# Modelling Food Waste: A Recursive Partitioning Approach to Consumer Segmentation

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**Abstract**

Food waste is a critical concern for sustainable food systems, especially in rapidly transforming food environments such as Albania. This study investigates the behavioural and demographic factors influencing food waste, using self-evaluated data on the quantity of waste from 41 food items across 420 households. Principal Component Analysis (PCA) revealed three distinct food waste patterns: (1) General Waste Pattern (across various categories), (2) Convenience Food Waste (e.g., ready meals, frozen products), and (3) Plant-Based and Dairy Waste.

Three behavioural drivers—inefficient planning and storage, overconsumption, and perishability mismanagement—were also extracted via PCA and used as predictors in CHAID decision trees. The first tree showed that general waste is primarily driven by perishability mismanagement, with further segmentation by planning skills and education. The second tree confirmed planning inefficiency as the most significant driver of convenience food waste, with younger, less-educated individuals paradoxically displaying better waste behaviour, echoing the food waste paradox, where lower-income or resource-constrained individuals waste less. The third pattern showed no significant differentiation.

These findings underscore the value of linking waste behaviours with both lifestyle and demographic profiles. They support tailored awareness campaigns and suggest future studies should integrate income and attitudinal variables for stronger predictive models.

**Keywords:** Food waste pattern, decision tree, consumer segments, demographics, PCA

## 1. Introduction

Food waste is increasingly recognised as a critical challenge for global food systems, with far-reaching consequences for environmental sustainability, food security, and efficient resource use (Araya-Bastias et al., 2024; Cattaneo et al., 2021; Conrad et al., 2018; Cooper et al., 2018; Feng et al., 2020, 2020; Franco et al., 2022; Lehmann, 2011; Tepper et al., 2022; Tucci et al., 2022). According to the FAO, nearly one-third of all food produced for human consumption is either lost or wasted, contributing to approximately 8–10% of global greenhouse gas emissions. Addressing food waste is, therefore, central to achieving key international policy goals, such as the United Nations Sustainable Development Goal 12.3 and the European Union's Green Deal and Farm to Fork Strategy. These frameworks call for urgent and coordinated action across the entire food chain to promote circularity, reduce emissions, and ensure sustainable access to nutritious food (Chidi et al., 2022; Conrad et al., 2018).

One of the structural contributors to food waste is the industrialisation of the food system, which has transformed traditional food regimes and reshaped consumption patterns (Ambikapathi et al., 2022; L. Baker et al., 2020; P. Baker & Friel, 2016; Cao & Li, 2023; Caron et al., 2018; Nikravech, 2023). The global proliferation of packaged and processed foods, combined with aggressive marketing, convenience culture, and supermarket-based supply chains, has weakened household practices related to food planning, preservation, and mindful consumption (Ambikapathi et al., 2022; Aschemann-Witzel et al., 2018; P. Baker & Friel, 2016; Brouwer et al., 2021). These shifts increase the risk of avoidable waste, especially in urban settings where over-purchasing and reliance on ready-made foods are more prevalent (Ambikapathi et al., 2022; Grando et al., 2017). While these developments are common across many countries, their impact varies depending on cultural context, infrastructure, and household behaviour. Albania is no exception to these global trends. The rationale for studying food waste behaviour in Albania is rooted in the country's rapid transformation of its food system, marked by accelerating trends of industrialisation, urbanisation, and market formalisation. Five key indicators highlight this structural shift. First, Albania experienced the highest increase in retail sales of ultra-processed foods (UPFs) in the region, with a 78% growth between 2017 and 2021, indicating a sharp rise in the availability and consumption of convenience-based products (Kokthi et al., 2023). Second, there was a 40% increase in the sale of packaged foods, signaling a shift away from fresh, unpackaged produce toward processed and industrially prepared items (UNECE, 2023). Third, per capita retail spending on packaged food reached $605.7 in 2021, reflecting both rising demand and greater accessibility to processed food options[1] . Fourth, the expansion of modern food retail, with 42.8 modern food stores and about 10 supermarkets per 100,000 inhabitants, suggests a consolidation of food access through formalised retail systems rather than traditional markets (Global Alliance for Improved Nutrition (GAIN) & Johns Hopkins University, 2020). Fifth, and critically, despite the growth in packaged food sales, Albanians still report cooking an average of 6.1 meals per week, suggesting a coexistence of traditional cooking practices with rising processed food consumption (FSD,2024). Together, these indicators reveal a transitional food system where industrialised consumption patterns are increasingly normalised, yet traditional behaviours persist (Kokthi, Guri, et al., 2025; Kokthi, Miftari, et al., 2025). This duality makes the Albanian context particularly valuable for examining how food system modernisation affects household food waste behaviour.

Industrial food products and fragmented shopping routines are increasingly replacing traditional diets based on local and seasonal ingredients (Aschemann-Witzel et al., 2018; P. Baker & Friel, 2016; Chadha et al., 2024; Llanaj et al., 2018; Vincze et al., 2023). Urban consumers, in particular, exhibit patterns of overconsumption, food forgetting, and limited use of leftovers (Al Mamun et al., 2024; Artmann et al.,

[1] Food system dashboard

2021; Aschemann-Witzel et al., 2018; Fardet & Rock, 2020; Liao et al., 2022; O'Neill, 2019; Thyberg & Tonjes, 2016). These shifts have significant implications for household-level food waste generation. Despite the relevance of the issue, systematic research on food waste behaviour in Albania remains scarce, especially when it comes to analysing waste by food category and linking it with behavioural and demographic drivers.

This paper addresses this gap by analyzing household food waste behaviour in Albania, with a specific focus on:

- the types and quantities of food categories wasted.
- the self-reported reasons that individuals associate with their food waste; and
- the demographic characteristics that influence household waste patterns.

Using original data from a structured household questionnaire, the study applies Principal Component Analysis (PCA) to uncover latent structures in both food waste behaviours and perceived waste drivers. It then utilises a CHAID decision tree model to classify and segment households based on their likelihood of high or low food waste across different categories. The aim is to develop behaviorally informed consumer profiles that can support targeted interventions, education strategies, and policy responses. The paper proceeds as follows: The next section outlines the methodology, including the data collection process, construction of variables, and statistical procedures. This is followed by the results and discussion, where the key behavioural patterns and demographic profiles are interpreted. The paper concludes by offering policy-relevant recommendations for food waste reduction in alignment with Albania's sustainability commitments and broader EU objectives.

## 2. Materials and methods

### *2.1 Sampling Description*

The study employed a convenience sampling strategy, targeting respondents in predominantly urban and semi-urban areas of Albania where supermarket access, lifestyle westernisation, and dietary transition are more pronounced. The final sample consisted of 420 valid responses, with a noticeable preponderance of female participants (80.5%) and respondents aged 18 to 40 years (categories 1 and 2 together representing 61%). Most participants reported living in households of 4–6 members, reflecting typical urban family structures, with a substantial portion (51.4%) indicating the presence of children. The sample was also characterised by relatively high educational attainment, with 65.2% of respondents holding a bachelor's degree or higher. This demographic composition reflects a segment of the population likely to be more exposed to globalised food systems, more engaged in household food purchasing and preparation, and thus more relevant for analysing food waste behaviour in modernising contexts.

### *2.2 Survey Instrument*

The survey instrument was a structured questionnaire developed specifically for this study to assess food waste behaviours, motivations, and socio-demographic characteristics at the household level. It consisted of three main sections. The first section focused on self-reported food waste behaviour, asking respondents to estimate the quantity of 41 specific food categories discarded in the previous seven days, using a standardised scale ranging from "less than 100 grams" to "more than 300 grams." The second section explored the perceived reasons for food waste, including statements related to over-purchasing, poor food planning, improper storage, and forgetfulness. Respondents rated these items on a five-point

Likert scale (1 = strongly disagree to 5 = strongly agree). The third section collected demographic data, including age, gender, education level, household size, and the presence of children. The questionnaire was administered in Albanian and designed to be easily comprehensible for a wide range of education levels, ensuring consistency and clarity across responses. The instrument was pre-tested for relevance and internal consistency prior to data collection.

*2.3 Statistical Analysis*

Descriptive statistics were first calculated to examine the frequency and distribution of demographic characteristics, food waste quantities by category, and self-reported reasons for food waste. To explore the latent behavioural drivers behind food waste, a principal component analysis (PCA) with Varimax rotation and Kaiser normalisation was conducted on 13 Likert-scale items measuring reasons for discarding food.

To classify households based on food waste frequency, a CHAID (Chi-square Automatic Interaction Detection) decision tree model was applied. The dependent variable waste quantity in the last seven days according to WWIOFS, represented the overall food waste assessment. Covariates included the quantities of 41 food categories discarded, the three behavioural components derived from PCA, and demographic variables such as age group, gender, education level, household size, and presence of children. The CHAID algorithm recursively splits the sample based on the most statistically significant predictors ($p < 0.05$, Bonferroni-adjusted), creating a hierarchical model of waste behaviour. This approach will enable the identification of distinct waste profiles and the influence of specific behavioural and contextual factors in driving household food waste patterns. The dataset was analysed using IBM SPSS Statistics 29.

## 3. Discussion of Results on Food Waste Patterns

### *3.1 Food Waste Patterns*

The PCA conducted on 41 food categories (WWIOFS) revealed a clear latent structure in household food waste behaviour. The Kaiser-Meyer-Olkin (KMO) value of 0.967 and a highly significant Bartlett's test ($\chi^2 = 22{,}558.93$; $p < 0.001$) confirmed very good sampling adequacy and the suitability of the data for factor analysis. The analysis extracted three components with eigenvalues greater than 1, cumulatively explaining 74.1% of the total variance. The first component, accounting for 28.4% of the variance, was characterized by high loadings on ultra-processed and convenience foods such as sauces, mayonnaise, pizza, sandwiches, and frozen meals. This component is interpreted as "Convenience-Driven Waste," reflecting high discard rates of pre-prepared or industrially produced food products.

High loadings on items such as dairy products, fresh fruits and vegetables, legumes, salads, and yoghurt marked the second component (22.9% variance). This factor, labelled "Perishable Healthy Foods", suggests a distinct waste pattern associated with fresh and nutritionally rich items prone to rapid wastage. The third component (22.7% variance) included strong associations with meat and animal-based products, including raw and cooked red and white meat, cold meat, chocolate, and alcohol. This pattern, interpreted as "Animal-Based and Indulgent Waste", points to waste behaviour linked to expensive, protein-rich, and indulgent foods.

The clear differentiation between these three components underscores the multidimensional nature of food waste, suggesting that households do not discard food uniformly across categories, but according to specific consumption logics. These findings are instrumental for tailoring waste reduction strategies. For example, interventions aimed at reducing convenience-driven waste may require targeting time-poor consumers and meal-planning habits. In contrast, those addressing fresh produce waste might

focus on storage skills or shopping frequency (Broekmeulen & van Donselaar, 2019). Similarly, waste of animal-based foods may relate more to ethical concerns, over-purchasing, or cultural food norms(Aschemann-Witzel et al., 2018; Liao et al., 2022).

### *3.2. Motivations Behind Food Waste*

The second PCA conducted on self-reported motivations for household food waste behaviour identified three distinct components, cumulatively explaining 52.2% of the total variance. The first component, accounting for 20.9% of the variance, grouped items such as *Buy Large*, *Shop Rarely*, *Cant Estimate*, *Fear Shortage*, *Poor Storage*, and *Buy Not Like,* see Table 3. These items suggest a pattern of Inefficient food planning and storage, where poor estimation of needs, bulk purchases, and improper storage contribute significantly to food waste. Similarly, this factor reflects structural inefficiencies in household food management, likely exacerbated by a lack of planning and knowledge regarding food preservation.

The second component, which explains 19.0% of the variance, includes *Buy Bulk*, *Cook Too Much*, *Buy Sales*, *Forget Food*, and *No Leftovers*. This pattern indicates impulsive overconsumption behaviour characterised by purchasing food due to promotions, over-preparation, and neglecting leftovers. This component aligns with behavioural tendencies linked to consumer habits influenced by abundance, convenience, and marketing stimuli.

The third component, contributing 12.3% of the variance, encompasses *Fruit Spoil* and *Food Expiring*. These variables load heavily onto a factor that we term "perishability mismanagement," which reflects household difficulties in handling perishable goods that spoil quickly due to insufficient freshness or a short shelf life.

Together, these components provide a robust framework for understanding the primary behavioural and structural drivers of food waste in Albanian households. Notably, the findings point to the coexistence of intentional (planned) and unintentional (habitual or structural) food waste behaviours. Thus, food waste requires tailored interventions that simultaneously target household planning capabilities, consumer behaviour patterns, and food preservation and perishability knowledge. These components were subsequently used as predictors in decision tree and moderation analyses to better understand their relative influence on food waste patterns by category and across different demographic segments.

*Table 1: Food waste patterns through PCA*

| **Components** | **Explained Variance (%)** | **Key Statements** |
|---|---|---|
| Inefficient Food Planning and Storage | 20.94 | Buy_Large, Shop_Rarely, Cant_Estimate, Fear_Shortage, Poor_Storage, Buy_NotLike |
| Impulsive Overconsumption Behaviour | 18.98 | Buy_Bulk, Cook_TooMuch, Buy_Sales, Forget_Food, No_Leftovers |
| Perishability Mismanagement | 12.31 | Fruit_Spoil, Food_Expiring |

Source: Author's elaboration

### *3.2 Decision tree discussion of results*

A decision tree analysis using the CHAID algorithm was conducted to identify the key demographic and behavioural drivers influencing household food waste. The first principal component (Factor 1 from the PCA on food waste patterns) served as the dependent variable. This component broadly captures general food waste behaviour across multiple food categories. The tree was grown with a maximum depth of 3 and minimum parent and child node sizes of 100 and 50 cases, respectively.

Among the independent variables, Perishability Mismanagement (REGR factor score three from PCA on waste drivers) emerged as the primary splitter in the model ($p < 0.001$), indicating it is the strongest predictor of food waste in this component. This suggests that respondents who mismanage perishable items by not consuming them before expiration or storing them poorly contribute significantly to higher waste levels.

Within the subgroup of individuals with higher Perishability Mismanagement scores, the tree further splits based on Inefficient Food Planning and Storage (REGR factor score 1). Those scoring higher on this dimension also showed increased waste behaviours, underlining the compounding effect of poor planning and perishability management. Education becomes the final discriminating factor for individuals with moderate planning inefficiencies. Specifically, those with lower education levels tend to report higher food waste levels.

The final tree consists of 7 nodes, including 4 terminal (leaf) nodes, indicating four distinct consumer segments regarding their food waste patterns. The highest mean waste score (0.354) was found in Node 4, representing individuals with high scores in Perishability Mismanagement and Inefficient Planning. Conversely, the lowest mean waste score (-0.444) was observed in Node 1, which is composed of individuals with lower tendencies towards Perishability management.

The model's risk estimate was 0.879 (SE = 0.070), indicating modest predictive performance, which is expected given the use of PCA scores and the complexity of food waste behaviours.

*Table 2 Summary Table – Decision Tree results*

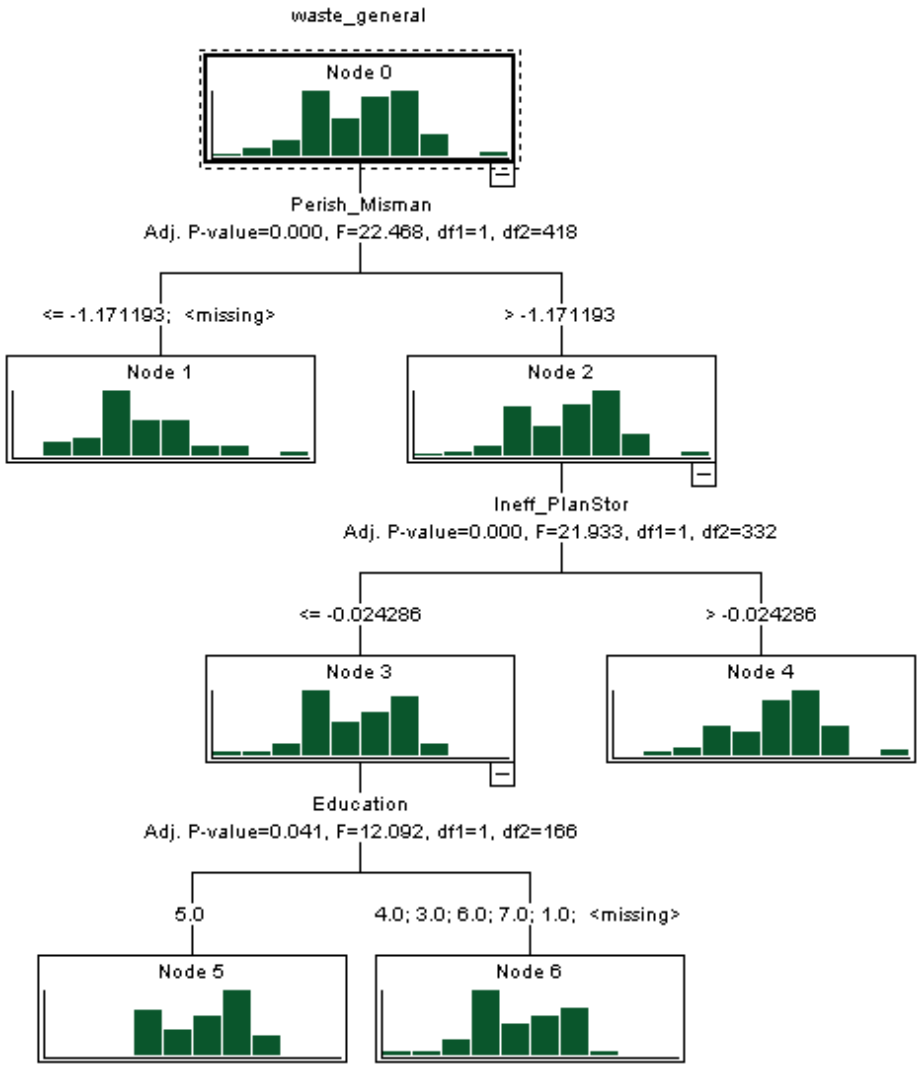
| Node | Segment Description | N | % | Mean Waste Score |
|---|---|---|---|---|
| Node 4 | High perishability mismanagement + high inefficient planning | 166 | 39.5% | 0.354 |
| Node 5 | Moderate planning inefficiency, lower education | 60 | 14.3% | 0.199 |
| Node 6 | Moderate planning inefficiency, higher education | 108 | 25.7% | -0.301 |
| Node 1 | Low perishability mismanagement | 86 | 20.5% | -0.444 |

Source: Author's elaboration

This analysis reinforces the idea that food waste is driven more by behavioural factors than by demographics alone (see Figure 1). Similarly, the findings highlight the critical roles of perishability mismanagement and planning inefficiencies, which are often overlooked in awareness campaigns.

Education appears to buffer against waste, potentially by enabling better food planning or increasing awareness of waste-related consequences.

*Figure 1: CHAID Decision Tree for General Food Waste Pattern*

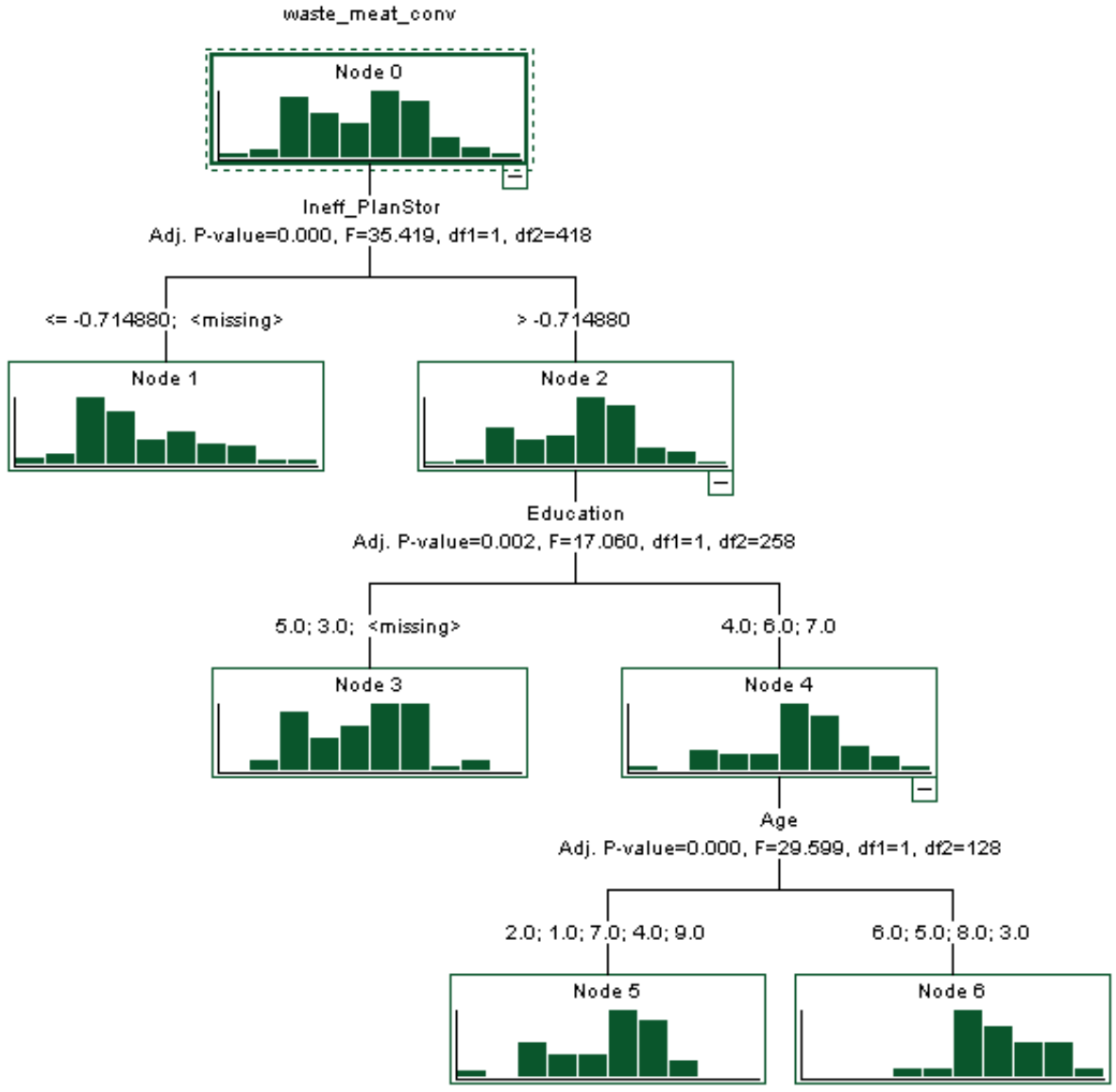



Source: Author`s elaboration

To complement these findings and disentangle the role of convenience-oriented consumption behaviours, we introduced a second decision tree, this time using Food Waste Pattern 3 focused on ready meals, frozen meals, and processed convenience foods as the dependent variable. This choice was driven by Albania's rapidly industrialising food system, rising urbanisation, and the significant increase in the availability and consumption of ultra-processed and packaged foods. Exploring this pattern offers crucial insights into how modern dietary shifts are shaping waste practices.

The second CHAID-based decision tree specifically focused on Waste Pattern 3, which is dominated by pre-prepared, frozen, and convenience foods (See figure 2). This analysis aimed to identify the demographic and behavioural drivers (using PCA-derived factor scores) most associated with this distinct waste cluster. Three variables emerged as statistically significant predictors: Inefficient Food Planning and Storage, education level, and age group.

*Figure 2: CHAID Decision Tree for Meat and Convenience Food Waste Pattern*




Source: Author`s elaboration

The model revealed seven nodes, with 4 terminal nodes. The first and most decisive split was based on inefficient planning and storage, highlighting that individuals scoring higher on this factor are significantly more likely to waste convenience foods (Node 6, Mean = 0.953). Among participants with

more efficient planning habits, the next split was based on education, where those with higher educational attainment showed moderately lower waste behaviour (Node 5, Mean = 0.139).
For less-educated individuals, age was the differentiating factor: younger respondents wasted less (Node 3, Mean = -0.014) compared to older ones (Node 1, Mean = -0.356). These results suggest that when planning inefficiency is minimised, socio-demographic factors become more salient, potentially due to differences in awareness, convenience reliance, or economic constraints.
The model's risk estimate was 0.837 (SE = 0.054), indicating a moderate yet informative level of predictive accuracy.

*Table 3: Terminal Nodes for Decision Tree 2 Waste Pattern 3 Convenience Food Waste*

| Node | Segment Description | N | % | Mean Score |
|---|---|---|---|---|
| 6 | High inefficient food planning and storage | 50 | 11.9% | 0.953 |
| 5 | Moderate planning inefficiency, higher education | 80 | 19.0% | 0.139 |
| 3 | Lower education, younger age group | 130 | 31.0% | -0.014 |
| 1 | Lower education, older age group | 160 | 38.1% | -0.356 |

Source: Author's elaboration

In this second tree, the first and most influential split was based on Inefficient Food Planning and Storage. Individuals with higher inefficiency in managing food planning were significantly more likely to waste larger quantities of convenience products (Node 6, Mean = 0.953). Among respondents with better planning, education emerged as the next critical discriminator, followed by age among lower-educated individuals. The younger, less-educated group (Node 3) exhibited relatively better waste behaviour compared to older counterparts (Node 1). The observation that younger and less-educated individuals (Node 3) exhibited lower levels of waste in convenience-oriented food categories, compared to older and more educated groups (Node 1), aligns with a phenomenon increasingly recognised in the literature as the "food waste paradox." Contrary to assumptions that higher education and income universally translate to more responsible consumption, studies have found that households with greater purchasing power often waste more food, not because of a lack of knowledge, but due to a reduced sensitivity to the economic and resource value of food (Principato et al., 2015; Secondi et al., 2015).
This paradox arises from a combination of factors. Higher-income households, often associated with higher educational levels, tend to over-purchase, seek greater variety, and are less reliant on leftovers, all of which increase the likelihood of discard (Porpino et al., 2015). In contrast, lower-income or resource-constrained households may adopt more sparing food management strategies, such as careful meal planning, creative use of leftovers, and reduced frequency of shopping trips, leading to lower waste levels despite potentially lower food literacy (Aschemann-Witzel et al., 2015, 2018; Evans et al., 2010).
In the Albanian context, where a significant share of the population still practices home cooking and demonstrates high food value consciousness, especially among the older or rural population segments, these dynamics may be shifting due to urbanisation and market modernisation. However, this study suggests that economic vulnerability or youth-driven financial constraints may still be enforcing cautious waste behaviour, particularly for ready-to-eat or pre-packaged foods, which are often seen as less essential. These counterintuitive dynamics highlight a critical point: awareness campaigns alone may be insufficient if they do not address structural and behavioural economic incentives. Policy interventions should thus not only focus on education but also consider economic behaviours, access to

affordable fresh foods, and cultural practices around food valuation. Recognising and addressing the food waste demographic paradox is vital for designing socially equitable and targeted food waste reduction strategies.
These two decision trees together allow for a multi-layered behavioural segmentation that distinguishes between generalist food waste behaviours and those driven by lifestyle convenience and system-level transitions. While the first model is more indicative of traditional household waste issues, the second highlights how modern retail structures and dietary westernisation are increasingly affecting food discard behaviours. Both models underscore the need for targeted interventions—from improved food planning campaigns to policies that address urban food environments and generational education gaps.

The comparison between the two decision models highlights the distinct behavioural pathways leading to food waste in different categories. While both models identify inefficient planning and education as significant factors, the first model (waste pattern 1) places greater emphasis on impulsive overconsumption (e.g., bulk buying and forgetting food), suggesting that unplanned purchasing and overcooking are key drivers of general food waste. In contrast, the second model (waste pattern 3), focused on ready-to-eat and processed foods, reveals that poor planning alone, especially among more educated and younger participants, plays a predominant role.
Interestingly, education appears in both trees but operates differently: in pattern 1, it distinguishes lower-waste households in combination with low impulsivity, while in pattern 3, it separates moderate waste when planning is poor. Additionally, age emerges only in the second tree, indicating that younger people, despite higher education, may be more prone to wasting convenience foods—possibly due to lifestyle habits, less cooking experience, or reliance on industrial food solutions.
The risk estimates of both models are comparable, with Tree 2 showing a slightly better fit (0.837 vs. 0.879). Together, these models illustrate the multifaceted nature of household food waste and reinforce the need for targeted interventions that account for both behavioural tendencies (such as impulsive or planning habits) and sociodemographic backgrounds.

The CHAID decision tree for the second food waste pattern (*Plant & Dairy Waste*) produced no significant splits, grouping all 420 respondents into a single node. This suggests that waste behaviour in this category is relatively homogeneous across the sample or not strongly influenced by the examined predictors. The result may reflect the routine and culturally embedded consumption of these foods in Albanian diets or point to unmeasured drivers requiring further investigation.

**Conclusions**

This study provides evidence on the behavioural and demographic drivers of household food waste in Albania, revealing distinct patterns and explanatory factors. Through principal component analysis, three major waste behaviour profiles were identified—General Food Waste, Convenience Food Waste, and Plant & Dairy Waste—each reflecting clusters of commonly wasted items.
Decision tree analyses highlighted that inefficient food planning and storage consistently predicted higher levels of waste in both general and convenience food categories. Furthermore, education and age moderate these relationships, indicating that food waste is not merely a result of access or knowledge but is deeply intertwined with habits and generational practices. The waste paradox also emerged, as lower—educated and older age groups, despite potentially having fewer resources, reported less waste, echoing findings from broader literature on food insecurity and frugality.
The absence of significant segmentation in the patterns of plant-based and dairy waste suggests a cultural uniformity in the use of these staples. However, it also signals the need to explore further variables, such as storage infrastructure, shopping frequency, and traditional preservation techniques.

Overall, these findings underscore the importance of targeted interventions that promote planning skills, storage awareness, and portion control, particularly among educated and urban consumers. Future research should incorporate attitudinal, psychological, and contextual factors to refine behavioural segmentation further and inform evidence-based policies for reducing household food waste.

This study offers a novel segmentation of food waste behaviour using PCA-derived patterns and CHAID decision trees, allowing the identification of distinct behavioural profiles. It provides actionable insights for tailoring interventions based on planning efficiency, education, and age, particularly in the context of Albania's urbanising environment, where convenience food consumption is on the rise.

While the use of self-reported survey data enables broad coverage, it is subject to social desirability and recall bias. Additionally, some waste categories (e.g., plant-based and dairy foods) showed no significant predictors, suggesting the need to include further behavioural or contextual variables in future research (e.g., habits, food literacy, or time constraints).

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