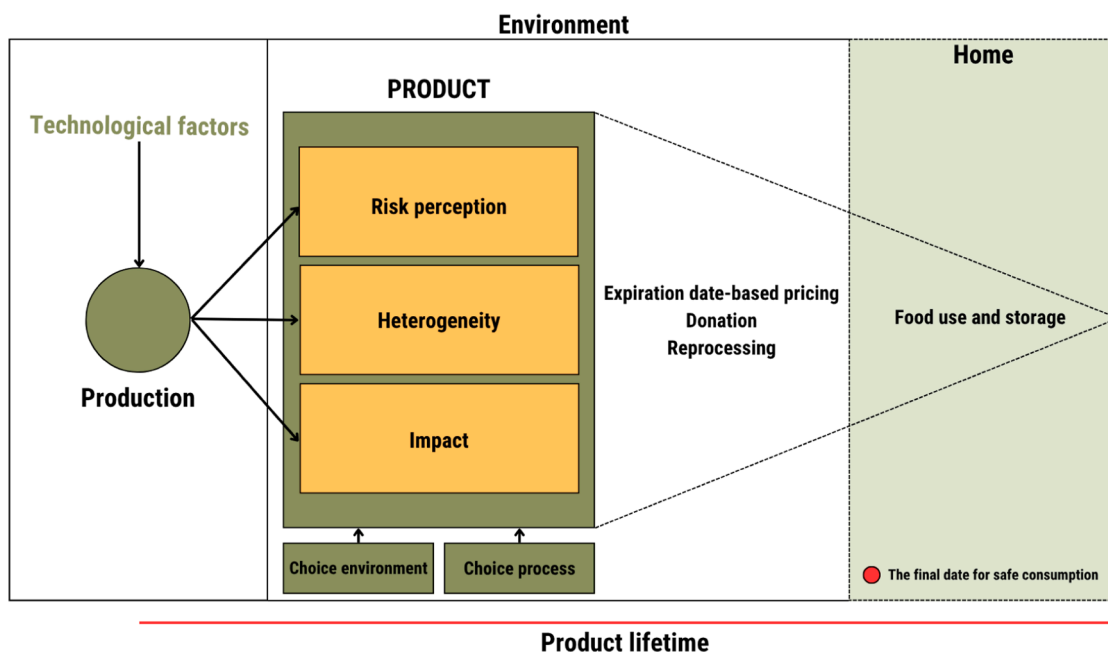


Fig. 1. A simplified framework of intervention entry points. Note: The simplified policy framework outlines the key policy intervention points across the product lifecycle. The product lifecycle progresses linearly from left to right, as indicated by the red arrow, and comprises three distinct stages: the production stage, the postpurchase stage, and the intermediate phase. The central rectangle represents the intermediate phase, where three principal intervention points emerge: (1) consumer risk perception, (2) product-level heterogeneity, and (UNEP, 2024) the product’s economic, social, and environmental impact. Policy measures should prioritize these focal areas. The two dashed lines represent the product’s edibility window, progressively narrowing over time and culminating at the red circle, signifying the final safe consumption date. Potential policy intervention tools and behavioral responses applicable throughout the lifecycle are highlighted between the dashed boundaries.

Source: Author’s compilation (2025).

Additionally, these technologies can assist consumers by providing symbolic signals (color and scent codes, QR code-based additional information). However, the effectiveness of translating complex social and environmental issues into simple symbolic signals is unclear.

Additionally, expiration date-based and suboptimal food pricing strategies are key stakeholder responses to minimize the expected amount of food waste. Two factors are worth highlighting. First, a successful strategy requires an appropriate price discount. However, as awareness of pricing practices continues to grow, establishing a consistent approach to these practices is important. The policy should aim to increase familiarity with these practices and their consistency. Furthermore, an effective form of information intervention is sharing and presenting best practices, which can significantly influence storage and consumption habits.

Other promising policy instruments, while not part of the study, are worth mentioning, such as food donation or reprocessing. These policy tools may face various legal and economic challenges depending on the region. The simplified framework also indicates that purchasing, consumption, and waste occur within a social infrastructure, which involves the complex interplay of everyday practices, habits, and norms. Policy interventions should primarily target consumer behaviors directly, mainly learned habits.

4.6. Limitations and remaining questions

The ambivalence of expiration date policies stems from the fact that the provided information must be efficiently used by the consumer. While expiration date labeling may be a systematic approach to the problem, considerable variation exists in the knowledge and use of expiration date labels, which is reflected in strong product and socio-demographic dependency. Thus, product-dependent policy actions may be required, as highlighted by the European Commission (European Commission 2018). Several key questions arise in this area. One is why

risk perception varies across different food products. Another is what psychological factors beyond food safety influence risk perception. In-store experiments may provide valuable insights, while kitchen or refrigerator “tours” may offer an opportunity to observe consumers at home with minimal intervention from researchers. However, these types of research were less common in the literature.

A limitation of this study is that we did not consider results from the gray literature or research studies in languages other than English. Neither did we have a specific strategy to choose keywords. However, alternative keywords did not lead to new results, and we identified general, comprehensive keywords to cover all relevant studies. Additionally, study-level heterogeneity allowed for subjective interpretation, as a comparative analysis of research studies was not feasible due to the different research questions, measurements, and methods. However, our thematic approach to the results facilitated comparison.

5. Conclusion

Expiration date labeling is a fundamental informational intervention with the broadest consumer reach and a significant role in producing food waste that would otherwise be avoidable. This unnecessary waste leads to economic losses and additional pressure on natural resources. Although consumers and producers commonly use expiration date labels, consumers often misunderstand them, confusing food safety indicators with those of food quality. Our research identified considerable variation in how people interpret the wording on labels, influenced by product and sociodemographic factors. Additionally, expiration date information weighed more heavily in consumers’ decision-making processes than the actual wording on the labels. Informational interventions, such as education and campaigns, were the most frequently suggested and supported measures, while the need for expiration date label harmonization and standardization was also emphasized.

These results imply that policy interventions must target multiple

areas to effectively reduce food waste. Consumer education through information campaigns is a viable option for policymakers; however, information transfer efficiency would be enhanced by standardizing expiration date labels and improving their physical qualities. There appears to be an interesting relationship between individual autonomy and the need for institutional cues. Consumers often rely on a combination of personal assessments and institutional signals when making decisions about food. Significant socioeconomic and product dependence was observed in nearly all studies, implying that different food products were associated with different levels of perceived risk. These tendencies suggest an opportunity for product-focused strategies. Additionally, expiration date-based pricing has significant potential, but its effect was found to be moderate in the literature. In addition to price discounts, familiarity with the process was essential to developing a habit of purchasing suboptimal foods. Finally, food waste should be examined in a broader context, an aspect that was overlooked in several studies. How consumers purchase, consume, and waste food is closely linked with their socioeconomic environments, habits, and behavioral patterns. We recommend conducting in-store or in-home experiments to observe real-life consumer behavior and gain a better understanding of risk perception.

Future research should focus more on the information that shapes risk perceptions for individual products. Additionally, further research should be conducted on how novel ecological labels could be integrated into the framework of traditional expiration date labels. Abstract concepts, such as sustainability and circularity, may produce further confusion. Sustainability initiatives, therefore, require a strong policy foundation, particularly in strategic areas such as food supply.

CRedit authorship contribution statement

János Szenderák: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Dániel Fróna:** Writing – review & editing, Writing – original draft, Conceptualization. **Mónika Rákos:** Writing – review & editing, Writing – original draft, Conceptualization.

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.

Appendix

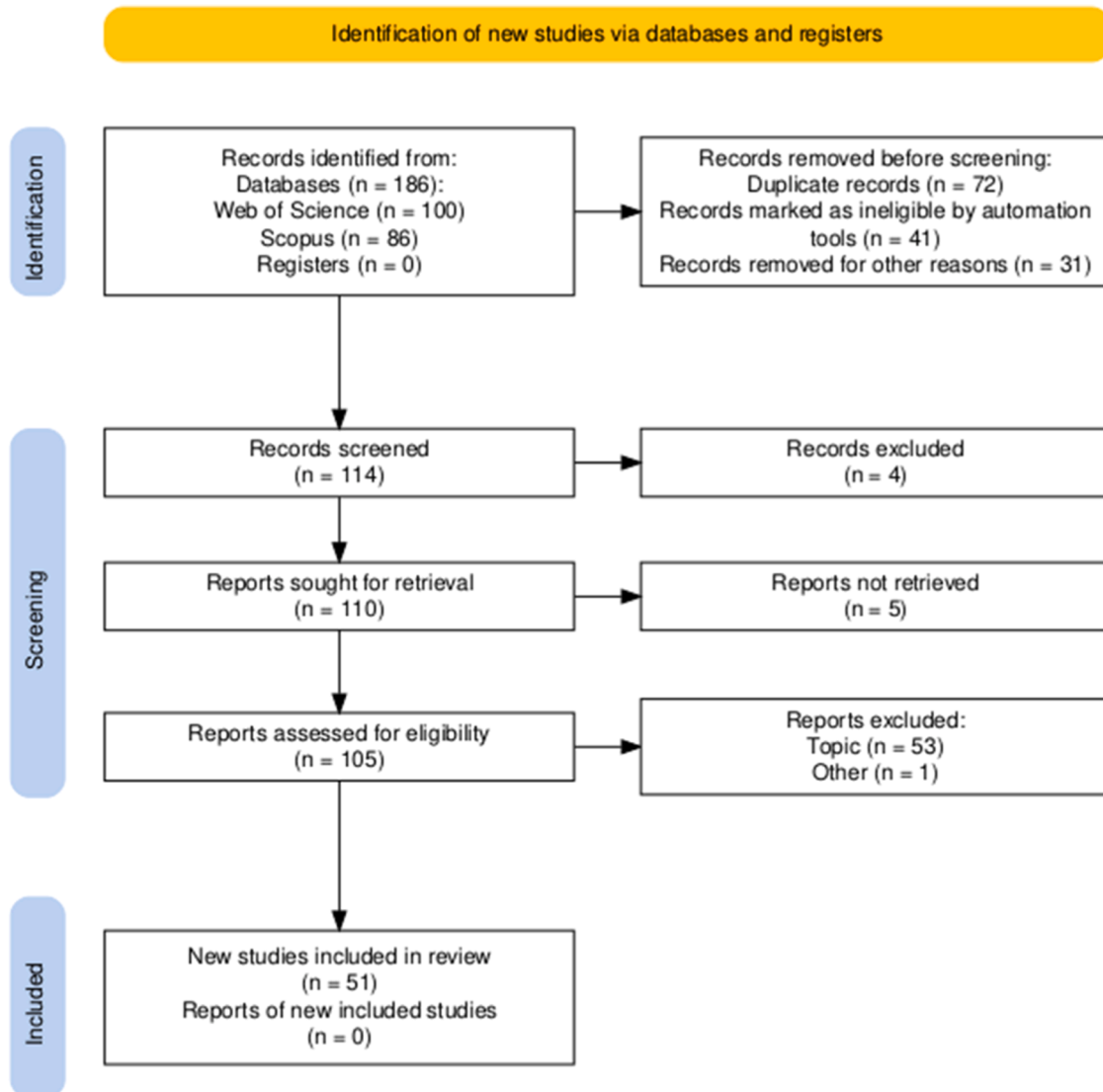


Fig. A1. Flowchart of the search process Source: Authors' own collection (2025) based on the R package and Shiny app for PRISMA2020 (Haddaway et al., 2022).

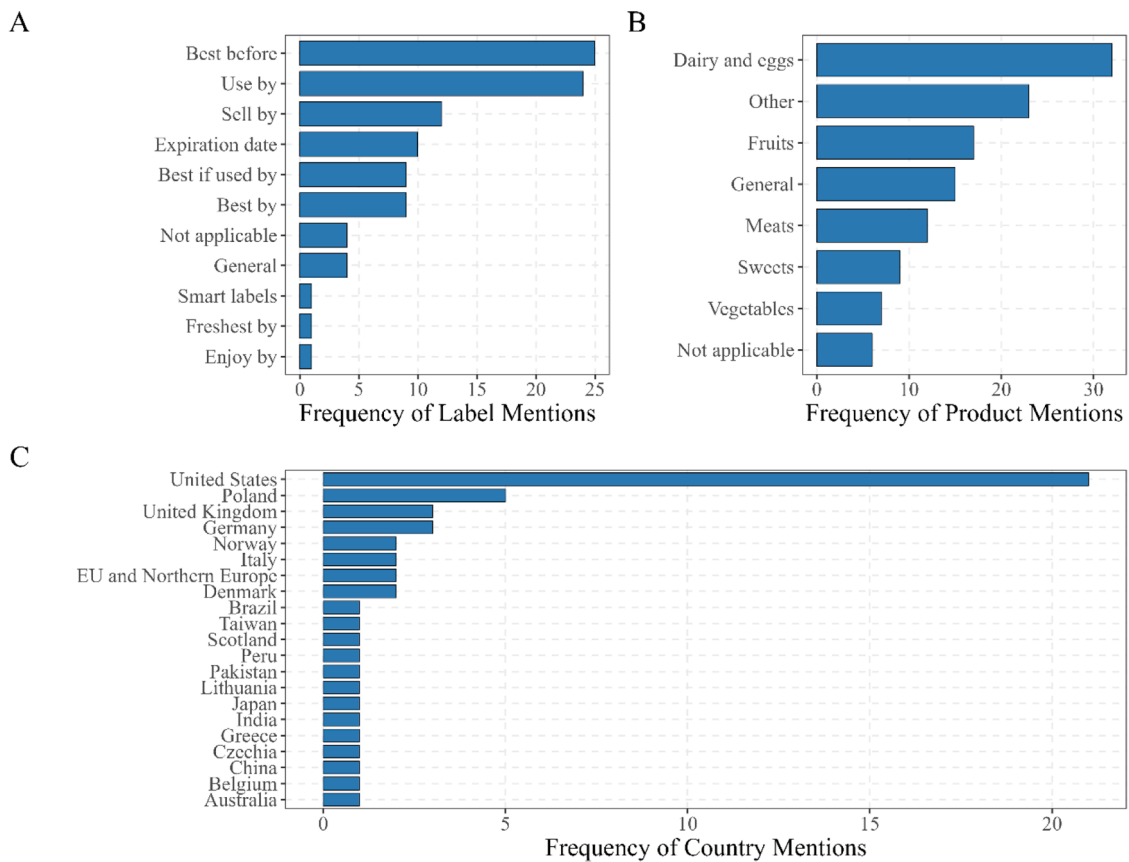


Fig. A2. Distribution of country, label, and product mentions in the 52 reviewed studies Source: Authors' own collection (2025).

Table A1

Descriptive statistics of the synthesized studies.

Authors	Methods	Sample	Region	Labels	Products
Abeliotis et al. (2014)	structured questionnaire, face-to-face interviews, descriptive statistics	231	Greece	Best before, Use by	general
Alongi et al. (2019)	experiments, survival analysis, ANOVA	700	Italy	Expiration date	fresh-cut lettuce
Ananda et al. (2022)	Tobit regression	3434	Australia	Best before, Expiration date	general
Ankiel and Samotyja (2020)	direct interview	1145	Poland	Best before, Use by	UHT and pasteurized fresh milk, rice, and rice milk dessert, ready-to-eat and ready-to-heat meals, canned fruits, and fresh-cut fruit salad
Aschemann-Witzel (2018)	ANOVA, logistic regression model	826	Denmark	Expiration date	rye bread, milk, fruit smoothie, pasta salad
Badiger et al. (2023)	in-person study and eye-tracking data analysis	70	US	Sell by, Best if used by, Use by	milk
Barone and Aschemann-Witzel (2022)	qualitative, asynchronous, and text-based focus group study with early smart label adopters for red meat	18	UK	Smart labels	red meat
Bilska et al. (2020)	cluster analysis based on computer-assisted personal interviews	1115	Poland	Best before, Use by	groats, eggs, canned corn, yogurt, flour, cold meats
Buttlar et al. (2021)	experiments, hierarchical regression, mediation analyses	224, 88 and 108	Germany	Best before	general
Cequea et al. (2021)	multiple regression analysis, Mann-Whitney U test	458 and 418	Peru and Brazil	General	not applicable
Chang and Su (2022)	between-subject experimental methods	569	Taiwan	Expiration date	refrigerated meat, soda crackers
Collart and Interis (2018)	non-hypothetical laboratory choice experiment	150	US	Best before	frozen blueberries, ice cream, juice, preserves, muffins
Connors and Schuelke (2022)	intercept surveys with content analysis	74	US	General	milk
D'Amato et al. (2023)	in-store experiments	200	Germany	Best before, Use by	eggs

(continued on next page)

Table A1 (continued)

Authors	Methods	Sample	Region	Labels	Products
Davenport et al. (2019)	a refrigerator-based study, logistic regressions	307 (baseline) and 169 (follow-up)	US	Best if used by, Best by, Best before, Use by, Sell by	general
de Hooge et al. (2017)	online choice experiment, logistic and multiple regression analysis	4214	Northern Europe	Best before, Expiration date	Apple, cucumber, milk, yogurt, fruit juice and biscuits
Dickinson et al. (2014)	'kitchen life study,' ethnographic methods	10 (households)	UK	General	general
Dordevic et al. (2020)	ANOVA, chi-squared test	1107	Czechia	Best before	general
Eičaitė et al. (2021)	face-to-face interviews, logistic models, chi-square test	1001	Lithuania	Best before, Use by	general
Fan et al. (2022)	factor analysis, regression models	1271	US	Not applicable	not applicable
Gong et al. (2022)	mixed-design experiment, ANOVA, linear regression	660	US	Best if used by, Use by, Sell by, Enjoy by, Expiration date	yogurt
Hebrok and Heidenström (2019)	fieldwork, "Fridge studies"	26 (households)	Norway	Not applicable	general
Kavanaugh and Quinlan (2020)	chi-square tests	1042	US	Best by, Use by, Sell by, Expiration date	general
Kawata and Kubota (2018)	choice experiments, random parameter logit model	996	Japan	Sell by	reprocessed fried chicken
Khalid et al. (2019)	nutritional waste estimation from collected household waste	51 (households)	Pakistan	Expiration date	not applicable
Lau et al. (2022)	8-week in-store experiments	79 QR code milk sales	US	Best by	milk
Li et al. (2020)	pre-registered field experiment	373	US	Best if used by, Use by, Expires on	yogurt smoothies
Melgaard et al. (2024)	logistic regression, Wilcoxon rank sum test	436	Denmark	Best before	dairy products
Neff et al. (2019)	survey-weighted linear and logistic regression	1029	US	Best by, Use by, Best if used by, Sell by, Expires on, Freshest by	deli meats, prepared foods, soft cheeses, raw chicken, pasteurized milk, raw eggs, bagged spinach, unopened canned goods, and breakfast cereals
Paterson and Clark (2020)	auction sessions, educational interventions, multivariate factor ANOVA	100	US	Best before, Expiration date	milk
Patra et al. (2022)	stakeholder needs assessment survey with basic statistical methods	123	US	Use by, Best by, Best if used by, Sell by	general
Plasil (2020)	interviews and online survey	37 and 373	Norway	General	milk
Qi and Roe (2016)	ordered logit regression, principal components analysis	500	US	Not applicable	not applicable
Read and Muth (2021)	input - output-based cost-effectiveness calculation	not applicable	US	Not applicable	not applicable
Rickard et al. (2022)	mixed-effects ordered logit model and simulation methods	579	US	Best by, Use by, Best if used by, Sell by + Biosensors (color coding)	bread, cookies, chicken, ham, eggs, fruit salad, packaged salad greens, milk, yogurt, juice, soda, butter, mixed nuts, canned soup, and jam
Roe et al. (2018)	sensory experiment, logistic regression	88	US	Sell by	milk
Samotyja and Sielicka-Różyńska (2021)	consumer sensory study, chi-square tests	180	Poland	Best before, Use by	rice, ready-made meals, milk and fruits
Samotyja (2021)	face-to-face interview	1145	Poland	Use by, Best before	general
Schmidt (2019)	choice experiments, structural equation modeling (SEM)	331	Germany	Best before	yogurts
Secondi (2019)	multinomial regression model	1003	Italy	Best before, Use by	general and spaghetti
Shamim et al. (2022)	chi-square statistics, ordinal logistic regression	389	India	Best before	general
Sielicka-Różyńska and Samotyja (2023)	consumer sensory study	110	Poland	Best before	rice, sponge cookies, canned fruit salad, and leaf tea
Song et al. (2021)	experiments, ANOVA	99, 259 and 400	China	Expiration date	bread, biscuits
Thompson et al. (2018)	chi-square tests and structural equation modeling (SEM)	548	Scotland	Best before, Use by	dairy products
Thompson et al. (2020)	structural equation modeling (SEM) with latent variables	548 (first stage), 383 (second stage)	US	Best before, Use by	dairy products
Toma et al. (2020)	structural equation modeling (SEM)	average sample size of 950 by Member States	EU member states	Best before, Use by	general
Turvey et al. (2021)	chi-square tests, logistic regression	2607	US	Use by, Sell by, Best before, Best if used by	general
Van Boxstael et al. (2014)	polytomous nominal regression, chi-square analyses	907	Belgium	Best before, Use by	mixed
Weis et al. (2021)	ordinal logit model	579 and 583	US, UK	Use by, Best if used by, Best before, Best by, Sell by +	bread, butter, chicken, cookies, eggs, fruit, ham, jam, juice, milk, nuts, salad, soda, soup, yogurt

(continued on next page)

Table A1 (continued)

Authors	Methods	Sample	Region	Labels	Products
Wilson et al. (2017)	a between-subject laboratory experiment with Becker-DeGroot-Marschak (BDM) auction	200	US	Colored freshness indicators Best by, Freshest by, Use by, Sell by	yogurt, ready-to-eat breakfast cereal, and salad greens
Wilson et al. (2018)	experiments, mean comparison methods, and linear regression	201	US	Best by, Use by	spaghetti sauce and deli meat

Source: Authors' own collection (2025).

Data availability

No data was used for the research described in the article.

References

- Abeliotis, K., Lasaridi, K., Chroni, C., 2014. Attitudes and behaviour of Greek households regarding food waste prevention. *Waste Manag. Res.* 32, 237–240. <https://doi.org/10.1177/0734242414521681>.
- Akerlof, G.A., 1970. The market for "lemons": quality uncertainty and the market mechanism. *Q. J. Econ.* 84, 488–500. <https://doi.org/10.2307/1879431>.
- Alongi, M., Sillani, S., Lagazio, C., Manzocco, L., 2019. Effect of expiry date communication on acceptability and waste of fresh-cut lettuce during storage at different temperatures. *Food Res. Int.* 116, 1121–1125. <https://doi.org/10.1016/j.foodres.2018.09.056>.
- Ananda, J., Gayana Karunasena, G., Pearson, D., 2022. Identifying interventions to reduce household food waste based on food categories. *Food Policy* 111, 102324. <https://doi.org/10.1016/j.foodpol.2022.102324>.
- Ankiel, M., Samotyja, U., 2020. The role of labels and perceived health risk in avoidable food wasting. *Sustainability* 12, 8725.
- Aschemann-Witzel, J., 2018. Consumer perception and preference for suboptimal food under the emerging practice of expiration date based pricing in supermarkets. *Food Qual. Preference.* 63, 119–128. <https://doi.org/10.1016/j.foodqual.2017.08.007>.
- Asioli, D., Aschemann-Witzel, J., Nayga, R.M., 2020. Sustainability-related food labels. *Annu. Rev. Resour. Econ.* 12, 171–185. <https://doi.org/10.1146/annurev-resource-100518-094103>.
- Badiger, A., Katz, T., Simons, C.T., Roe, B.E., 2023. When considering whether to waste food, consumers focus attention on food label dates rather than phrases. *Waste Management* 168, 230–234. <https://doi.org/10.1016/j.wasman.2023.06.006>.
- Barone, A.M., Aschemann-Witzel, J., 2022. Food handling practices and expiration dates: consumers' perception of smart labels. *Food Control* 133, 108615. <https://doi.org/10.1016/j.foodcont.2021.108615>.
- Bilska, B., Tomaszewska, M., Kolożyn-Krajewska, D., Piecsek, M., 2020. Segmentation of Polish households taking into account food waste. *Foods* 9, 379.
- Brennan, L., Langley, S., Verghese, K., Lockrey, S., Ryder, M., Francis, C., Phan-Le, N.T., Hill, A., 2021. The role of packaging in fighting food waste: a systematised review of consumer perceptions of packaging. *J. Cleaner Prod.* 281, 125276. <https://doi.org/10.1016/j.jclepro.2020.125276>.
- Buttlar, B., Löwenstein, L., Geske, M.-S., Ahlmer, H., Walther, E., 2021. Love food, hate waste? Ambivalence towards food fosters people's willingness to waste food. *Sustainability* 13, 3971.
- Cequera, M.M., Vásquez Neyra, J.M., Schmitt, V.G.H., Ferasso, M., 2021. Household food consumption and wastage during the COVID-19 pandemic outbreak: a comparison between Peru and Brazil. *Sustainability* 13, 7583.
- Chang, H.-H., Su, J.-W., 2022. Sustainable consumption in Taiwan retailing: the impact of product features and price promotion on purchase behaviors toward expiring products. *Food Qual. Preference.* 96, 104452. <https://doi.org/10.1016/j.foodqual.2021.104452>.
- Collart, A.J., Interis, M.G., 2018. Consumer imperfect information in the market for expired and nearly expired foods and implications for reducing food waste. *Sustainability* 10, 3835.
- Connors, P.L., Schuelke, W.C., 2022. Date labels and college student perceptions of Milk drinkability. *J. Food Compos. Anal.* 105, 104249. <https://doi.org/10.1016/j.jfca.2021.104249>.
- Creutzig, F., Roy, J., Lamb, W.F., Azevedo, I.M.L., Bruine de Bruin, W., Dalkmann, H., Edelenbosch, O.Y., Geels, F.W., Grubler, A., Hepburn, C., Hertwich, E.G., Khosla, R., Mattauch, L., Minx, J.C., Ramakrishnan, A., Rao, N.D., Steinberger, J.K., Tavoni, M., Ürge-Vorsatz, D., Weber, E.U., 2018. Towards demand-side solutions for mitigating climate change. *Nat. Clim. Chang.* 8, 260–263. <https://doi.org/10.1038/s41558-018-0121-1>.
- D'Amato, A., Goeschl, T., Lorè, L., Zoli, M., 2023. True to type? EU-style date marking and the valuation of perishable food. *Food Policy* 114, 102381. <https://doi.org/10.1016/j.foodpol.2022.102381>.
- Davenport, M.L., Qi, D., Roe, B.E., 2019. Food-related routines, product characteristics, and household food waste in the United States: a refrigerator-based pilot study. *Resour. Conserv. Recycl.* 150, 104440. <https://doi.org/10.1016/j.resconrec.2019.104440>.
- de Hooge, I.E., Oostindjer, M., Aschemann-Witzel, J., Normann, A., Loose, S.M., Almi, V. L., 2017. This apple is too ugly for me!: consumer preferences for suboptimal food products in the supermarket and at home. *Food Qual. Preference.* 56, 80–92. <https://doi.org/10.1016/j.foodqual.2016.09.012>.
- DellaVigna, S., 2009. Psychology and economics: evidence from the field. *J. Econ. Lit.* 47, 315–372. <https://doi.org/10.1257/jel.47.2.315>.
- DellaVigna, S., Linos, E., 2022. RCTs to scale: comprehensive evidence from two nudge units. *Econometrica* 90, 81–116. <https://doi.org/10.3982/ECTA18709>.
- Dickinson, A., Wills, W., Meah, A., Short, F., 2014. Food safety and older people: the Kitchen Life study. *Br. J. Community Nurs.* 19, 226–232. <https://doi.org/10.12968/bjcn.2014.19.5.226>.
- Dordevic, D., Cazalilla, R.M., Javurkova, Z., Buchtova, H., Jancikova, S., 2020. Consumers' response to different shelf life food labelling. *Qual. Assur. Saf. Crop.* 12, 24–34.
- Eičaitė, O., Alencikienė, G., Pauliukaiytė, I., Šalaševičienė, A., 2021. Eat or throw away? Factors differentiating high food wasters from low food wasters. *Sustainability* 13, 10741.
- European Commission, 2018. Market study on date marking and other information provided on food labels and food waste prevention. Final Report. European Commission, Brussels, p. 100.
- European Commission, 2020. Farm to Fork Strategy. For a fair, Healthy and Environmentally-Friendly Food System. European Commission, p. 23. https://ec.europa.eu/food/horizontal-topics/farm-to-fork-strategy_hu#Strategy.
- Fan, L., Ellison, B., Wilson, N.L.W., 2022. What food waste solutions do people support? *J. Cleaner Prod.* 330, 129907. <https://doi.org/10.1016/j.jclepro.2021.129907>.
- Gong, Z., Su, L.Y.-F., Zhang, J.S., Chen, T., Wang, Y.-C., 2022. Understanding the association between date labels and consumer-level food waste. *Food Qual. Preference.* 96, 104373. <https://doi.org/10.1016/j.foodqual.2021.104373>.
- Haddaway, N.R., Page, M.J., Pritchard, C.C., McGuinness, L.A., 2022. PRISMA2020: an R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open synthesis. *Campbell Systematic Reviews* 18, e1230. <https://doi.org/10.1002/cl2.1230>.
- Hebrok, M., Heidenström, N., 2019. Contextualising food waste prevention - decisive moments within everyday practices. *J. Cleaner Prod.* 210, 1435–1448. <https://doi.org/10.1016/j.jclepro.2018.11.141>.
- Hermanussen, H., Loy, J.-P., 2024. Household food waste: a meta-analysis. *Environ. Challenges.* 14, 100809. <https://doi.org/10.1016/j.envc.2023.100809>.
- Jiang, S., Chen, H., Zhang, J., Shan, P., Ma, W., 2024. Promoting public participation in reducing food waste: a large-scale multiple randomized controlled trial. *J. Retail. Consum. Serv.* 81, 104022. <https://doi.org/10.1016/j.jretconser.2024.104022>.
- Kavanaugh, M., Quinlan, J.J., 2020. Consumer knowledge and behaviors regarding food date labels and food waste. *Food Control* 115, 107285. <https://doi.org/10.1016/j.foodcont.2020.107285>.
- Kawata, Y., Kubota, S., 2018. Consumers' willingness to pay for reprocessed fried chicken: a way of reducing uneaten food. *Appetite* 120, 571–577. <https://doi.org/10.1016/j.appet.2017.09.015>.
- Khalid, S., Naseer, A., Shahid, M., Shah, G.M., Ullah, M.I., Waqar, A., Abbas, T., Imran, M., Rehman, F., 2019. Assessment of nutritional loss with food waste and factors governing this waste at household level in Pakistan. *J. Cleaner Prod.* 206, 1015–1024. <https://doi.org/10.1016/j.jclepro.2018.09.138>.
- Klitkou, A., Bolwig, S., Huber, A., Ingeborgrud, L., Pluciński, P., Rohrer, H., Scharfing, D., Thiene, M., Zuk, P., 2022. The interconnected dynamics of social practices and their implications for transformative change: a review. *Sustainable Prod. Consumption.* 31, 603–614. <https://doi.org/10.1016/j.spc.2022.03.027>.
- Kollmans, A., Agyeman, J., 2002. Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environ. Educ. Res.* 8, 239–260. <https://doi.org/10.1080/13504620220145401>.
- Kristal, A.S., Davidai, S., 2023. The "hearts-and-minds frame": not all i-frame interventions are ineffective, but education-based interventions can be particularly bad. *Behav. Brain Sci.* 46, e166. <https://doi.org/10.1017/S0140525x23001036>.
- Lau, S., Wiedmann, M., Adalja, A., 2022. Consumer perceptions of QR code technology for enhanced fluid milk shelf-life information provision in a retail setting. *JDS Communications* 3, 393–397. <https://doi.org/10.3168/jds.2022-0256>.
- Lehner, M., Mont, O., Heiskanen, E., 2016. Nudging – a promising tool for sustainable consumption behaviour? *J. Cleaner Prod.* 134, 166–177. <https://doi.org/10.1016/j.jclepro.2015.11.086>.
- Li, T., Messer, K.D., Kaiser, H.M., 2020. The impact of expiration dates labels on hedonic markets for perishable products. *Food Policy* 93, 101894. <https://doi.org/10.1016/j.foodpol.2020.101894>.
- Mehmood, A., Ahmed, S., Viza, E., Bogush, A., Ayyub, R.M., 2021. Drivers and barriers towards circular economy in agri-food supply chain: a review. *Business Strategy & Development* 4, 465–481. <https://doi.org/10.1002/bsd2.171>.

- Melgaard, C.V., E. Voss, M.F. Hansen, M. Lassen, M. Hvidtfeldt, S. Pandey, M.A. Rasmussen, and M. Thomsen, 2024. Danish consumers' knowledge about and willingness to buy dairy products close to the best-before-date, *Food Front.* 5, 494–507. <https://doi.org/10.1002/fft.2.337>.
- Mertens, S., Herberz, M., Hahnel, U.J.J., Brosch, T., 2022. The effectiveness of nudging: a meta-analysis of choice architecture interventions across behavioral domains. *Proceed. Nat. Acad. Sci.* 119, e2107346118. <https://doi.org/10.1073/pnas.2107346118>.
- Murawski, C., Bossaerts, P., 2016. How humans solve complex problems: the case of the knapsack problem. *Sci. Rep.* 6, 34851. <https://doi.org/10.1038/srep34851>.
- 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 Management* 86, 123–132. <https://doi.org/10.1016/j.wasman.2019.01.023>.
- Pace, D.D., Imai, T., Schwardmann, P., van der Weele, J.J., 2025. Uncertainty about carbon impact and the willingness to avoid CO2 emissions. *Ecol. Econ.* 227, 108401. <https://doi.org/10.1016/j.ecolecon.2024.108401>.
- Paterson, M., Clark, S., 2020. Use of auctions to assess consumer value for fresh and end-of-code milk. *J. Dairy Sci.* 103, 4138–4150. <https://doi.org/10.3168/jds.2019-17418>.
- Patra, D., Feng, S., Howard, J.W., 2022a. Confusion of food-date label with food safety — Implications for food waste. *Curr. Opin. Food sci.* 48, 100917. <https://doi.org/10.1016/j.cofs.2022.100917>.
- Patra, D., Henley, S.C., Benefo, E.O., Pradhan, A.K., Shirmohammadi, A., 2022b. Understanding and addressing food waste from confusion in date labeling using a stakeholders' survey. *J. Agric. Food Res.* 8, 100295. <https://doi.org/10.1016/j.jafr.2022.100295>.
- Plasil, T., 2020. Black boxing milk: date labeling, quality, and waste throughout the Norwegian milk chain. *Food Foodways* 28, 22–42. <https://doi.org/10.1080/07409710.2020.1718274>.
- Qi, D., Roe, B.E., 2016. Household food waste: multivariate regression and principal components analyses of awareness and attitudes among U.S. Consumers. *PLoS One* 11, e0159250. <https://doi.org/10.1371/journal.pone.0159250>.
- Read, Q.D., Muth, M.K., 2021. Cost-effectiveness of four food waste interventions: is food waste reduction a “win-win”? *Resour. Conserv. Recycl.* 168, 105448. <https://doi.org/10.1016/j.resconrec.2021.105448>.
- Rickard, B.J., Ho, S.-T., Livat, F., Okrent, A.M., 2022. Date labels, food waste and supply chain implications. *Eur. Rev. Agric. Econ.* 50, 29–58. <https://doi.org/10.1093/erae/jbac021>.
- 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. Preference.* 66, 13–18. <https://doi.org/10.1016/j.foodqual.2017.12.016>.
- Samotyja, U., 2021. The system of date labelling in the food supply chain—the weak links from the perspective of final consumers. *LogForum.* 17.
- Samotyja, U., Sielicka-Różyńska, M., 2021. How date type, freshness labelling and food category influence consumer rejection. *Int. J. Consum. Stud.* 45, 441–455. <https://doi.org/10.1111/ijcs.12634>.
- Santagata, R., Ripa, M., Genovese, A., Ulgiati, S., 2021. Food waste recovery pathways: challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment. *J. Cleaner Prod.* 286, 125490. <https://doi.org/10.1016/j.jclepro.2020.125490>.
- Schanes, K., Dobernig, K., Gözet, B., 2018. Food waste matters - A systematic review of household food waste practices and their policy implications. *J. Cleaner Prod.* 182, 978–991. <https://doi.org/10.1016/j.jclepro.2018.02.030>.
- Schill, C., Anderies, J.M., Lindahl, T., Folke, C., Polasky, S., Cárdenas, J.C., Crépin, A.-S., Janssen, M.A., Norberg, J., Schlüter, M., 2019. A more dynamic understanding of human behaviour for the Anthropocene. *Nat. Sustainability.* 2, 1075–1082. <https://doi.org/10.1038/s41893-019-0419-7>.
- Schmidt, K., 2019. Predicting the consumption of expired food by an extended theory of Planned behavior. *Food Qual. Preference.* 78, 103746. <https://doi.org/10.1016/j.foodqual.2019.103746>.
- Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., Matthews, E., Klirs, C., 2019. Creating a sustainable food future: a menu of solutions to feed nearly 10 billion people by 2050. Final report. *World Resources Report.* 96.
- Secondi, L., 2019. Expiry dates, consumer behavior, and food waste: how would Italian consumers react if there were No longer “best before” labels? *Sustainability* 11, 6821.
- Shamim, K., Ahmad, S., Alam, M.A., 2022. Consumer understanding of food date labels: preventing food wastage. *Br. Food J.* 124, 3116–3132. <https://doi.org/10.1108/BFJ-06-2021-0672>.
- Sielicka-Różyńska, M., Samotyja, U., 2023. Influence of “best before” dates on expected and actual food liking. *Br. Food J.* 125, 1317–1334. <https://doi.org/10.1108/BFJ-08-2021-0935>.
- Song, M., Zhao, Y., Li, X., Meng, L., 2021. The influence exerted by time frames on consumers' Willingness to buy nearly expired food. *Front. Psychol.* 12. <https://doi.org/10.3389/fpsyg.2021.790727>.
- Spurling, N.J., McMeekin, A., Southerton, D., Shove, E.A., Welch, D., 2013. Interventions in practice: Reframing Policy Approaches to Consumer Behaviour. *Sustainable Practices Research Group Report, Manchester*, p. 56.
- 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 Management* 78, 124–134. <https://doi.org/10.1016/j.wasman.2018.05.021>.
- Thompson, B., Toma, L., Barnes, A.P., Revoredo-Giha, C., 2020. Date-label use and the waste of dairy products by consumers. *J. Cleaner Prod.* 247, 119174. <https://doi.org/10.1016/j.jclepro.2019.119174>.
- Toma, L., Font, M.Costa, Thompson, B., 2020. Impact of consumers' understanding of date labelling on food waste behaviour. *Operational Research* 20, 543–560. <https://doi.org/10.1007/s12351-017-0352-3>.
- Turvey, C., Moran, M., Scheck, J., Arashiro, A., Huang, Q., Heley, K., Johnston, E., Neff, R., 2021. Impact of messaging strategy on consumer understanding of food date labels. *J. Nutr. Educ. Behav.* 53, 389–400. <https://doi.org/10.1016/j.jneb.2021.03.007>.
- UN, A/RES/70/1 resolution adopted by the General Assembly on 25 September 2015 in General Assembly. 2015, United Nations. p. 35.
- UNEP, 2024. *Food Waste Index Report 2024. Think eat save: tracking progress to halve global Food waste. Food Waste Index Report. United Nations Environment Programme: Nairobi*, p. 193.
- 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. <https://doi.org/10.1016/j.foodcont.2013.08.043>.
- Wang, Y., Yuan, Z., Tang, Y., 2021. Enhancing food security and environmental sustainability: a critical review of food loss and waste management. *Resour. Environ. Sustainability.* 4, 100023. <https://doi.org/10.1016/j.resenv.2021.100023>.
- Weis, C., Narang, A., Rickard, B., Souza-Monteiro, D.M., 2021. Effects of date labels and freshness indicators on food waste patterns in the United States and the United Kingdom. *Sustainability* 13, 7897.
- Westgate, M.J., 2019a. revtools: an R package to support article screening for evidence synthesis. *Res. Synth. Methods.* 10, 606–614. <https://doi.org/10.1002/jrsm.1374>.
- Westgate, M.J., 2019b. revtools: tools to support evidence synthesis. R Package Version 0.4.1. The R Project for Statistical Computing. <https://CRAN.R-project.org/package=revtools>.
- Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S.E., Srinath Reddy, K., Narain, S., Nishtar, S., Murray, C.J.L., 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet* 393, 447–492. [https://doi.org/10.1016/S0140-6736\(18\)31788-4](https://doi.org/10.1016/S0140-6736(18)31788-4).
- Wilson, N.L.W., Miao, R., Weis, C., 2018. Seeing is not believing: perceptions of date labels over food and attributes. *J. Food Prod. Mark.* 24, 611–631. <https://doi.org/10.1080/10454446.2018.1472700>.
- Wilson, N.L.W., Rickard, B.J., Saputo, R., Ho, S.-T., 2017. Food waste: the role of date labels, package size, and product category. *Food Qual. Preference.* 55, 35–44. <https://doi.org/10.1016/j.foodqual.2016.08.004>.
- Zhang, Q., Dhir, A., Kaur, P., 2022. Circular economy and the food sector: a systematic literature review. *Sustainable Prod. Consumption.* 32, 655–668. <https://doi.org/10.1016/j.spc.2022.05.010>.
- Zilberman, D., Kaplan, S., Gordon, B., 2018. The political economy of labeling. *Food Policy* 78, 6–13. <https://doi.org/10.1016/j.foodpol.2018.02.008>.