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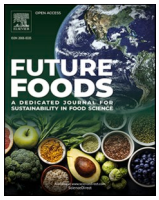

# Chilling the waste: Analysing household bread-freezing behaviours and their effect on bread waste

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ABSTRACT

Consumer bread storage practices significantly affect the shelf life of bread, which is one of the most wasted food items in households. Addressing consumer bread waste is crucial for reducing overall food waste at home. However, despite the vital role of bread and bakery products in our diets, consumer behaviour regarding freezing bread has received limited attention. This research investigates the connection between bread-freezing habits and household bread waste based on a nationally representative sample of 2033 Australian households. Most households usually purchase white bread, followed by wholemeal bread. Approximately 27 % of respondents indicated that they freeze bread immediately after shopping, while most do not freeze or refrigerate it as the expiry date approaches. The likelihood of freezing bread rises significantly for those who buy larger quantities. Rural and isolated consumers are inclined to freeze bread right after shopping, while those not in the workforce are less inclined. The findings indicate that freezing bread at home effectively reduces bread waste.

## 1. Introduction

Food waste is a significant global sustainability issue (Manzoor et al., 2024). In 2021, the world wasted 1.1 billion tonnes of food, which is about one-fifth of the food available for consumers at household, retail, and food service levels (UNEP, 2024). Considerable economic, environmental and social costs are involved in global food loss and waste. For instance, Australia wastes 7.6 million tonnes of food annually, costing the economy $36.6 billion (End Food Waste Australia, 2024) and generating 7.6 million tonnes of carbon dioxide emissions (FIAL, 2021). In Australia, the bulk of food waste (32 %) is generated by households (FIAL, 2021).

Household bread waste is a major contributor to food waste at home (Karunasena and Pearson, 2022). Bread loses its freshness during the short storage period due to staling and microbial contamination (Noshirvani and Abolghasemi Fakhri, 2025). It is an integral part of the daily diet of consumers around the globe (Sadowski et al., 2024). Therefore, it is not surprising that bread and bakery products constitute a significant portion of household food waste. While fruits and vegetables are the most wasted foods by weight, the category of cereals, including bread, represents the largest share of food wasted (53 % of global food loss and waste) when considering calories (FAO, 2011; Lipinski et al., 2013).

Household food management routines and practices are responsible for bread waste at home (Ananda et al., 2024). For example, over one-third of bread waste in Sweden emanates from households (Brancoli et al., 2019). In the UK, bread is the second-most wasted food, with 20 million slices discarded daily, contributing to 10 % of total household food waste (Hafyan et al., 2024). In Australia, more than 319,000 tonnes of food is wasted across the bread and bakery value chain, equivalent to the weight of 456 million loaves of bread (Stop Food Waste Australia, 2022).

Several previous studies have explored the influence of storage practices on general food waste (Gong et al., 2022; Keegan and Breadsell, 2021; Teng et al., 2020). However, the same attention has not been given to product and food category-level waste. Storage practices are imperative because different food categories and products possess different shelf-life features and elicit different consumer behaviours in food storage management. The literature has not explored consumer behaviours relating to storage practices (Chu et al., 2020). Specifically, studies focused on consumer storage practices, such as bread-freezing, are virtually non-existent. Further, freezing as a strategy to reduce consumer bread waste is underexplored thus far in the literature. It is also contended that storage advice on packaged food in Australia is often

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absent, incoherent, or misinterpreted (Langley et al., 2021). Despite the importance of addressing bread waste, there is a shortage of research focusing on the issue.

This study examines the impact of consumer bread-freezing practices on household bread waste. To the authors' knowledge, this research is the first to investigate the link between consumer bread-freezing habits and bread waste at home. This paper makes a novel contribution to the emerging literature on product-level food waste by addressing the research gap in consumer perspectives regarding household bread waste. The focus of our paper is on the product-level behavioural insights linked to bread waste. The vast majority of the existing body of work addresses food waste as a composite. This approach is problematic, particularly when designing food waste reduction interventions. Developing effective interventions or awareness programmes requires more nuanced insights that target major food types, categories, and identify specific high-wasting consumer cohorts. This paper evaluates the relationship between consumer bread-freezing practices and bread waste in homes. Furthermore, it examines various factors related to household bread-freezing practices.

## 2. Conceptual framework

Consumers play an important role in both generating bread waste and presenting significant opportunities for implementing potential bread waste reduction solutions. Bread waste at home is quite widespread across high income countries (Ananda et al., 2024). Fresh bread, in particular, is the most commonly wasted type of bread (Hanssen et al., 2016). Annually, an estimated 80,410 MT of bread waste (equivalent to 8 kg per capita per annum) has been reported across the supply chain in Sweden (Brancoli et al., 2019). Norwegian consumers discard 5.5 kg of bread per person each year (Hanssen et al., 2016).

Several past studies have examined the factors associated with consumer bread waste. Shopping behaviour has been identified as having a major influence on consumer bread waste (Middha and Willand, 2018). In particular, consumer bread purchasing behaviours such as grocery shopping frequency and precautionary or contingency (just-in-case) buying have been reported to be linked with consumer bread waste (Ananda et al., 2024).

Freezing and toasting bread have been shown to reduce bread waste at home (Middha and Willand, 2018). Freezing and repacking practices are common among low-waste groups (Middha and Willand, 2018). Like other food product waste, several socio-demographic factors can influence bread freezing and disposal behaviours, including household income, age of the household, young families (Ananda et al., 2024), geographical region (metropolitan, regional/remote), gender, and household type (presence of children at home) (Middha and Willand, 2018). Fig. 1 summarises key influences with regard to consumer behaviours and socio-demographic factors involved in bread freezing and disposal at home, which are analysed in this study.

## 3. Materials and methods

### 3.1. Data and sample description

We employed the Household Simulation Survey, commissioned by End Food Waste Australia and the Queensland Government in 2023. The online survey focused on consumer behaviours related to selected food products and their disposal. We implemented a quota sampling strategy and recruited respondents through an online panel provider. Participants were over 18 years old and fully or partially responsible for food management at home. All participants completed a consent form outlining the voluntary nature of participation, the anticipated use of survey data, the potential benefits and risks of participation, and instructions for withdrawing from the survey and lodging complaints. The market research company provided participants with a A$10 gift voucher or reward points for their involvement. The study was approved by the Human Research Ethics Committee of the host university (Approval No.: 0000024094). Section 1 of the survey gathered

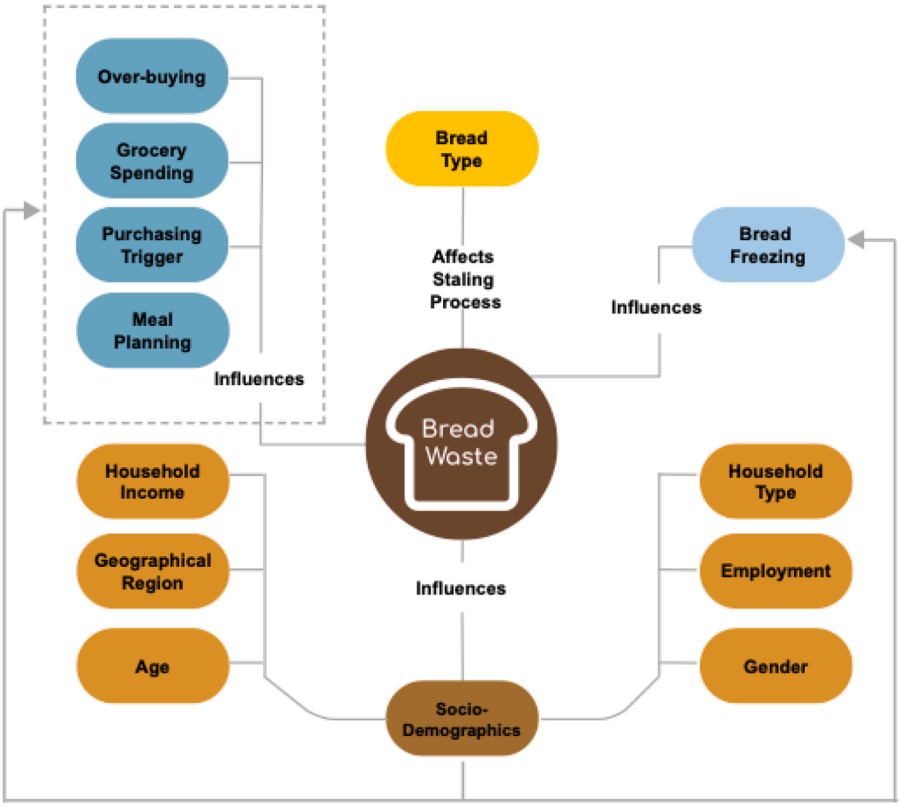


**Fig. 1.** Conceptual framework showing links between consumer behaviours, socio-demographic factors and bread disposal.

demographic, food management, and purchasing data. Section 2 included questions about the frequency of bread grocery shopping, the amount and types of bread purchased, and storage habits. The final section contained questions about bread disposal behaviours and quantities. Respondents were asked to estimate the bread discarded by them or their household members in the previous seven days in 250 g container equivalents. The choice of seven days for reporting bread waste was based on two considerations. The accuracy of self-reporting food waste depends on the respondent's ability to understand, recall and record food discarded (Hebrok and Boks, 2017). Therefore, from a practical point of view, 7 days is a reasonable time period to recall bread waste accurately. Second, the overwhelming majority of past studies have used 7-day period as the appropriate time period to recall and self-report food waste (Karunasena et al., 2021; Langley et al., 2009). They were also reminded of all possible disposal options, including throwing bread in the waste bin, composting it, or feeding it to pets. The survey was pre-tested with 15 target respondents, and the final sample comprised 2033 households.

### 3.2. Behavioural factors affecting bread freezing

Table 1 summarises the variables used in the analysis. Behavioural and socio-demographic information was collected as part of the data collection process. Behavioural variables represent food planning and food provisioning: buying too much food, trigger level for bread buying, changing meal plans, not using bread as planned, the bread type, and refrigerating food. Several variables, such as 'Buy too much food' and 'changing meal plans', were measured using a 6-point Likert scale, wherein participants expressed the frequency of the behaviour in question: 6 indicating 'almost every time', 5 'most times', 4 'half the time', 3 'sometimes', 2 'rarely', and 1 'never'. These variables were converted to dichotomous variables (Column 3 of Table 3) by collapsing 'almost every time' and 'most times' responses as 'Yes', while categorising other responses as 'No' for the ease of model estimation.

**Table 1**
Behavioural and socio-demographic variables.

| Label | Description | Coding |
|---|---|---|
| *Buy too much food* | "When doing the main shopping, how often do you or other members of your household buy too much food? (6=Almost every time; 1=Never) | Binary (Yes = 1; No = 0) |
| *Trigger level for bread buying* | 'What level of bread remaining in your household would prompt a top-up?': No bread; ⟨ half a loaf; ⟩ one loaf | Categorical |
| *Changing meal plans* | 'How often do you change meal plans last minute?' (6=Almost every time; 1=Never) | Binary (Yes = 1; No = 0) |
| *Not using bread as planned* | 'How many times in the last 7 days did you or members of your household order take-away or home-delivery?' | Integer |
| *Bread type* | 'What type(s) of bread have you or other household members bought in the last 2 weeks?': Standard bread (ex. white bread, wholemeal bread, multigrain bread); Specialty bread (ex. sourdough bread, rye bread, gluten-free bread, etc.) | Categorical |
| *Bread waste* | 'Amount of bread disposed of during last 7 days (250 g equivalents) | Integer |
| *Region* | 'Which best describes where you live': Metropolitan; Regional; Rural/Remote area | Categorical |
| *No. of persons in the household* | 'Indicate the number of persons in your household' | Numeric |
| *Age* | Age of the respondent (Household member who is responsible for food mgt.): 18–30 years; 31–40 years; 41–50 years; 51–70 years; 71+ years | Categorical |
| *Gender* | Gender of the respondent (Household member who is responsible for food mgt.): Male; Female | Categorical |
| *Employment status* | Unemployed; Employed | Binary (Yes = 1; No = 0) |
| *Household income* | 'Which of the following best describes your household income (before tax per week)?': <A$1000; A$1000-1999; A$2000-2999; >A$3000 | Categorical |

Note: A$ - Australian dollars

#### 3.2.1. Dependent variables

We used two ordinal dependent variables relating to bread-freezing behaviours: Stored bread in the freezer straight after shopping, and moved bread to the freezer when nearing the expiry date. The survey statement for the former variable was presented as follows: ' *We move bread to the freezer straight after shopping*'. Respondents reported the frequency of this practice at home using a 6-point Likert scale (see Section 3.2), where higher values imply households freeze bread almost every time or most of the time.

### 3.3. Statistical analysis

Ordinal multivariate logistic regression analysis is deemed suitable for analysing household bread-freezing behaviour given that the dependent variable, the bread-freezing frequency, was measured as an ordinal variable. Ordinal multivariate logistic regression explicitly incorporates the natural ordering of the dependent variable, unlike multinomial logistic regression, which treats categories as unordered. Therefore, the model chosen makes an efficient use of ordered information. The responses to the dependent variable for participant $i$ was specified as integer values, 1 to 6. The below ordered logistic model treats the dependent variable as a latent or unobserved variable.

$$y_i^* = X_i'\beta + u_i, i = 1, 2, \ldots n \quad (1)$$

where $X_i'$ is a vector of relevant bread management behaviours of household $i$, and $\beta$ is a vector of coefficients associated with the variables, $X_i'$ vector.

Key requirements in ordinal logistic regression include the dependent variable being measured on an ordinal scale, one or more of the independent variables being either continuous, categorical or ordinal, the absence of multicollinearity, and the proportional odds assumption, which requires each independent variable to have an identical effect at each cumulative split of the ordinal variable. By assuming proportional odds, the model improves the statistical power and requires a fewer parameters than multinomial models, which estimate separate coefficients for each category.

The ordered logistic regression output provides coefficients ($\beta$), representing the change in the log odds of being in a higher category (higher likelihood of freezing bread) for a one-unit change in the predictor variables while holding other predictors constant. A positive coefficient indicates that an increase in the predictor variable is associated with higher log odds of bread freezing. In contrast, a negative coefficient suggests that an increase in the predictor variable reduces the log odds of bread freezing. Odds ratios (OR) are relatively more straightforward to interpret and can be computed by exponentiating the ordered logit coefficients. An OR greater than one indicates that a one-unit increase in the predictor variable is associated with higher odds of bread freezing. In contrast, an OR less than one indicates that a unit increase in the predictor is associated with lower odds of bread freezing.

## 4. Results and discussion

### 4.1. Description of key variables

The survey data were refined by removing responses with missing values for variables used in the ordered logistic regression analysis. This

resulted in a sample of 1084 complete survey responses. Table 2 summarises the descriptive statistics of key variables used in the ordered logistic regression analysis.

### 4.2. Consumer bread refrigeration and freezing practices

Consumer bread storage practices were explored, and Fig. 2 summarises the responses. Twenty-five percent (25 %) of the sample stored bread in the refrigerator, and 31 % stored bread in the freezer *almost every time* to keep it as long as possible. Interestingly, about 27 % of respondents freeze bread straight after shopping *almost every time*. Respondents were asked whether they consume bread directly from the freezer, and 19 % of the sample responded in the affirmative. An analysis of the age distribution of the above cohort revealed that about 45 % of this group belongs to households over 60 years. A common misconception is that refrigeration of bread prolongs its shelf life. However, the temperature reduction during refrigeration accelerated the bread staling process (Alpers et al., 2021).

Responses to bread storage management questions are shown in Fig. 3. Most respondents did not move bread to the refrigerator (41 %) or freezer (39 %) when nearing the expiry date. Similar proportions were reported (35 % refrigerator and 38 % freezer) for not moving bread after a day or two of purchasing. Only a tiny fraction, ranging from 7–9 % of respondents, moved bread either to the fridge or freezer when nearing the expiry date or a day or two after purchasing. Although storing bread in the refrigerator accelerates the staling process, similar proportions of households moved bread to the fridge. It is essential to point out that the type of packaging also affects the staling process and the loss of softness. However, the survey did not contain information about bread packaging when stored.

**Table 2**
Descriptive statistics of the sample.

| Variable | $N = 1084$ |
|---|---|
| Buy too much bread: Yes | 151 (14 %) |
| Trigger level for bread buying | |
| < Half a loaf at home | 716 (67 %) |
| > One loaf at home | 93 (8.7 %) |
| Zero bread at home | 266 (25 %) |
| Change meal plans: Yes | 157 (14 %) |
| Grocery expenditure | |
| <$100 per week | 265 (24 %) |
| $100–149 per week | 255 (24 %) |
| $150–199 per week | 210 (19 %) |
| >$200 per week | 354 (33 %) |
| Bread type | |
| Speciality bread | 212 (20 %) |
| Standard bread | 872 (80 %) |
| Bread waste per week (kg) [1] | 1.0 (0.0, 3.0) |
| Region | |
| Metro | 747 (69 %) |
| Regional | 258 (24 %) |
| Rural/Remote | 79 (7.3 %) |
| Single household | |
| Other | 913 (84 %) |
| Single | 171 (16 %) |
| Count of persons[1] | 2.00 (2.00, 4.00) |
| Unemployed: Yes | 332 (31 %) |
| Age | |
| 18–30 years | 282 (26 %) |
| 31–40 years | 249 (23 %) |
| 41–50 years | 180 (17 %) |
| 51–70 years | 260 (24 %) |
| 71+ years | 113 (10 %) |
| Gender | |
| Female | 661 (61 %) |
| Male | 420 (39 %) |
| Household income | |
| <A$1000 per week | 346 (32 %) |
| A$1000-A$1999 per week | 384 (35 %) |
| A$2000-A$2999 per week | 180 (17 %) |
| A$3000+ per week | 174 (16 %) |

n (%).
[1] Median (Inter Quartile Range); A$ - Australian dollars.

### 4.3. Types of bread bought

Fig. 4 shows the types of bread bought by Australian households. The overwhelming majority (46.3 % of the sample) bought white bread, followed by wholemeal bread (16.5 %), other (13.6 %) and multigrain bread (13.3 %). The other bread categories included baguette, brioche, spelt, Turkish/Foccacia, and fruit bread. About 5 % of respondents bought sourdough bread, while a small percentage of households purchased other specialty bread. We also explored the correlation of bread waste among various bread types. The results are presented in Fig. A1 of Appendix 1.

### 4.4. Influence of freezing bread on bread waste

The effect of bread freezing on household bread waste was examined by dividing the sample into two groups: bread freezers and bread non-freezers. Respondents who reported freezing bread '*almost all the time*' were categorised as bread freezers, while the rest were classified as non-freezers. On average, a household freezing bread incurs 0.404 kg (SD = 0.923) of bread waste per week, while a household that does not freeze bread is associated with 0.534 kg (SD = 0.953) of bread waste per week (Fig. 5). The Wilcox-rank sum test indicated that freezers' median bread waste is significantly different from non-freezers ($W = 231{,}004$, $p$-value $< 0.001$).

### 4.5. Modelling results of bread freezing

Table 3 shows the ordered logistic regression modelling results for two slightly different dependent variables related to household bread freezing: (1) freezing bread straight after shopping and (2) freezing bread nearing expiry. Robustness checks of the two models using the Brant test (Schlegel and Steenbergen, 2020) confirmed the validity of the proportional odds assumption. The multicollinearity assumption was tested using the *'performance'* R package (Lüdecke et al., 2021). Household income showed high correlation (VIF > 10), grocery expenditure, region, and age variables indicated a moderate correlation (VIF 5–10) and other variables did not indicate multicollinearity.

#### 4.5.1. Behavioural associations of bread freezing

Both multivariate ordinal regression model results indicate a positive association ($p < 0.01$) between bread freezing and households purchasing too much bread (Table 3). Fig. 6 summarises the results of model 1 (freezing bread straight after shopping) in terms of probabilities. Given the short shelf life of bread, it is plausible that those consumers who buy more bread freeze their bread to extend the shelf life. Consumers who freeze bread straight after shopping showed a positive association ($p < 0.001$) between bread freezing and top-up shopping for bread when more than one loaf of bread is available at home.

Households that change their meal plans are associated with bread-freezing behaviour in both ordered logistic regression models. Particularly, bread freezing was associated with the consumer practice of overbuying bread. Table 3 shows that the odds of bread freezing increase by 78 % for those who over-purchase bread compared to those who do not. It is well-established that shopping behaviour is intrinsically linked to bread waste (Middha and Willand, 2018). For example, Ananda et al. (2024) reported that top-up grocery shopping and just-in-case buying are positively associated with bread waste. It is reasonable to assume that those who buy extra loaves of bread find freezing a pragmatic solution to bread storage and extend shelf life. Moreover, it is also possible that some consumers over-purchase because they freeze bread.

The trigger level for bread purchasing showed a positive association with bread freezing. Purchasing bread when one loaf of bread remains at

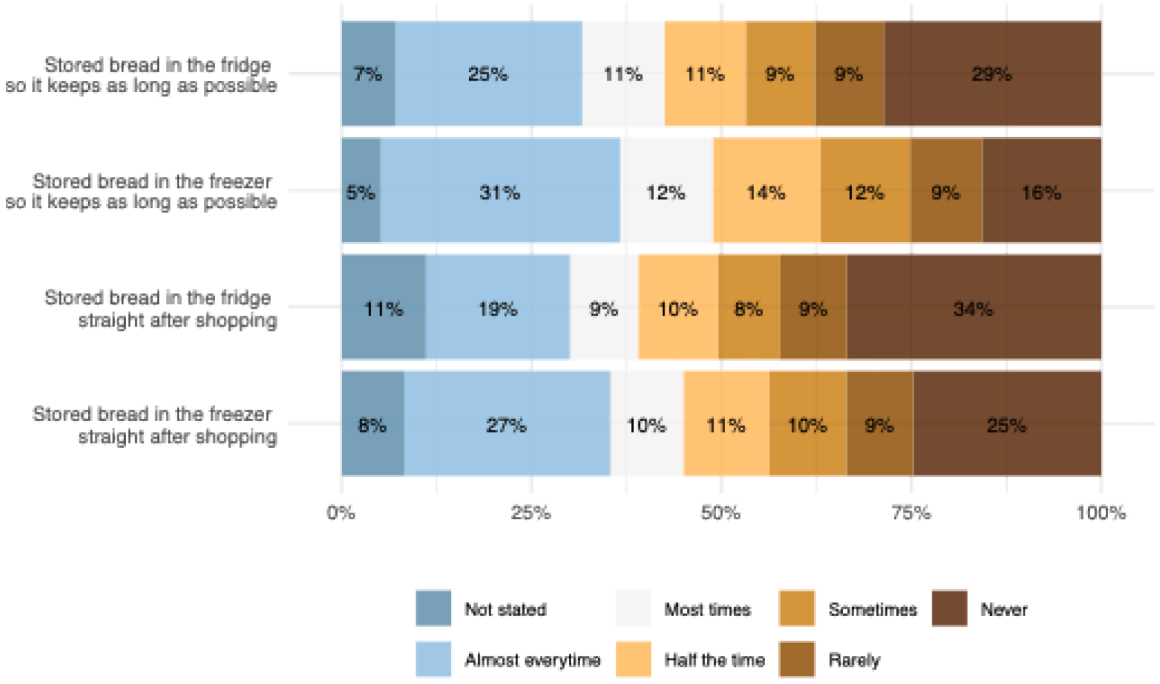


**Fig. 2.** Consumer bread refrigerating and freezing practices. The proportions of the sample storing bread in the refrigerator and freezer: The top two bar charts show freezing/refrigerating to extend shelf-life; the bottom two charts show freezing/refrigerating straight after shopping.

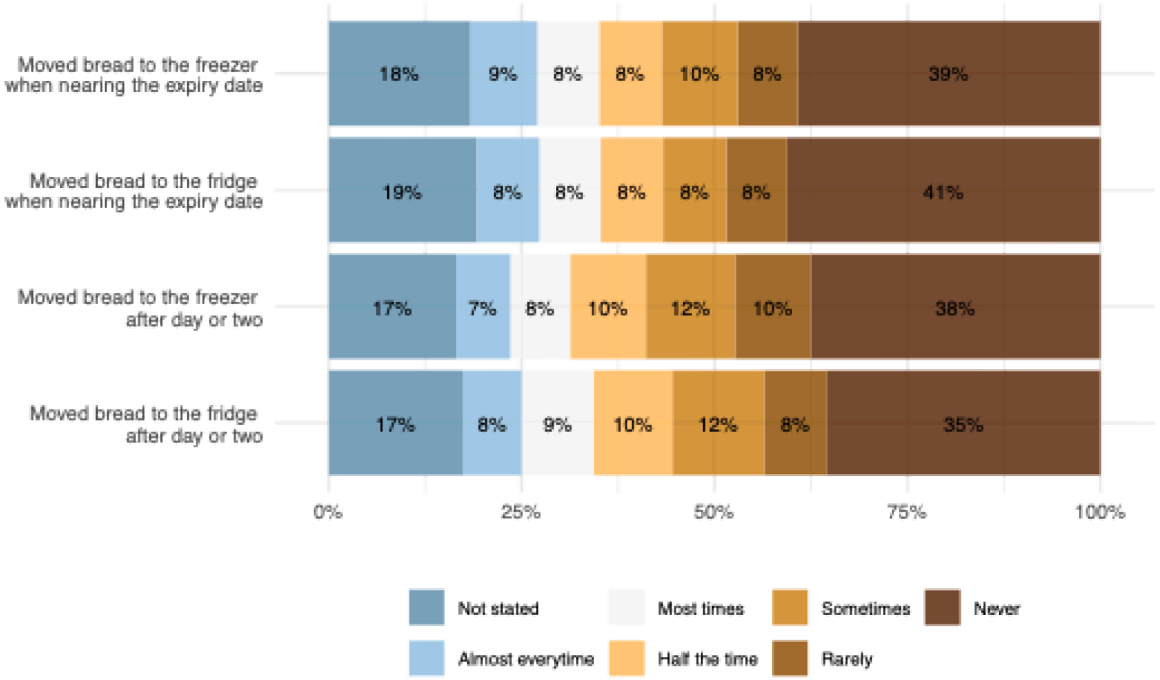


**Fig. 3.** Consumer bread storage management practices. The proportions of the sample moving bread to the refrigerator and freezer: The top two bar charts show moving bread to the freezer/refrigerator when nearing the expiry date, and the bottom two bar charts show moving bread to the freezer/refrigerator after a day or two of purchasing.

home increases the odds of freezing by 91 % compared to those who buy bread when no bread is available at home (Fig. 6). This implies that bread freezers tend to keep the bread inventory in check. The shopping trigger level also highlights the potential 'just-in-time' (JIT) grocery shopping (Ellison et al., 2022) tendency in bread purchasing. In this approach, consumers make smaller grocery trips more frequently to purchase food items needed for their immediate needs rather than stocking up. Ellison et al. (2022) reported that consumers that adopt a JIT approach incur less food waste. However, this appears more relevant to non-freezers than freezers.

Time availability and distance to the store influence the bread top-up trigger. Geographical location's influence on consumer bread-freezing behaviour confirms this. Rural and remote consumers' odds of bread-freezing increase by 117 % compared to metropolitan consumers (Fig. 6). This could be due to the relatively large distances to grocery stores in remote areas, which make consumers buy more bread and

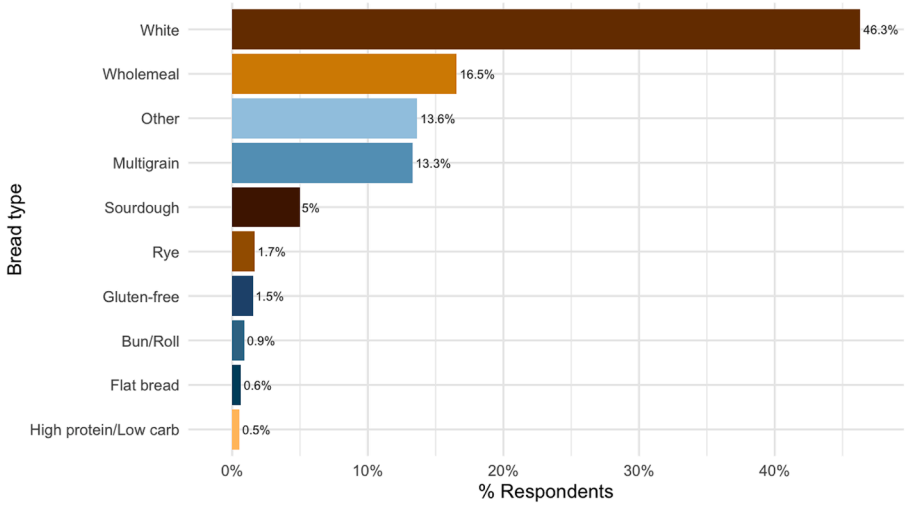


**Fig. 4.** Types of bread purchased by the respondents. The horizontal axis displays the percentage (%) of respondents who purchased each type of bread. The 'Other' category comprises the bread types: baguette, brioche, spelt, Turkish focaccia, and fruit bread.

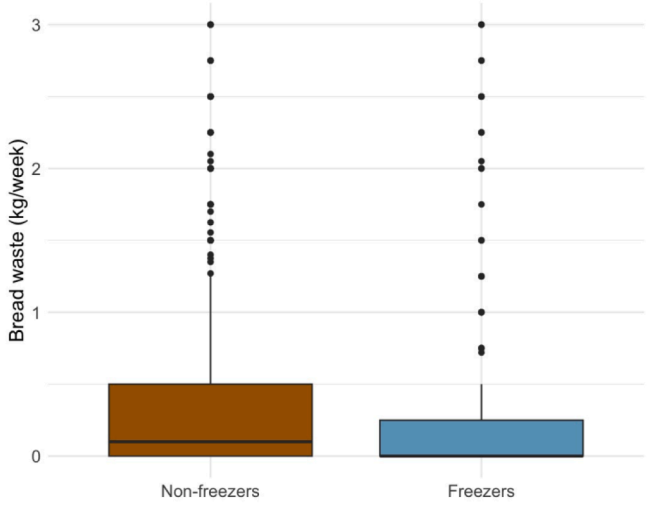


**Fig. 5.** A boxplot comparison of bread waste between households that freeze bread (Freezers) and those that do not (Non-freezers). The shaded box represents the interquartile range or the middle 50 % of values.

freeze it, and/or the relatively sizeable freezing capacity in rural and remote households.

Consumers who do not use bread as planned were associated with bread-freezing behaviour. The probability of bread freezing increases by 17 % if consumers do not use bread as planned. Households that lack planning skills for meals may find bread freezing a useful means of managing their bread inventories efficiently. Standard bread, compared to specialty bread, did not show a significant association with freezing practices.

People who are not in the workforce decrease the odds of bread-freezing by 31 % compared to working people. This is consistent with the existing evidence on general food waste. Those not in the workforce include unemployed people, stay-at-home parents and retired people. Unfortunately, we did not have information to distinguish between these groups in our dataset. Nevertheless, the available evidence suggests that people not in the workforce have relatively more time for food management at home than those employed (Qi and Roe, 2016), which could influence this group's bread-freezing behaviour. Cecere et al. (2014) found that full-time employed people have less time and tend to generate more food waste than those not in the workforce (Schanes

**Table 3**
Ordered logistic regression model results for bread freezing.

| Variable | *Freeze bread straight after shopping* | | *Freeze bread nearing expiry* | |
|---|---|---|---|---|
| | Coeff | *p*-value | Coeff | *p*-value |
| Buy too much bread [Yes] | 0.510 | 0.003*** | 1.065 | 0.000*** |
| Trigger level for bread buying | | | | |
| > One loaf of bread at home | 0.901 | 0.000*** | 0.225 | 0.278 |
| Zero bread at home | −0.254 | 0.054* | 0.078 | 0.568 |
| Change meal plans [Yes] | 0.751 | 0.000*** | 0.870 | 0.000*** |
| Bread not used as planned [Yes] | 0.155 | 0.047** | 0.370 | 0.000*** |
| Grocery expenditure | | | | |
| A$100–149 per week | −0.494 | 0.003*** | −0.037 | 0.832 |
| A$150–199 per week | −0.037 | 0.832 | 0.061 | 0.735 |
| >A$200 per week | −0.160 | 0.316 | −0.138 | 0.414 |
| Bread type | | | | |
| Standard bread | 0.109 | 0.438 | 0.032 | 0.826 |
| Bread waste | 0.009 | 0.360 | 0.039 | 0.000*** |
| Region | | | | |
| Regional | 0.091 | 0.494 | −0.115 | 0.410 |
| Rural/Remote | 0.795 | 0.000*** | 0.170 | 0.475 |
| No. of persons in the household | 0.054 | 0.166 | −0.063 | 0.142 |
| Age | | | | |
| 31–40 years | −0.241 | 0.118 | −0.103 | 0.517 |
| 41–50 years | −0.177 | 0.308 | −0.544 | 0.002*** |
| 51–70 years | 0.232 | 0.181 | −0.690 | 0.000*** |
| 71+ years | 0.209 | 0.384 | −1.170 | 0.000*** |
| Gender | | | | |
| Male | −0.049 | 0.675 | 0.226 | 0.060* |
| Unemployed [Yes] | −0.326 | 0.033** | −0.452 | 0.005*** |
| Household income | | | | |
| A$1000–1999 per week | −0.202 | 0.172 | −0.353 | 0.023** |
| A$2000–2999 per week | −0.313 | 0.080* | −0.385 | 0.045** |
| A$3000+ per week | −0.445 | 0.016** | −0.194 | 0.309 |
| Cut 1\|2 | −0.954 | 0.000*** | −0.740 | 0.003*** |
| Cut 2\|3 | −0.449 | 0.056* | −0.239 | 0.335 |
| Cut 3\|4 | 0.143 | 0.542 | 0.430 | 0.084* |
| Cut 4\|5 | 0.783 | 0.000*** | 1.068 | 0.000*** |
| Cut 5\|6 | 1.401 | 0.000*** | 1.975 | 0.000*** |
| Log Likelihood | −1779 | | −1568 | |
| Pseudo $R^2$ (McFadden) | 0.03 | | 0.07 | |

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

Note: Cut points (Cut 1, Cut 2, etc.) represent thresholds on an unobserved latent variable that determine the observed ordinal outcome categories. The reference levels for categorical variables are not shown in the table.

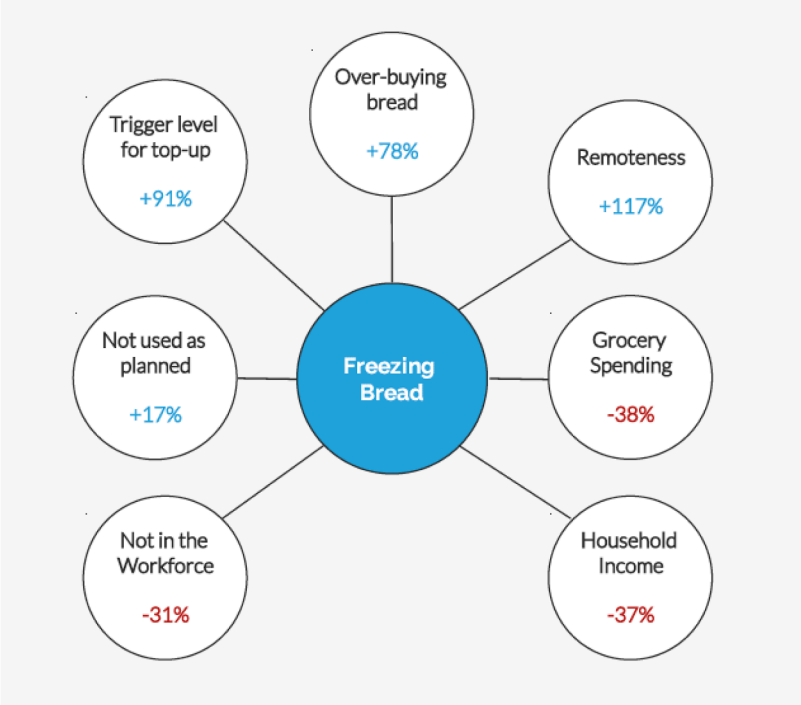


**Fig. 6.** Factors influencing consumer bread-freezing behaviour. Only statistically significant ($p < 0.05$) variables are shown. Positive and negative percentages indicate increasing and decreasing odds of freezing bread.

et al., 2018).

Both relatively high-income earners and grocery spenders showed significant associations with freezing bread. Specifically, households that spend $100-$149 weekly on groceries had lower odds of bread freezing than households that spend less than $100 weekly on groceries. Similarly, the household income category, $1000-$1999 per week, was associated with lower odds of bread freezing than households with a weekly income of less than $1000.

Fig. 7 shows the results of the second model estimated for bread freezing behaviour. In this model, the bread-freezing frequency of bread nearing the expiry date was considered as the dependent variable. As expected, slightly different covariates showed associations with this

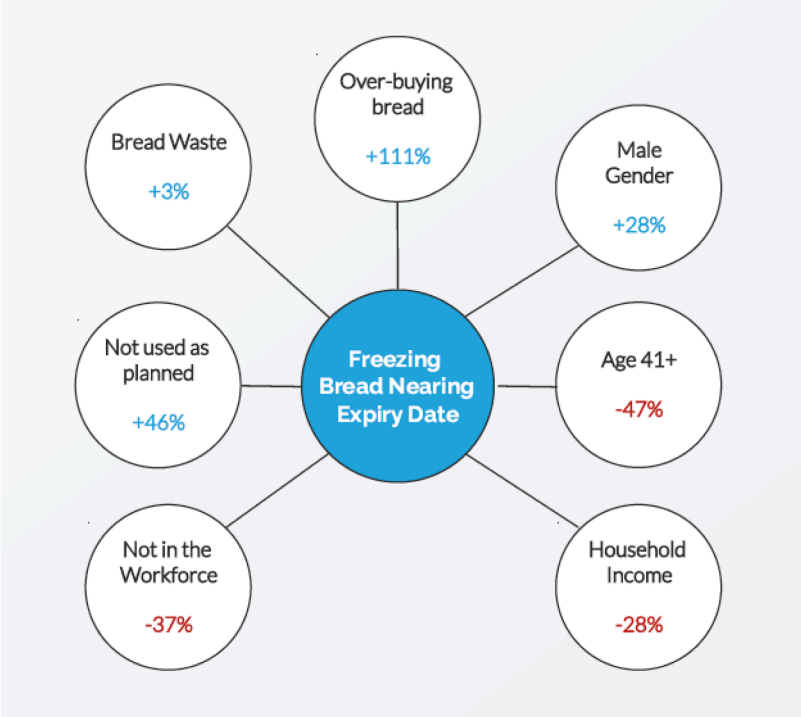


**Fig. 7.** Factors influencing near expiry date bread-freezing behaviour. Only statistically significant ($p < 0.05$) variables are shown. Positive and negative percentages indicate increasing and decreasing probabilities of freezing bread.

behaviour. For example, freezing bread near the expiration date was positively associated with bread waste, and the male gender depicted a higher likelihood of this behaviour than females. Older cohorts and people not in the workforce are less likely to freeze bread nearing the expiry date.

## 5. Policy implications

### 5.1. The role of packaging

A recent review of packaging solutions to reduce household food waste (Chan, 2022) found that fruit and vegetables, fresh meat, and poultry have received more attention than bakery items. Consumers report seeking storage advice on meat and dairy items but not other products (Brennan et al., 2023). Consumers are often unaware of the best way to store food to extend shelf life. Freezing bread is perceived as inconvenient and takes away the pleasure of fresh bread (WRAP, 2011). There are opportunities for the industry to take action to reduce bread wastage in households by providing storage and freezing guidance on packaging (Llagas et al., 2025).

Further research found that the guidance on freezing and defrosting can feel like 'the small print' and could be more salient (WRAP, 2019). Feedback from a packaging design trial suggested that consumers need assurance about freezing bread and that it will still suit their needs and taste good if defrosted (WRAP, 2019). The Bread and Bakery Sector Action Plan (Stop Food Waste Australia, 2022) recommended adding visual cues about storage advice, including freezing and a 'freeze from here' line, to bread packaging to reduce household food waste. The likelihood of bread manufacturers adopting such packaging cues relies on their commitment to reducing bread waste and evidence that these actions effectively reduce waste.

Ideally, packaging should have simple cues about freezing on the front, such as a snowflake logo, to normalise the practice of freezing bread. Motivational messages such as 'Never bin a slice again' allow consumers to infer the benefits of freezing bread. A simple tagline, such as 'Freeze in freshness,' can help dispel the notion that freezing bread will significantly reduce its quality.

Further information on the back of the pack must give the consumer confidence about how to freeze and defrost bread correctly. For example, if a whole loaf is sliced or cut into smaller portions before freezing, consumers can defrost a suitable amount when required rather than the entire loaf, which may result in wasted defrosted bread. Helpful information could include;

- Wrap the bread tightly in plastic, expelling air to avoid freezer burn and absorption of freezer flavours;
- Label and date bread so the oldest can be used first (End Food Waste Australia, 2025);
- Best used within 3 months of freezing (Love Food Hate Waste, n.d.; WRAP, 2019);
- Defrosting bread in its wrapping retains moisture in the loaf;
- Slice bread before freezing so you can quickly defrost an appropriate amount;
- Bread can be used from frozen to toast or make sandwiches.

Bread manufacturers could also encourage consumers to freeze bread using packaging material suitable for home freezing. The consumer should be aware that the packaging is suitable for freezing as sometimes it is not perceived that the original packaging is suitable for storage (Middha and Willand, 2018). However, further research is needed to ensure that the benefits of reducing food waste outweigh the environmental costs associated with the packaging.

For bread not sold packaged, in-store advice on freezing bread to prolong its shelf life or information cards could be provided. However, it should also be emphasised that freezing bread alone will not resolve the bread waste issue. For example, there is evidence that a small proportion (6 % in the U.S.) of household food waste emanates from frozen food (Xu et al., 2024). Consumer perceptions about the convenience of bread freezing/thawing and the sensory quality of frozen bread are also unclear. Despite large parts of Australia having warmer climates, the findings of the present study suggest that bread freezing is not widespread among households. Further research is needed on the effectiveness of information received during purchase and consumer perceptions regarding storage temperature and changes in bread quality.

### 5.2. Rural and remote consumers

It was found that rural and remote consumers tended to freeze bread straight after purchase. It would be helpful to understand more about the drivers of this behaviour. It could be related to the fact that due to the distance from shops, consumers shop less frequently, buying more at each shop, and so are more aware of practices of prolonging shelf life. Alternatively, it could be driven by the fact that rural dwellings tend to have a larger footprint and have more space available for larger freezers (Middha and Willand, 2025; Taylor, 2022) so they can quickly freeze bread.

### 5.3. Over-purchasing

Retailers can influence household consumption patterns and waste rates (FIAL, n.d.), primarily through sales promotions such as Buy One Get One Free (BOGOF) on perishable food items, which may encourage consumers to purchase more than they need. These promotions may assist supermarkets in minimising food waste by facilitating the sale of foods nearing expiration but may transfer the food waste responsibility to the consumer. That said, van Lin et al. (2023) no evidence was found of BOGOF promotions contributing to household perishable food waste. More research is needed to understand the potential risks of such promotions driving household food waste. Therefore, food manufacturers and retailers play a role in ensuring that food promotions do not lead to increased perishable food waste at the consumer level.

## 6. Conclusions

This study examined the relationship between freezing bread and household bread waste in Australia, utilising a comprehensive national food product and behaviour dataset. Logistic regression models were used to evaluate the behavioural and socio-demographic factors that influence consumer bread freezing practices. To the authors' knowledge, this is the first study to underscore the behavioural influences of bread freezing in Australian households. As a result, the study enhances understanding of product-level household food waste, which is essential for creating effective and targeted interventions to tackle the food waste problem.

The analysis revealed several consumer behaviours and socio-demographic factors related to home bread-freezing practices. Over-purchasing and its triggers were linked to a higher likelihood of freezing bread. Bread freezers also did not utilise bread as intended. Freezing may result from not using bread as planned. Remote and rural households are more inclined to freeze bread than their metropolitan counterparts. Interestingly, individuals not in the workforce are less likely to freeze bread, while low grocery spenders and middle-income households also exhibit a lower tendency to freeze bread. We also found that freezing bread is associated with reduced bread waste at home. These insights can inform household bread waste reduction campaigns focusing on education and raising awareness.

### 6.1. Limitations and future research directions

The study has several limitations. The survey lacked information about household freezer capacities, which can vary based on socio-economic status and whether the household is in an urban or rural

area. Notably, the findings suggest that rural or remote households freeze bread more frequently and may also have larger freezer capacities than their metropolitan counterparts.

The bread waste values used in the study are estimates provided by respondents. As with many self-reported food waste studies, the measurement of bread waste is subject to several limitations. First, the recall bias (Quested et al., 2020) could interfere with the accuracy of estimates. Second, estimates of wasted bread were based on 250 g increments, which may have contributed to measurement bias. Future studies can benefit from testing and establishing more accurate measurement techniques for self-reported bread waste. The presence of multicollinearity in some variables is another limitation. Using regularisation methods to reduce the impact of multicollinearity without removing predictor variables may help improve the reliability of the results.

Future research should investigate the heterogeneity in freezing capacity to determine how household freezer capacity influences bread-freezing behaviour in urban and remote regions. It can also be applied to various household types. Another potential research theme arising from this study is the influence of bread packaging and labelling information on bread waste. The research can be extended to explore the waste impact of various freezing instructions (textural, snowflake logo, etc.), which is less explored thus far. This study examined the relationship between over-purchasing and bread freezing. However, future studies could benefit from modelling the impact of the quantity of bread purchased on bread-freezing behaviour and the waste impact of the 'just-in-time' grocery shopping approach.

## Ethical statement

This research was conducted following the ethical review and approval of CQ University Australia (HREC ethics approval number: 0000024094).

## CRediT authorship contribution statement

**Jayanath Ananda:** Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **David Pearson:** Writing – review & editing, Supervision, Resources, Investigation, Funding acquisition. **Sarah Hughes:** Writing – original draft, Resources, Project administration, Investigation.

## 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 1

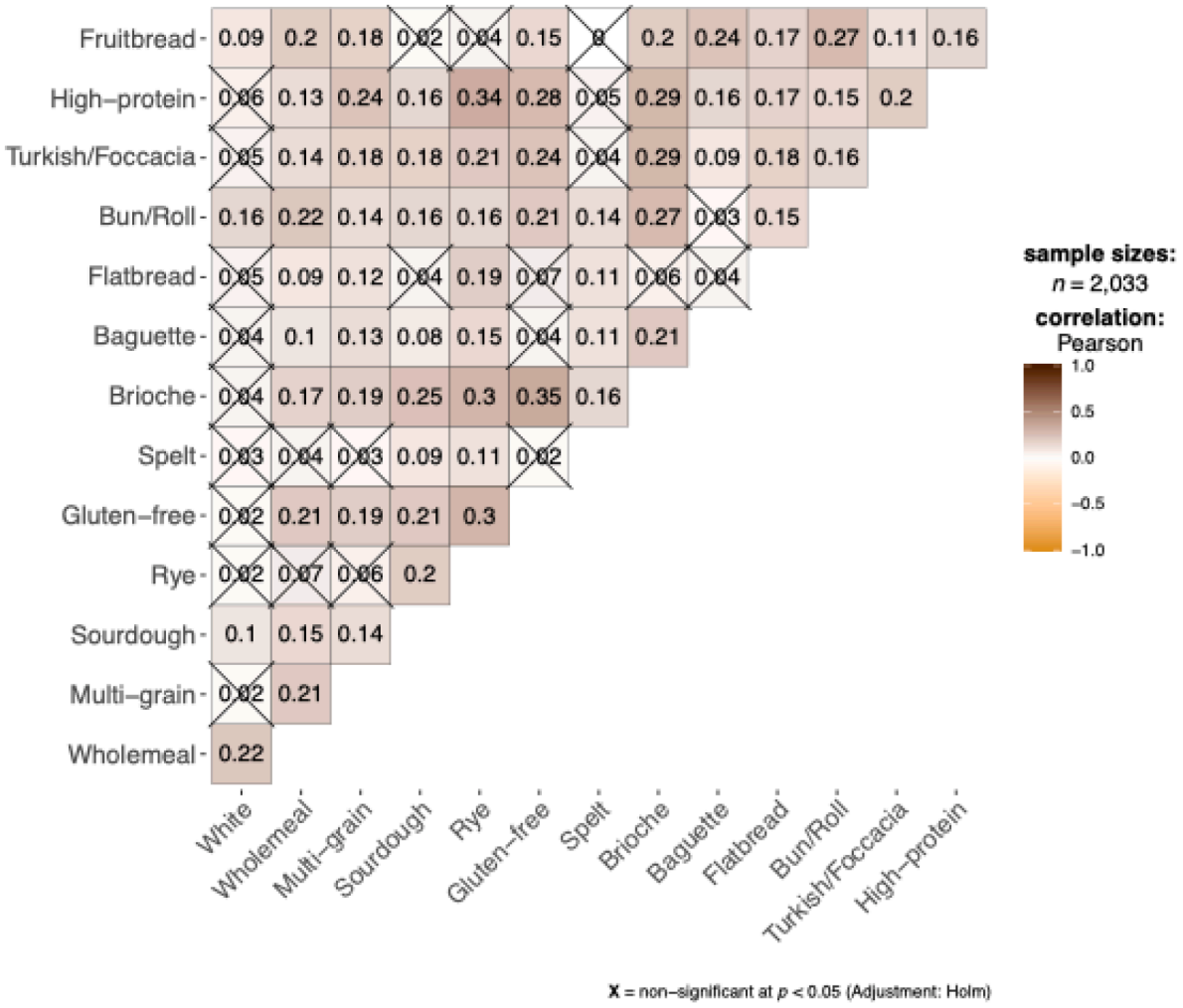


**Fig. A1.** Correlations among various types of bread waste. Correlations coefficients that are crossed are not statistically significant. The values are Pearson correlation coefficients.

## Data availability

The data that has been used is confidential.

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