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European consumers' involvement with date labels and implications for household food waste

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ABSTRACT

Food waste (FW) in the European Union remains a significant challenge, with over 58 million tons generated annually. Consumer behavior, particularly in relation to food-date labels, is a key factor influencing FW. This study focuses on patterns of involvement with date labels, examining how understanding, attention, and behavioral responses to date labels vary across consumer segments. By clustering consumers based on these dimensions, the research aims to identify distinct involvement patterns toward date labels and the impact on FW decisions.

The study involved 1507 consumers (54.6 % female, mean age = 44.9 years) from six EU countries (Belgium, France, Germany, Italy, Spain, Sweden). Participants completed an online questionnaire assessing their understanding, attention, and behavioral responses to date labels, alongside their reported domestic FW behaviors, sociodemographics, and FW management skills.

Results indicate that 75.2 % of European consumers understand the difference between 'use by' and 'best before' dates, and over 80 % correctly identify the meanings of these terms. Increased understanding correlates with reduced household FW, but this factor alone is insufficient to significantly lower waste levels. Additionally, enhanced use of date labels plays a crucial role in minimizing FW.

The study identifies distinct consumer segments toward date labels: "Higher involvement" segment (23.9 % of subjects), who rely on date labels for food management, "Lower involvement" segment (33.4 %), who base their decisions on other elements such as sensory cues, and "Medium involvement" segment (42.6 %), which shows intermediate characteristics. This segmentation provides valuable insights for designing targeted interventions aimed at improving date label usage and reducing household FW.

1. Introduction

1.1. The challenge of FW in Europe and related causes

In the European Union (EU) alone, estimates provided by Eurostat (2023) show that over 58 million tons of food waste (FW) are generated annually corresponding to 131 kg/inhabitant and an associated market value of 132 billion euros. In response to this critical issue, the EU Commission has set a target to reduce per capita FW by 30 % in retail sales and consumption by 2030 compared to 2020 levels (European Commission, 2023). Notably, the consumption stage has been identified by different studies as the most detrimental in terms of FW with estimates of 53–54 % of FW occurring among consumers at the household level, resulting in 70–79 kg of FW per person per year (FUSION, 2015; Eurostat, 2023; United Nations Environment Programme, 2021). These figures are highlighting the need for targeted interventions to mitigate FW at its most significant source. Consumers might discard food for several reasons, including fresh produce that is no longer deemed optimal, leftover or unused food in food-service sectors or households, plate waste, over purchasing, improper storage, and incorrect interpretation or use of food-date labels (Kavanaugh and Quinlan, 2020). Among these factors, food-date labeling stands out as a significant driver, shaping consumer behavior and influencing decisions to discard food (Toma et al., 2020). This underscores the need to raise consumer awareness as a crucial approach to reducing FW.

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1.2. The food date labeling in Europe and consumer confusion

Regulation (EU) No 1169/2011 reaffirmed previous European legislation (e.g., Directive 2000/13/EC) and standardized labeling rules, including those related to date marking, across EU member states. This legislation mandates that food products display either a 'best before' date or a 'use by' date. The 'best before' date indicates the period during which the food maintains its expected quality, such as flavor and texture, under proper storage. The 'use by' date, however, signifies the last day the food is safe to eat, and it applies to highly perishable items such as fresh meat or dairy products. Despite the intended simplicity of the interpretation, consumers had difficulty understanding the 'best before' date and often confused it with the 'use by' date, as reported by studies conducted after these labels were introduced (Eurobarometer 425, European Commission, 2015; Toma et al., 2020). This unclear labeling significantly contributes to consumer confusion about food safety (Hall-Phillips & Shah, 2017; Patra et al., 2022). It impacts the purchasing decisions and can lead to unnecessary FW, with an estimated 10 % of FW in the EU supply chain linked to date marking (European Commission, 2018). To address this, research has been conducted at the EU level to better understand the factors that influence the comprehension and adoption of date labels. The resulting body of literature was examined by considering the main dimensions that can affect the interaction between consumers and food labels, using the conceptual framework presented in Grunert (2011), Grunert and Wills (2007), and Ketelsen et al. (2020) as a reference. This framework focuses on the dimensions influencing the adoption of sustainability labels on food products. Through this approach, key factors influencing the use of date labels were identified, which in the present research can be referred to as understanding, attention, and behavior toward date labels.

1.3. Factors of date label processing and relation with food waste

Subjective understanding refers to the interpretation consumers assign to the information perceived on a label, including the degree to which they believe they have "understood" the intended message. Consumers integrate the perceived information with their existing knowledge, using this combination to infer meaning (Grunert and Wills, 2007). Understanding date labels has been extensively studied due to their strong connection to FW, as consumer confusion on best before labels is a major contributor to unnecessary waste (Secondi et al., 2015). The survey Eurobarometer 425 (28 member states with an average sample size of 950 observations), highlighted that a significant portion of EU citizens lacks clarity regarding terms such as "Best before" and "Use by," with only 47 % of EU citizens correctly understanding "Best before" and only 40 % correctly understanding "Use by" at the time of the survey (European Commission, 2015). This confusion often leads consumers to discard food unnecessarily, as they misinterpret these labels as indicators of safety rather than quality (Zielińska et al., 2020). At the same time, the literature indicates that consumers with a higher level of understanding of date labels are more likely to use them regularly, which is associated with reduced FW (Toma et al., 2020). This lack of understanding underscores the need for clearer labeling and consumer education to reduce unnecessary FW across different cultural contexts.

Labels can only influence consumers if they are exposed to them, and the likelihood of exposure increases when consumers actively seek out label information (Grunert, 2011; Grunert & Wills, 2007). Attention is a cognitive process that determines how and on which stimuli to focus, thereby influencing the effectiveness with which information is processed and retained (Posner & Petersen, 1990). In the FW context, attention to date labels is another key dimension that has gained attention and was previously regarded as directly influenced by knowledge (Toma et al., 2020). According to a study conducted on Eurobarometer 425, frequency of date label checking has a strong significant negative effect on FW among European consumers (Toma et al., 2020). This behavior suggests that consumers who pay more attention to date labels are likely to discard fewer items prematurely, thus helping reduce overall FW. However, previous studies in the UK (WRAP, 2011) point out inconsistent behavioral trends. Certain behaviors associated with high involvement to date labels may lead to reduced FW. At the same time, there are behaviors linked to low date involvement or infrequent checking, such as a willingness to eat leftovers or food past its date, which may also lead to lower FW. This suggests that consumer behaviors related to attention to date labels may exhibit significant diversity, even if they lead to the same outcome.

The integration and understanding of label perception is applied to guide subsequent decision-making regarding consumption or purchase. However, this effect is not necessarily linear and must account for multiple confounding factors (Grunert, 2011; Grunert & Wills, 2007). Studies across the fields of environmental science have demonstrated that declarative understanding is necessary but insufficient on its own to drive actual behavior. For instance, Kaiser and Fuhrer (2003) and Redman and Redman (2014) observed that objective or declarative understanding alone may have limited impact and contended that it must be integrated with other domains to influence behavior effectively. In parallel, the ability to pay attention to and accurately interpret date labels is essential, yet it does not always lead to correct usage or effective reduction of FW. Research by WRAP (2011) and van Boxstael et al. (2014) suggests that while consumers may recognize different types of date labels, many do not consistently apply this knowledge when purchasing or managing food at home. Instead, they often rely on personal judgments of product freshness rather than strictly adhering to label guidelines. For example, van Boxstael et al. (2014) found that 82.5 % of Belgian consumers primarily use visual and olfactory cues to determine food edibility, with 67.5 % taking date labels into account and 50.4 % relying on taste. This behavior underscores the complex interplay between the use of shelf-life dates and the influence of sensory perceptions on food consumption and resulting FW.

In this context, distinguishing between FW from used and partially used food packaging within the framework of date labels is relevant. This differentiation is conceptually significant, as it acknowledges that packaged foods and opened foods represent the two primary conditions where date labels are typically applied in a domestic setting. Each condition is likely to involve distinct consumer decision-making processes regarding FW, which could be influenced by how date labels are interpreted and acted upon. For instance, consumers may prioritize date labels more heavily when dealing with unopened packaged goods, which are perceived as shelf-stable, compared to products that have been opened, which may trigger different behaviors based on sensory cues or storage practices (van Boxstael et al., 2014; Toma et al., 2020). As the current literature on this distinction remains limited, further research is necessary to explore how these two conditions are associated with FW behaviors and the impact of date labels on such decisions.

1.4. Patterns of involvement toward date labels

While some consumers actively engage with date labels, incorporating them into their food-related decisions, others tend to rely more on sensory cues, such as sight, smell, and taste, or follow pre-existing habits (Sielicka-Różyńska & Samotyja, 2023; van Boxstael et al., 2014). The literature indicates that these varying approaches to date labels are critical in understanding FW behaviors, as they highlight the differing levels of attention consumers give to expiration dates and the complex role of declarative understanding versus personal judgments in food consumption. Despite this, existing literature shows inconsistent findings regarding the impact of these dimensions on FW decision-making, suggesting that different consumer segments exhibit different behaviors toward date labels (e.g., Dinnella et al., 2014; Närvänen et al., 2023). While segmentation based on FW behaviors has been widely studied (e.g., Knezevic et al., 2023; Annunziata et al., 2022; Myhrer et al., 2024), the segmentation concerning date label behaviors remains relatively underexplored (WRAP, 2011). Understanding the patterns of

consumer involvement with date labels, and how they relate to FW, is essential for improving FW reduction strategies.

Consumers involvement with date labels may demonstrate distinct patterns influenced by a combination of understanding, attention, and behavior toward label information. These patterns are shaped by how consumers interpret and integrate label information into their food management practices. A holistic approach that considers understanding, attention, and behavioral responses offers a more comprehensive view of consumer engagement with date labels. This integrated approach is particularly valuable, as it helps to clarify existing inconsistencies in the literature about the relationship between date labels and FW.

For a more comprehensive understanding of the identified patterns, it is essential to consider key socioeconomic and behavioral factors influencing FW. These include socio-demographic characteristics (e.g., age, income, education) that shape waste-related behaviors (Toma et al., 2020; Zielińska et al., 2020), as well as FW management skills, which affect household waste levels (Secondi, 2019). Additionally, consumer shopping habits, such as planning and impulse buying and dietary patterns, which influence food consumption and disposal (Priefer et al., 2016), play a crucial role. Understanding these interconnected factors provides a more holistic perspective on FW drivers and informs targeted reduction strategies.

1.5. Research aims and overview of the empirical approach

Building on the above, this study aims to provide an updated EU perspective on: i.) how understanding, attention, and behavioral responses to date labels influence household FW of unused and partially used food; ii.) how identifying consumer clusters based on these dimensions can make more identifiable the presence of involvement patterns toward date labels and the subsequent impact on FW. The empirical approach involves an exploratory online survey conducted in six European countries. The survey includes questions related to understanding, attention, and behavioral responses to date labels, as well as questions about the perceived level of household FW from different sources. Additionally, it characterizes consumers based on a range of sociodemographic variables, food-related behaviors, and attitudes. Hierarchical clustering analysis was applied to composite indices of understanding, attention to and behavioral responses to date labels to identify consumer clusters with different involvement patterns toward date labels.

This research is part of the "SISTERS" project (Systemic Innovations for a Sustainable Reduction of European Food Wastage), aimed at reducing food loss and waste along the European food supply chain.

2. Materials and methods

2.1. Consumer sample

Participants ($n = 1507$; female = 54.6 %; $age_{mean} = 44.9y$; $age_{std\ dev} = 15.5y$) were recruited from six EU countries: Italy ($n = 374$), Spain ($n = 241$), France ($n = 216$), Germany ($n = 231$), Belgium ($n = 225$), and Sweden ($n = 212$). An additional 8 participants with nationality from other EU countries but domiciled in the investigated countries were also included, given the limited sample size. The sample size was determined based on previous research on date labels conducted in geographical areas comparable to Europe (e.g., Kavanaugh & Quinlan, 2020; Neff et al., 2019). Recruitment was conducted primarily through a recruitment agency (60.7 %), ensuring a representative distribution by gender and age groups, and through online channels (39.3 %). Inclusion criteria required participants to be between 18 and 75 years of age and reside in the investigated EU countries. Pre-survey recruitment filters targeting age and gender were implemented in each country to ensure that the sample accurately reflected the demographic profile of the population in this age range. Participation was voluntary, and confidentiality of responses was guaranteed. Participants could withdraw from the survey at any time. Those recruited by the agency received compensation for completing the survey. The study was approved by the Research Ethics Committee of the University of Trento (protocol 2023–002).

2.2. Online survey

The survey was conducted remotely using a computer-assisted web interviewing methodology and was distributed to residents of Belgium, France, Germany, Italy, Spain, and Sweden. To participate in the study, respondents provided electronic informed consent, which was displayed on the invitation page of the online survey. Participants accessed the survey link after reviewing an online information sheet that detailed the objectives, procedures, and data management. The survey was originally designed in Italian and then translated by native speakers or professional translators into the languages of the countries involved in the study, except for questionnaires that have already been developed and validated in English. All versions were back translated to English to verify fidelity to the original text. To ensure the quality of responses, two repeated questions (gender, age) and a completion speed check (completion times under 5 min were removed) were included as posterior screening measures. An internal pilot test was conducted with a total of 5 participants per country, interviewed either via email (Belgium, France, Germany, Spain, and Sweden) or in person (Italy). The internal pilot aimed to assess textual clarity, focusing on the absence of ambiguity, ease of understanding, and grammatical accuracy. An external pilot test involving 100 participants across the countries ensured the procedure's functionality and timely completion of the questionnaire. The pilot studies did not highlight any critical issues, so no modifications were made to the questionnaire design. Data collection of the complete sample was conducted using Qualtrics software (Qualtrics LLC, USA) and spanned 6 months (April–September 2023).

2.3. Measures

2.3.1. Overview of questionnaire structure

According to the general objective of the SISTERS project, the questionnaire was designed in a multipurpose extended version of 48 questions that explored four thematic areas: i.) Food waste; ii.) Food quality labels; iii.) Bio-based packaging; and iv.) Consumers' habits, attitudes, and demographics. In the present study, we focus on 24 selected questions designed to address the key mediators of understanding, attention, and behavioral responses to date labels. Specifically, these questions are organized into the following categories: i.) Understanding, covering variables related to the understanding about food date labels; ii.) Attention, covering variables related to the attention given to food date labels along consumption phases, iii.) Declared behavioral responses, addressing variables related to how date labels influence food consumption and household FW; iv.) Declared household food waste; and v.) Consumer characterization variables. Detailed measures are discussed in the following paragraphs. The selected version of the questionnaire is provided in the Supplementary Material (Table S1).

2.3.2. Understanding of date labels

A set of three questions was designed to address label understanding. Participants were asked if they were aware of the existence of the two different labels, "Best before" and "Use by," on food packaging. Next, participants were asked to indicate whether they believe each of the following statements is true: "It is still possible to consume a product that has passed its 'best before' date", and "A 'use by' statement indicates until when a food can be used safely". For each question, participants could respond with "Yes," "No," or "I don't know" (Table S1 – Question LA1 and LA2). The first question focuses on explicit understanding of the difference between the two phrases (van Boxstael et al., 2014), while the other two involve identifying the correct response, as

previously examined in the literature to measure consumer understanding about expiration dates (e.g., Kavanaugh and Quinlan, 2020; Neff et al., 2019; Toma et al., 2020).

2.3.3. Attention to date labels

A question was designed to explore the attention given to the expiration date (the date after which the product is no longer safe to consume) throughout the entire product lifecycle in relation to consumer interaction. Participants were asked to identify all the stages of the food consumption cycle where they pay the most attention to date labels. They could choose all applicable options from the following: "During the purchase," "When I organize the pantry," "At the time of consumption/preparation," "When I start to see signs of spoilage in the product," "Before the next shopping," and "Never" (Table S1 – Question LA4).

2.3.4. Behavioral responses to date labels

Two questions were designed to explore the causes of FW and domestic reduction strategies at the household level. The items for these questions were developed and selected through a focus group involving internal resources from the research team ($n = 11$) and based on the recommendations for action in FW prevention for consumers (EU Platform on Food Losses and Food Waste 2019).

Regarding the first question, participants were asked to indicate the main reasons that lead them to throw away food, choosing from 12 options. In the present study, we focused on the two responses associated with negative behavior in the relationship between date labels and FW: "I generate FW at home because I forget the expiration date and let the food deteriorate", and "I generate FW at home because the foods sold are already close to expiring." Regarding the second question, participants were asked to identify the main strategies they use to reduce FW at home, selecting from 12 options. We focused on three answers related to a positive behavior in the relationship between date labels and FW: "I reduce FW because I keep my pantry, fridge, and freezer well organized by expiration date"; "I reduce FW because I prioritize consumption of perishable or expiring food", and "I reduce FW because I consume recently expired foods after carefully checking them."

2.3.5. Declared household food discard

Four questions were designed to explore the perceived FW at home. Participants were asked to indicate how often they discard food at home regarding the following situations: "Throw away completely unused food"; "Throw away partially used food"; "Throw away leftover meals left on the plate"; "Throw away leftover meals stored in the fridge". For each question, participants could respond with a 5-point category scale anchored with: 1-Never, 2-Rarely, 3-Occasionally, 4-Often, and 5-Always.

2.3.6. Food waste management skills

The FW management skills questionnaire (Kennedy et al., 2019; Pedrotti et al., 2023) was used to measure domestic FW management. The scale consists of seven items (i.e., "Planning meals in advance", "Planning your shopping", "Planning the amount of food to buy", "Cooking/preparing meals while minimizing preparation waste", "Using leftovers to create another meal", "Using storage information to consume food by date", "Balancing meals based on nutritional advice on what is healthy"). Participants were instructed to rate their level of skill for each situation using a 9-point scale (1 = "Extremely bad", 9 = "Extremely good").

Participants were asked to express how often they go for food shopping for his/her self or the family (i.e., "Never", "Rarely", "Occasionally", "Often", "Always"), and their dietary regime (i.e., "Omnivorous (eat all foods)", "Flexitarian (I limit the consumption of meat)", "Vegetarian (I don't eat meat)", "Vegan (I do not consume products of animal origin)", "Other").

2.3.7. Demographic and socioeconomic characteristics

Seven questions were designed to characterize consumers. Participants were asked to indicate: gender, age, level of education, working condition, monthly household net income, country, living area, people in household. The details on the items are provided in Supplementary materials (Table S1).

2.4. Data processing and analysis

Given the total number of responses received ($n = 2427$), participants who did not complete the questionnaire, completed it too quickly (under 300 s in total), or did not provide coherent responses during quality checks were excluded from subsequent data analysis ($n = 920$). The high number of excluded subjects resulted from the rigorous procedure aimed at ensuring high-quality responses.

The levels of sociodemographic variables were grouped coherently to ensure that each group constituted at least 10 % of the total sample. For variables related to FW management skills, the household FW index was calculated by summing the scale responses for both completely unused and partially used foods and dishes. The 33rd and 66th percentiles were identified as cutoff levels to form three groups with relatively low, medium, and high levels of household FW, respectively. The FW management skills index was individually calculated by averaging the questionnaire items (Pedrotti et al., 2023). The 33rd and 66th percentiles were used as cutoff levels to form three groups with relatively low, medium, and high FW management skills, respectively. Composite indices for understanding (score range = 0–3), attention (score range = 0–5), and behavioral responses to date labels (score range = 0–5) were obtained by summing binary scores of respective dimensions, appropriately reversed so that higher scores indicate higher levels of understanding (i.e., the higher the index, the more I understand the meaning of date labels), attention (i.e., the higher the index, the more I check date labels), and behavioral responses to date labels (i.e., the higher the index, the more my consumption behaviors are determined by date labels). The reliability of the scales was assessed using Cronbach's alpha (Cronbach, 1951) for Likert scales and Guttman's split-half Lambda 4 coefficient for dichotomous scales (Guttman, 1945).

Following exploratory and descriptive analyses, ordered logistic regression was used to assess the relationship between the declared household FW of completely unused food or partially used food (Y) and the individual items related to understanding, attention, and behavioral responses to date labels (Neff et al., 2019). Effect sizes in ordered logistic regressions was assessed considering McFadden's R^2 (Hardin & Hilbe, 2007). Hierarchical clustering analysis using Ward's method was applied to the composite indices of understanding, attention to and behavioral responses to date labels to identify consumer clusters with different involvement patterns toward date labels (Müller & Hamm, 2014). Clusters were selected through dendrogram inspection, and the quality of cluster separation was assessed using the silhouette method (Gere, 2023). The effect of the clusters on socio-demographic variables and FW management skills was assessed using chi-square tests.

All data analyses were performed with an alpha level of 0.05 using the R Statistics Package version 4.3.9 (R Core Team, 2015), with the packages MASS v7.3, psych v 2.4.6.26, and cluster v2.1.6.

3. Results

3.1. Characterization of participants

The global sociodemographic characteristics and food-related habits of the participants are detailed in Table 1. The gender distribution was balanced. The age groups reflect the general population distribution, with 40.6 % of subjects in the 35–54 age range, with a mean age of 44.9 years (sd = 15.5 years). A significant portion of the participants (74.4 %) had medium to high educational levels, having completed secondary education or higher. Regarding employment status, 62.4 % of the

Table 1
- Sociodemographic, food waste (FW) habits, and FW management skills for all respondents (n = 1507).

	%
Gender	
Male	45.1
Female	54.6
Age group	
18–24	10.9
25–34	18.6
35–44	19.9
45–54	20.7
55–64	15.4
65–75	14.4
Level of education	
Lower secondary school or lower degree	17.5
Upper secondary school degree	35.0
Bachelor or higher degree	47.5
Working condition	
Employee, part-time job	13.9
Employee, full-time job	48.5
Unemployed	37.5
Monthly household net income (Euro)	
Less than 2000	33.3
Between 2000 and 4000	47.1
Above 4000	19.6
Country	
Italy	24.8
Spain	16.0
France	15.3
Germany	14.9
Sweden	14.3
Belgium	14.1
Living area	
Metropolitan or large urban area	23.9
Small or medium-sized urban area	39.8
Nearby or remote rural area	36.2
People in household	
1	16.9
2	30.1
3	22.6
4	19.9
≥ 5	10.6
Household FW index	
Low	36.9
Medium	45.7
High	17.4
FW management skills	
Low	32.2
Medium	32.2
High	35.6
Food shopping involvement	
Never or rarely	18.7
Occasionally	44.6
Often or always	36.7
Diet	
Omnivorous	67.8
Flexitarian	22.0
Vegetarian or vegan	5.5
Other	4.7

participants were employed either full-time or part-time. Additionally, 53 % of participants reported a household net income between 1000 and 3000 euros. The study included participants from six EU countries with balanced numerosity (average 249.8 subjects per country), with a slightly higher representation of Italian individuals. In accordance with the inclusion criteria, the age and gender distribution reflect the general population of the investigated countries. More than half of the subjects (53.3 %) lived in areas of low urban density, and 46.9 % belonged to small households of 1 or 2 people.

Regarding the household FW, most subjects reported a moderate level of FW generation in the household (45.7 %). Specifically, the results showed that 72.8 % reported rarely or never discarding unused food and 72.9 % reported rarely or never discarding partially used foods. Occasionally or frequently discarding unused or partially used food was reported by 25.5 % and 26.4 %, respectively. Participants also reported having medium to high FW management skills (67.8 %) and shopped for groceries with medium to high frequency (81.3 %). In terms of dietary habits, most subjects identified as omnivores (67.8 %).

The sample differs from the general EU population in a few keyways. It is more highly educated, with a larger share of participants having completed at least secondary education. There is also a higher proportion of individuals living in low urban density areas, whereas the general EU population is more urbanized. Additionally, small households (1–2 people) are overrepresented, which may impact food-related behaviors (Eurostat, 2024).

3.2. Understanding, attention, and behavioral responses regarding date labels

Table 2 details the overall frequencies for understanding, attention, and behavioral responses regarding date labels among EU consumers.

The measurement of date labels understanding demonstrated moderate internal consistency (Lambda 4 coefficient = 0.51). Most subjects (75.2 %) claim to know the difference between “use by” and “best before” dates. 86.7 % of respondents correctly stated that it is safe to consume food past the “best before” date, while 82.3 % correctly indicated that it is not safe to consume food past the “use by” date.

The attention measurement scale demonstrated moderate internal consistency (Lambda 4 coefficient = 0.53). Participants paid significantly more attention to expiration date during the purchase (64.6 %) and consumption/preparation phases (41.9 %). Subsequently, attention was also given to date labels during pantry organization (28.0 %), upon noticing signs of deterioration (21.3 %), and before the next shopping trip (18.9 %).

The behavioral measurement demonstrated moderate internal consistency (Lambda 4 coefficient = 0.62). 42.2 % of participants admitted to wasting food because they forgot the expiration date. The importance of expiration date was evident as 55.3 % prioritized consuming food nearing its expiration date. However, 36.4 % reported consuming food past the expiration date after sensory inspection.

3.3. Implications of understanding, attention, and behavioral responses regarding date labels on food waste

Table 3 presents ordered logistic regression models with ordinal responses for declared household FW and binary responses for understanding, attention, and behavioral responses items as independent variables.

Table 2
- Response frequency of items on understanding, attention, and behavioral responses regarding date labels among EU consumers (n = 1507).

	%
Understanding of date labels (% right answer)	
Difference “best before” and “use by”	*75.2*
Possible consume after “best before”	*86.7*
Not possible consume after “use by”	*82.3*
Attention to date labels (% - multiple choice)	
During the purchase	*64.6*
When I organize the pantry	*28.0*
At the time of consumption/preparation	*41.9*
When I see signs of spoilage	*21.3*
Before the next shopping	*18.9*
Never	*1.7*
Behavioral responses to date labels (% - multiple choice)	
FW generation from forgetting expiration date	*42.2*
FW generation from foods close expiring	*13.9*
FW reduction with food organization by expiration date	*34.9*
FW reduction with priority of consumption by expiration date	*55.3*
FW reduction with consumption of expired foods	*36.4*

Notes
FW = food waste.

Table 3
- Ordered logistic regression of association between declared household FW of unused and partially used food (Y) and items related to understanding, attention, and behavioral responses toward date labels (X) among European consumers (n = 1507).

OR (CI 95 %)	Waste of completely unused food	Waste of partially used food
Understanding of date labels		
Difference "best before" and "use by"	0.9 (0.7, 1.1)	0.9 (0.8, 1.2)
Possible consume after "best before"	**0.7* (0.5, 0.9)**	1.1 (0.8, 1.4)
Not possible consume after "use by"	**1.3* (1.0, 1.7)**	1.0 (0.7, 1.2)
Attention to date labels		
During the purchase	0.9 (0.7, 1.1)	0.8 (0.7, 1.0)
When I organize the pantry	1.0 (0.8, 1.3)	1.0 (0.8, 1.3)
At the time of consumption/ preparation	1.1 (0.9, 1.4)	**1.2* (1.0, 1.5)**
When I see signs of spoilage	1.0 (0.8, 1.3)	1.1 (0.9, 1.4)
Before the next shopping	0.9 (0.7, 1.2)	0.9 (0.7, 1.2)
Never	**0.4* (0.2, 0.9)**	1.0 (0.4, 2.2)
Behavioral responses to date labels		
FW generation from forgetting expiration date	**2.6*** (2.1, 3.2)**	**2.0*** (1.7, 2.5)**
FW generation from foods close expiring	**1.5** (1.1, 2.0)**	**1.6*** (1.2, 2.1)**
FW reduction with food organization by expiration date	**0.8* (0.6, 1.0)**	**0.7** (0.6, 0.9)**
FW reduction with priority of consumption by expiration date	0.8 (0.7, 1.0)	0.9 (0.8, 1.2)
FW reduction with consumption of expired foods	0.8 (0.7, 1.0)	1.0 (0.8, 1.2)

*Notes: OR = Odds ratio; CI = confidence interval; FW = food waste. Each column represents a separated ordered logistic regression. Sample interpretation: Holding other variables constant, people who believe it is possible to consume food after the "best before" date throw away unused food 0.7 times (30 % less) than those who state it is not possible. * p < 0.05 **p < 0.01 ***p < 0.001*

Understanding of date labels primarily impacted unused FW. Participants who believed it is possible to consume food after the "best before" date (86.7 % of the total sample) discarded unused food 0.7 times (30 % less; *p*-value = 0.010; McFadden's R^2 = 0.38) compared to those who stated it is not possible. Additionally, participants who believe that food cannot be consumed past the "use by" date (82.3 % of the total sample) waste unused food 1.3 times (30 % more; *p*-value = 0.043; McFadden's R^2 = 0.31) compared to those who state that is possible. No significant effects were highlighted regarding the understanding of date labels on FW from partially used foods.

Attention to date labels had a mixed and limited impact on FW. Participants who paid more attention during consumption/preparation wasted 1.2 times more partially used food (20 % more; *p*-value = 0.044; McFadden's R^2 = 0.29), while those who never paid attention wasted unused food 0.4 times less (60 % less; p-value = 0.029; McFadden's R^2 = 0.35). The attention given to date labels in the remaining stages of consumption was not associated with variations in declared household FW.

Behavioral response influences both unused and partially used FW. Specifically, participants who reported generating FW due to forgetting expiration date or because the expiration date was approaching, tended to produce more waste in both categories. Notably, participants who believed they generated FW due to forgetting expiration date discarded unused food 2.6 times more frequently (160 % more; p-value <0.001; McFadden's R^2 = 0.44) compared to those who did not report this behavior. Similarly, those who generate FW due to forgetting expiration date discarded partially used food 2.0 times more often (100 % more; p-value <0.001; McFadden's R^2 = 0.39). Additionally, participants who believed they generated FW due to purchasing food with expiration date close to the end of their shelf-life discarded unused food 1.5 times more frequently (50 % more; *p*-value = 0.004; McFadden's R^2 = 0.32) than those who did not report this behavior. Likewise, those who generate FW due to the same reason discarded partially used food 1.6 times more often (60 % more; *p*-value <0.001; McFadden's R^2 = 0.35). In contrast, those who organize their pantry based on the expiration date produced less FW in both unused and partially used categories, with reductions of 0.8 times (20 % less; *p*-value = 0.022; McFadden's R^2 = 0.31) and 0.7 times (30 % less; *p*-value = 0.002; McFadden's R^2 = 0.37), respectively. Prioritizing consumption based on expiration dates, as well as consuming food after the expiration date, was not significantly associated with variations in declared household FW.

3.4. Identified patterns of involvement with date labels among European consumers

The hierarchical cluster analysis on understanding, attention and behavioral responses to date labels indices revealed three primary patterns of involvement regarding date labels (Fig. 1). The Lower Involvement cluster (LI) represents 33.4 % of the subjects and exhibits lower attention and use of date labels compared to the other two clusters, although their understanding of date labels is only slightly lower than the other clusters. The Higher Involvement cluster (HI) represents 23.9 % of the subjects and demonstrates the highest indices of understanding, attention, and use of date labels. The Medium Involvement cluster (MI) represents 42.6 % of the subjects and exhibits intermediate characteristics, with attention similar to the LI cluster and understanding and use similar to the HI cluster (Fig. 2).

Cluster characterization revealed differences in sociodemographic variables (Table 4). Gender distribution varied, with a higher percentage of females in the HI cluster and a balanced distribution in the LI and MI clusters (*p*-value = 0.018). Regarding age, the LI cluster comprised predominantly younger individuals, the MI cluster skewed toward older participants, while the HI cluster predominantly consisted of middle-aged adults (p-value <0.001). Educational attainment was higher in the LI and HI clusters, with medium to high levels in the MI cluster (p-value <0.001). Regarding the country, the LI cluster had a higher presence of participants from Northern Europe, the MI cluster showed a balanced distribution across countries, and the HI cluster had a higher representation from Southern Europe (p-value <0.001).

All clusters exhibited medium to low levels of domestic FW, with values leaning higher in the LI cluster (p-value <0.001). In terms of FW management skills (Cronbach's alpha = 0.85), the LI cluster showed lower levels, the MI cluster had a balanced distribution, and the HI cluster demonstrated high levels (p-value <0.001). In terms of food shopping involvement, the HI cluster exhibited higher involvement compared to the other two clusters, whereas the LI segment demonstrated the lowest frequencies (p-value <0.001).

4. Discussion

4.1. The relationship between understanding, attention, and behavioral responses regarding date labels with household food waste in Europe

Understanding about date labels reveals that 75.2 % of participants understand the difference between 'use by' and 'best before' dates, with over 80 % correctly identifying the meanings of both terms. This represents an improvement compared to earlier European surveys conducted before the implementation of Regulation 1169/2011, such as data collection from Eurobarometer 425 in 2014, where correct understanding was on average 47 %. Although in the former study understanding to date labels was measured using a different scale than in the present one (Single-choice multiple-choice question vs. Extended dichotomous question), the magnitude of the difference suggests a

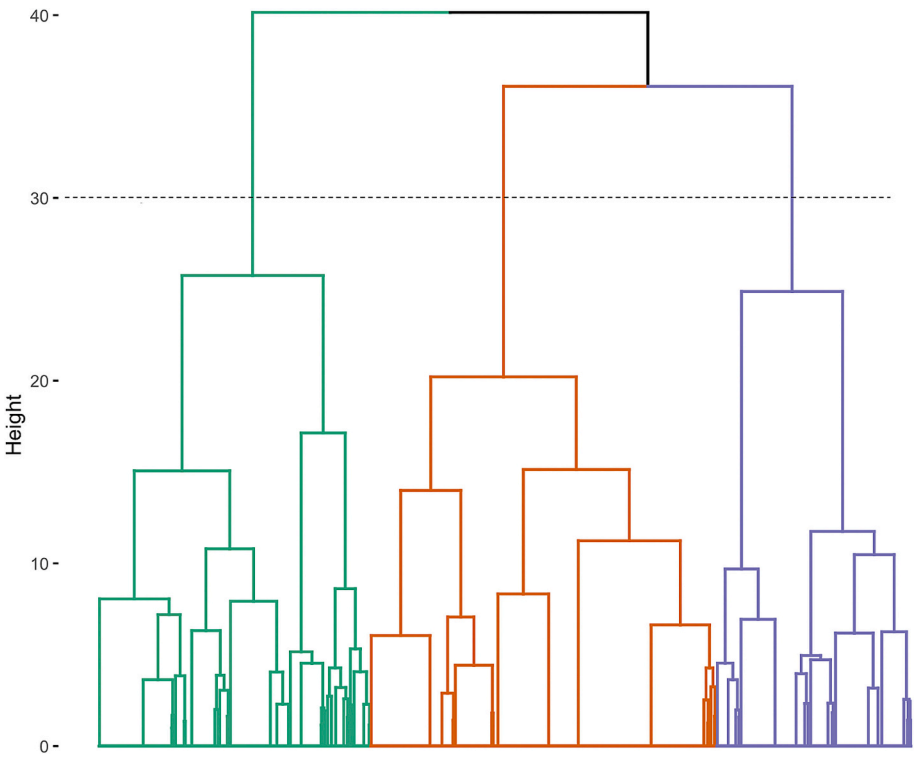

Fig. 1. - Hierarchical cluster analysis on consumers' indices of understanding, attention, and behavioral responses toward date labels (n = 1507). Dashed line separates the Lower Involvement segment (n = 504, green color), Medium involvement segment (n = 642, orange color), and Higher involvement segment (n = 361, purple color). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

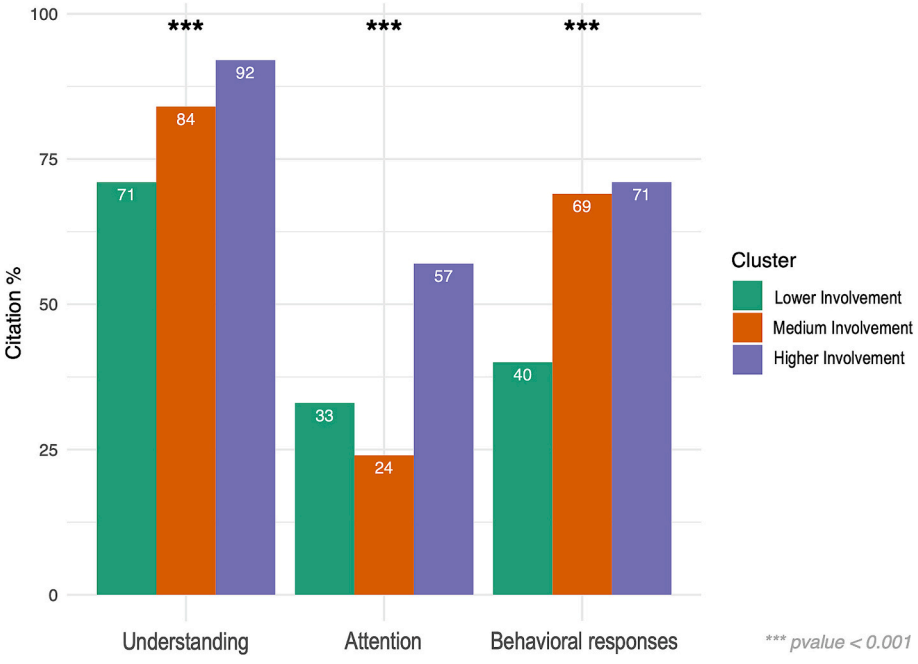

Fig. 2. - Citation percentage of understanding, attention, and behavioral responses toward date labels among Lower Involvement (n = 504), Medium Involvement (n = 642), and Higher Involvement (n = 361) segments.

generalized improvement in EU consumers' understanding of date labels, a trend also confirmed by more recent studies on consumer understanding of date labels in European countries (e.g., Malgaard et al., 2024; Hansen & Lähteenmäki, 2021). The enhanced consumer understanding of expiration dates in Europe is likely attributable to a combination of policy initiatives (e.g., European Commission, 2019; FSA, 2025), which may have increased exposure to and familiarity with labeling terminology, as well as broader public awareness efforts. Additionally, media coverage and the proliferation of digital tools (e.g., Too Good To Go) may have played a crucial role in reinforcing consumer understanding of date labels.

In addition to the promising results regarding the understanding of

Table 4
- Sociodemographic characteristics, Food Waste (FW) habits, and FW management skills across segments with varying levels of involvement with date labels: Lower Involvement, Medium Involvement, and Higher Involvement.

	Cluster			p-value
	Lower Involvement (n = 504)	*Medium Involvement (n = 642)*	*Higher Involvement (n = 361)*	
Gender (%)				
Male	45.0	48.6	39.3	**0.018**
Female	55.0	51.4	60.7	
Age group (%)				
18–24	14.3	11.1	6.1	
25–34	21.8	15.0	20.8	
35–44	17.7	21.5	20.2	**<0.001**
45–54	20.4	19.8	22.7	
55–64	14.5	15.4	16.6	
65–75	11.3	17.3	13.6	
Level of education (%)				
Lower secondary school or lower degree	19.4	19.0	11.6	
Upper secondary school degree	32.1	38.0	33.8	**<0.001**
Bachelor or higher degree	48.4	43.0	54.6	
Working condition (%)				
Employee, part-time job	15.1	14.6	11.1	
Employee, full-time job	50.4	46.0	50.7	0.180
Unemployed	34.5	39.4	38.2	
Monthly household net income (Euro) (%)				
Less than 2000	30.6	34.9	34.3	
Between 2000 and 4000	49.4	45.8	46.3	0.612
Above 4000	20.0	19.3	19.4	
Country (%)				
Italy	18.3	26.3	31.9	
Spain	14.5	16.7	17.5	
France	11.5	14.8	17.7	**<0.001**
Germany	20.8	13.1	11.9	
Sweden	18.8	14.0	7.8	
Belgium	16.1	15.1	13.3	
Living area (%)				
Metropolitan or large urban area	23.8	25.2	21.9	
Small or medium-sized urban area	40.9	39.6	38.8	0.626
Nearby or remote rural area	35.3	35.2	39.3	
People in household (%)				
1	17.7	17.4	14.7	
2	30.0	29.6	31.0	
3	22.2	22.0	24.1	0.490
4	19.8	18.7	22.2	
≥ 5	10.3	12.3	8.0	
Household FW index (%)				
Low	27.6	40.0	44.3	
Medium	50.6	44.2	41.6	**<0.001**
High	21.8	15.7	14.1	
FW management skills (%)				
Low	41.1	33.3	17.7	
Medium	32.5	30.5	34.6	**<0.001**
High	26.4	36.1	47.6	
Food shopping involvement (%)				
Never or rarely	22.0	19.8	12.2	
Occasionally	46.0	44.2	43.2	**<0.001**
Often or always	31.9	36.0	44.6	
Diet (%)				
Omnivorous	67.1	70.4	64.0	
Flexitarian	24.2	18.1	26.0	**0.049**
Vegetarian or vegan	4.6	5.7	6.4	
Other	4.2	5.8	3.6	

Notes: Percentages are calculated within each column for each factor. Significant comparisons among clusters according to chi-square test are reported in bold

date labels, the study highlights that increased understanding of the meaning of date labels remains associated with a reduction in household FW from unused food, i.e., packaged and unopened food. Specifically, European consumers who correctly understand that food can be consumed after the 'best before' date report disposing of unused food 30 % less frequently than those who believe this is not possible. This finding is consistent with previous research at the European level (Eičaitė et al., 2021; Secondi et al., 2015; Toma et al., 2020; Zielińska et al., 2020) and U.S. level (Kavanaugh and Quinlan, 2020; Neff et al., 2019), confirming the importance of accurate comprehension of the 'best before' label in reducing FW of unused food. In parallel, it is worth noting that individuals who misinterpret the 'use by' date tend to generate lower levels of FW from unused food. This reduction may result from misinterpretation or incorrect use of the 'use by' date label, which poses a potential food safety issue, as observed in studies of Belgian consumers (van Boxstael et al., 2014). This gap highlights that the understanding of date labels is just one factor that works alongside attention and use to influence consumer behavior, suggesting that other factors likely contribute to their application in decision-making processes (e.g., the accessibility of date labels after removing food from its packaging).

Conversely, the misinterpretation of the "best before" and "use by" labels does not appear to influence the waste of partially used food, defined as food that remains in its packaging after partial consumption. This finding suggests that misunderstanding date labels has a selective

impact, primarily affecting the waste of unused food. For unopened food products, date labels may be perceived as absolute safety indicators, potentially leading to excessive waste when misinterpreted (Plasil, 2020; Weis et al., 2021). In contrast, for partially used food, risk perception may be influenced by additional factors such as the time elapsed since opening or storage conditions. After opening, individuals are more likely to rely on sensory cues to assess food edibility (Gong et al., 2021), making the misinterpretation of expiration dates less relevant. Additionally, consumers may follow established consumption patterns for partially used food (e.g., refrigeration, repurposing in recipes), which contribute to waste reduction even in the absence of a clear understanding of date labels (Wallnoefer et al., 2024).

In the present study, date labeling attention was not generally associated with variations in domestic FW concerning unused food. Contrary to the overall sample, the subgroup of individuals who reported never paying attention to expiration dates showed lower FW for unused food. These findings contrast with data from Eurobarometer 425 (Toma et al., 2020), which indicate that greater attention to date labels correlates with reduced FW. Nevertheless, evidence from WRAP (2011) suggests that date label attention alone is not a reliable metric for distinguishing between low and high food wasters. This discrepancy arises from the complex interplay of behaviors associated with date label involvement. For example, individuals with high attention to date labels often engage in practices such as food planning and precise shopping, which can contribute to reduced FW. Conversely, individuals with lower attention might adopt practices such as consuming leftovers or using food past its expiration date, potentially leading to lower FW. Therefore, the relationship between date label attention and FW is mediated by different behaviors (e.g., Myhrer et al., 2024), complicating the direct correlation between date label awareness and actual levels of FW (WRAP, 2011).

Consistent with previous evidence, it has been observed that attention to date labels for partially used food does not have an overall effect on FW reduction. However, individuals who pay close attention to date labels at the time of consumption tend to generate more domestic FW from partially used items. The perception that a food item becomes unsafe or has unacceptable sensory properties once the expiration date has passed may be stronger among consumers who focus on label details (Dinnella et al., 2014; Sielicka-Różyńska and Samotyja, 2023). This could lead them to discard partially used food without considering factors such as appearance or taste, which might otherwise indicate that the product is still edible.

The behavioral responses to date labels emerged as one of the strongest predictors of the amount of FW generated at the household level for both unused and partially used foods. The positive relationship between the conscious use of date labels and FW was strongly highlighted, consistent with previous literature identifying date labels as a key determinant of FW (Visschers et al., 2016; Kavanaugh and Quinlan, 2020; Toma et al., 2020). Furthermore, this study reveals that one in three respondents might consider eating food past the expiration date after carefully assessing it based on sensory properties. Assessments of food product acceptability are influenced by a variety of factors, with date labels serving as a key reference point in conjunction with other information, such as appearance, aroma, and flavor (Lyndhurst, 2011; Wansink & Wright, 2006). This suggests that while date labels significantly influence consumer decisions, many also rely on product sensory properties to determine food consumption (Chu et al., 2020; WRAP, 2023).

The discussion regarding the use of date labels should be embedded with the consideration of sensory assessments, as both tools are essential for evaluating food edibility. While date labels provide a structured, "information-driven" approach, sensory assessments such as smell, appearance, and texture offer a "perception-driven" method. These two tools are acknowledged in the literature as key factors influencing food consumption decisions (Chu et al., 2020; Koller et al., 2023). This study highlights that, although date labels are a critical reference, consumers may turn to sensory assessments to make final judgments about food safety. This dual reliance on both sensory and informational cues reflects a nuanced approach to food decision-making, offering new insights into how these factors interact. While relying on sensory assessments may reduce FW by encouraging consumers to consume food past its expiration date (Samotyja & Sielicka-Różyńska, 2021; Wallnoefer et al., 2024), it raises potential food safety concerns, as sensory judgments may not always accurately reflect food safety (Gong et al., 2021). Therefore, a balanced approach combining sensory evaluation with adherence to expiration dates is needed to minimize health risks and FW.

4.2. *Identification of consumer clusters differing in date labels involvement to clarify the relationship between date labels and food waste*

Our results support previous research on the effect of consumer profiles on household FW (Annunziata et al., 2022; Coskun, 2021; Myhrer et al., 2024) and highlight the importance of considering understanding, attention, and behavioral responses to date labels when developing strategies to reduce consumer FW. Notably, it has become evident that household FW reduction can be achieved through a variety of declared and often opposite behaviors. In general, this highlights that different behavioral approaches (i.e., sensory based vs. information based) may be associated with the mitigation of household FW, despite variations in how individuals understand and manage date labels. The research identified contrasting behavioral patterns regarding "involvement with date labels", defined as a composite dimension encompassing understanding, attention, and behavioral responses. Based on the opposite poles of involvement, the Higher Involvement (HI) and the Lower Involvement (LI) segments will be discussed.

The HI segment (23.9 % of subjects) consists of people whose consumption behavior is determined by the information conveyed by the date labels. These consumers pay attention to date labels, understand their significance, and throw away food after the "use by" date. FW reduction is achieved in this segment through proper planning of food consumption based on date labels, while the generation of FW is due to the strict observance of these dates. In the FW literature, such behavior has been observed in Sielicka-Różyńska and Samotyja (2023), where expiration date was found to play a more significant role than sensory attributes in influencing food consumption decisions. Närvänen et al. (2023) conducted a segmentation study on a large sample of retail consumers, identifying the "Trust in Date Labels" segment, which is characterized by a higher proportion of adult female consumers and a strong reliance on expiration dates as the primary determinant of FW. Similarly, in Myhrer et al. (2024), the "Want to Change" segment is defined by a high proportion of female participants, a strong sense of responsibility toward reducing FW, and lower levels of household FW. This group reports discarding food only once the "best before" or "use-by" date has passed. Likewise, Annunziata et al. (2022) identified the "Proactive" segment, which is distinguished by a greater female presence, responsible behavior in managing leftovers, a heightened tendency to pay attention to label information, and an enhanced ability to interpret expiration dates.

On the other hand, the LI segment (33.4 % of subjects) consists of people whose behavior toward food consumption is less influenced by date labels, relying instead on the perceptual qualities of the product. These individuals pay little attention to date labels, have a lower understanding of them, and may consume food past the expiration date after checking its smell and appearance. FW reduction is achieved by consuming food past its expiration date, while FW generation can result from improper food management based on date labels. This behavior was observed for example in van Boxstael et al. (2014), which found that sensory attributes outweighed date labels in determining the consumption of food past its expiration date. In Malgaard et al. (2024), the "High/High" segment was characterized by a higher presence of younger individuals and females, and it was found to be less involved with date labels when consuming foods close to their "best before" date,

despite understanding its meaning. In Dinnella et al. (2014), the "Cluster 2" segment tends to be less influenced by information related to the shelf life when evaluating freshness, with sensory properties appearing to be the most important indicator. In Myhrer et al. (2024), the "Need to Change" segment exhibited confusion regarding the terms "best before" and "use-by date," resulting in uncertainty about food safety beyond the labeled date. Furthermore, they placed significant emphasis on sensory quality. This group reported the highest average level of perceived FW during dinner. They also scored low in terms of their attitudes toward FW, showing no strong intention to reduce it. Additionally, they do not receive inspiration from family and friends to minimize their FW.

The segmentation into HI and LI segments helps clarify the conflicting findings in the literature (e.g., Samotyja & Sielicka-Różyńska, 2021; Sielicka-Różyńska & Samotyja, 2023; van Boxstael et al., 2014)), confirming that consumer behavior toward date labels is not uniform (Närvänen et al., 2023). By recognizing these distinct segments, it becomes apparent that the varying consumer responses to date labels stem from underlying differences in their decision-making processes. This nuanced understanding of consumer behavior provides a more comprehensive explanation of the contradictory results found in previous research regarding how attitudes toward expiration dates can influence FW, shedding light on the fact that differing behaviors toward expiration dates can contribute to household FW reduction. On one hand, high attention to expiration dates and their active use in consumption planning can lead to FW reduction (e.g., Samotyja and Sielicka-Różyńska, 2021), while on the other hand, a strategy based on sensory attributes associated with product quality and freshness may also help mitigate FW (van Boxstael et al., 2014). These findings highlight the role of perception-driven and information-driven factors in shaping consumers' decisions regarding food edibility assessment (e.g., Dinnella et al., 2014; Malgaard et al., 2024). Consumers in the HI segment predominantly rely on date labels as a structured, rule-based approach to determine food safety (Sielicka-Różyńska and Samotyja, 2023), whereas those in the LI segment prioritize sensory assessment, using smell, appearance, and texture as primary indicators (van Boxstael et al., 2014; Coskun, 2021). The preference for one behavior over the other is influenced by factors such as trust in labeling systems, confidence in sensory evaluation, and individual risk perception (Myhrer et al., 2024; Wallnoefer et al., 2024). Recognizing these underlying mechanisms—particularly the differences in attention, understanding, and use within each segment—can provide valuable insights for designing targeted interventions aimed at promoting FW reduction while ensuring food safety.

4.3. The characterization of consumer clusters differing in date labels involvement

The literature has indicated that socio-demographic characteristics can be related to understanding, attention, and behavioral responses regarding date labels (Toma et al., 2020; van Boxstael et al., 2014; WRAP, 2011; Zielińska et al., 2020). Exploring the identified segments according to characteristic variables may therefore be of interest for a deeper understanding of their nature and underlying mechanisms.

In the present study, gender demonstrated an effect on the segments, with a higher representation of men in the segment less involved with date labels. However, gender is generally not a variable that has been found to impact understanding and use of date labels in previous research within the European context (Toma et al., 2020; van Boxstael et al., 2014; WRAP, 2011; Zielińska et al., 2020). However, the literature has highlighted greater FW among the female population, although the higher presence of women in domestic food preparation may represent a confounding factor (Visschers et al., 2016).

Although the segments are generally balanced across adult age groups, lower involvement to date labels was associated with a higher percentage of younger individuals. The literature indicates that age significantly influences how well people understand and use date labels. European studies have found that younger adults typically have a lower understanding of food date labels compared to older adults, particularly regarding "best before" dates (Broad Leib et al., 2016; van Boxstael et al., 2014). Our data, align with other research that has identified a negative relationship between consumers' age and the amount of FW generated (Quested et al., 2013; Visschers et al., 2016).

Respondents' country had a significant effect on the segments, with a higher proportion of individuals from Central and Northern European countries (Sweden, Belgium, Germany) in cluster associated with decreased date labels involvement. Regional differences within the EU have already been observed regarding the importance of date labeling for consumption decisions (Eurobarometer 425), with Southern European countries showing a higher frequency of checking date labels and a greater influence of these dates on their consumption decisions (Toma et al., 2020).

In addition to socio-demographic variables, the segments differed in food consumption habits and food management practices. Consistent with the segments, higher involvement to date labels was associated with better food management and lower levels of household FW. While different segments may adopt various strategies for reducing FW (e.g., consuming after the expiration date vs. prioritizing consumption based on date labels), greater involvement to date labels was found to be the most effective behavior in minimizing FW. It is also noteworthy that the segment with higher involvement to date labels includes a larger proportion of individuals responsible for grocery shopping for their household. This finding may be attributed to the greater exposure individuals with higher involvement with date labels likely receive from food provisioning messages within the household. Alternatively, it is possible that those with greater involvement to date labels, being more frequently involved in food provision and management, have acquired more experience with label understanding and usage (Neff et al., 2019).

4.4. Practical implications and policy recommendations

A decade after the last regulatory harmonization of date labels in the EU, it has been found that the stated understanding of these labels has significantly improved among EU citizens. The strategy of introducing variations (e.g., Secondi et al., 2015) or integrations in nomenclature (e.g., Wallnoefer et al., 2024) should be evaluated cautiously, as this may lead to increased consumer confusion about the meaning of date labels, which may take additional time for European consumers to assimilate. An alternative could be to improve education and communication about existing labels, particularly regarding their meaning and behavioral usage (Kavanaugh and Quinlan, 2020). Understanding the specific behavioral patterns of different consumer segments regarding date labels offers valuable insights for policymakers, food industries, educators, and other stakeholders involved in the regulation and management of the food system. Practical recommendations for reducing FW can be developed by considering the two contrasting behavioral patterns identified in the study, tailoring interventions to align with the distinct ways consumers interact with and respond to date labels.

The HI segment is characterized by a heightened understanding, attention, and behavioral engagement with date labels. This segment tends to strictly follow expiration dates, often overlooking sensory evaluation, which could help identify products still suitable for consumption. Based on these assumptions, targeted communication strategies that encourage the use of sensory evaluation for products past their "Best Before" date but still safe for consumption could be crucial in reducing FW within this segment (Ray et al., 2024). For example, the use of labels such as Look-Smell-Taste labels (Wallnoefer et al., 2024), which provide visual cues prompting consumers to engage in sensory food assessments, could be especially effective for this segment.

Furthermore, since this segment strictly follows label information, planning tools can play a crucial role in aligning their consumption habits with expiration dates (Delley and Brunner, 2017). These tools, such as the usage of shopping lists and meal planning apps, should aim

to improve their ability to manage and prioritize food items effectively, preventing the disposal of products solely based on strict adherence to date labels. Additionally, educational initiatives focused on food preservation techniques or the creation of network groups for sharing tips and inspiration can support consumers of this cluster in extending the shelf life of their groceries (Ishangulyyev et al., 2019; Myhrer et al., 2024). Given the composition of the HI segment, these strategies and informational campaigns should primarily target female consumers who are more actively engaged in food management. To effectively reach this segment, retailers could implement initiatives such as setting up educational spaces in stores or providing resources on their media (Huang et al., 2021).

The LI segment is characterized by lower attention and reduced behavioral engagement with date labels. Considering this, potential strategies to enhance involvement with expiration dates could focus on raising awareness of possible behaviors related to date labels, with the aim of reducing household FW. Awareness can be improved by disseminating basic and easily implementable food management practices within this group, such as the FIFO (First In, First Out) rule or better freezer management (Pikora, Trzaska, & Ponder, 2021). Additionally, greater attention can be achieved by making date labels more visible and clearer, as this information is often not easily accessible or prominently displayed. This approach can increase exposure to consumers who do not actively seek date labels and are more likely to generate household FW due to forgetting them. Additionally, solutions that do not rely on the use of date labels could further contribute to improving attention to product freshness in these consumers (e.g., Mimica Touch – Närvänen et al., 2023).

Furthermore, the development of communication and educational materials that go beyond data interpretation and include information on storage (e.g., smart labels) could be valuable in increasing awareness of the shelf life of purchased food products for this segment (Annunziata et al., 2022; Gong et al., 2021). Considering that this segment results in lower awareness of date labels, targeted informational campaigns aimed at increasing the understanding of date labels' meaning could be helpful (Attiq et al., 2021; Gaiani et al., 2018). Furthermore, given the consumption of expired foods, it is important from a food safety perspective to better communicate the meaning of the "Use by" label and the risks associated with ignoring this expiration date. In accordance with Annunziata et al. (2022), these strategies and informational campaigns should be primarily targeted at young male consumers. In this regard, it would be beneficial to involve opinion leaders who can act as influential figures to encourage young consumers to become more aware of date labels and storage methods, particularly by using media platforms commonly used by this demographic (e.g., social media) (Teoh et al., 2021).

4.5. Research limitations and future research directions

To reach a large number of consumers across multiple European countries, this study used an online questionnaire with self-reported responses. While this method enables broad reach, self-administered questionnaires are prone to self-presentation biases, where participants may answer based on social acceptability rather than true behaviors, especially regarding sustainability (Cerri et al., 2019). Respondents may also struggle with accurately recalling or quantifying behaviors, leading to data inconsistencies. Future research could improve by directly observing consumer behavior through recorded tasks (e.g., diaries – den Boer et al., 2024), providing more accurate data and validating reported behavioral patterns related to FW.

Additionally, household FW was estimated qualitatively, without frequency-based measures. Even in high-reliability measures, consumers under report FW (Hoover & Moreno, 2017). Direct measurements, such as waste compositional analysis or a more structured questionnaire, could yield more accurate FW data (Pedrotti et al., 2023).

Another limitation is the moderate internal consistency observed for understanding, attention, and behavioral responses to date labels. Future research should consider revising scales for better internal consistency or using alternatives with higher reliability.

Given the confusion around date labels and various packaging types (e.g., packaged vs. non-packaged food), future research could use more specific terminology in questionnaires to better identify consumer behaviors and avoid general assumptions.

Lastly, most existing studies on consumer behavior regarding date labels have focused on demographic or socio-economic factors (e.g., Toma et al., 2020). This study expanded characterization by including behavioral aspects. Understanding involvement patterns could benefit from including psychological traits (e.g., risk propensity, disgust sensitivity – Marton et al., 2021; Sevi and Shook, 2021) or personality traits (e.g., Myhrer et al., 2024).

5. Conclusions

The study provides an updated European perspective on the link between date labels and household FW, focusing on understanding, attention, and behavioral responses to date labels. It confirms that a significant proportion of European consumers, 75.2 %, understand the difference between "use by" and "best before" dates. While better understanding of date labels correlates with reduced FW, it alone is not enough to significantly lower waste levels. Behavioral responses to date labels prove to be a stronger predictor, with individuals who manage date labels effectively generating less FW. However, 36.4 % consume recently expired foods as a strategy to reduce FW, highlighting potential risks in terms of food safety. Segmentation analysis reveals three main consumer clusters regarding date labels: "Lower" (33.4 % of subjects), "Medium" (42.6 %), and "Higher involvement" (23.9 %) segments. Considering opposite poles, the "Higher involvement" segment closely follows date labels and tends to waste less food due to better planning. In contrast, "Lower involvement" segment relies on sensory evaluations and frequently consumes food past expiration date. This segmentation clarifies how different behaviors toward date labels affect FW, suggesting that targeted interventions should address these specific consumer patterns. The study also finds that males, younger individuals, and consumers from Central and Northern European countries tend to show lower involvement to date labels. Effective FW reduction requires not only understanding date labels but also addressing these behavioral tendencies and demographic factors. Tailoring interventions based on consumer segments and regional characteristics could improve FW management across Europe and help the EU reaching its Agenda 2030 SDGs.

CRediT authorship contribution statement

D. Cliceri: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **M. Pedrotti:** Writing – review & editing, Conceptualization. **F. Gasperi:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **I. Endrizzi:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Ethical statement

All the procedures to collect consent for subject participation and experimental activities of the present research have been reviewed and approved by the Ethics Committee of the University of Trento (Protocol No. 2023–002).

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used chatGPT

(OpenAI) to improve readability and language. After using this tool/service, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2025.105522.

Data availability

Data will be made available on request.

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