THE INTERSECTION BETWEEN PACKAGING AND AMERICAN HOUSEHOLD FOOD WASTE

By

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A THESIS

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ABSTRACT

Household food waste (HFW) hinders sustainable food systems. Using appropriate structural packaging (materials + formats), features, and technology can reduce household food waste. However, American consumer awareness and perceptions of packaging's HFW-reducing impact is unknown same as the relationship between HFW and packaging materials and formats. The aim of this study was to explore what role packaging can or does currently play in reducing household food waste and how aware consumers are of its value. A 31-question online survey was developed to collect responses from 1,000 US consumers. The responses were analyzed first overall, then by population segments. The first portion of this study shows that American consumers know little about packaging features, materials, formats, structural designs, and technologies that keep food fresh and reduce HFW. However, after learning about it, consumers were willing to buy and pay extra for food in packaging that reduces food waste. The second phase of this study, which quantified food waste and its relation to packaging, shows that Americans waste fruits and vegetables the most on an average week compared to other food categories. Plastic and unpackaged food were primarily associated with these products by participants. In addition, Americans threw away half-eaten packaged food and spoiled food without packaging the most compared to other form of food waste. Education should target certain demographic segments since some waste more food than others as significant differences (P < 0.05) and two-way interactions were identified. The study's findings can help develop new packaging, education campaigns, and policies to reduce HFW in the US.

Dedicated to my parents, Mr. Anthony Fennell and Mrs. Katharine Fennell

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LIST OF ABBREVIATIONS

- HFW Household Food Waste
- MAP Modified Atmosphere Packaging
- AP Active Packaging
- IP Intelligent Packaging
- VP Vacuum Packaging
- ASP Aseptic Packaging
- RP Retort Packaging

CHAPTER 1 INTRODUCTION

1.1 Introduction

Food waste affects the environment, the economy, society, and health and is a major barrier to the establishment of sustainable food systems. Over \$408 billion is lost annually due to food waste, with 119 billion pounds of food wasted only in the US (Feeding America, 2023). Households account for 43% of this waste (RTS, 2020). Consequently, packaging is one of the household-level strategies that might significantly reduce food waste in the US (Wikström et al., 2019; Chan, 2022). Packaging can assist by serving as a preservation container, facilitating easy access to the contents, and offering cooking guidelines (ReFed, 2022).

The food sector uses a variety of cutting-edge packaging technologies to extend the shelf life of fresh food. A food product's shelf life can be extended through the use of various packaging technologies, such as MAP, AP, IP, ASP, RP, and VP (Almenar, 2020; Almenar and Gonzalez-Buesa, 2024; Jeyapriya and Kantale, 2022; Sanjana et al., 2019; Soltani Firouz et al., 2021). Furthermore, the food industry also uses many packaging materials, formats, and/or features that can contribute to reducing food waste. Although these packaging components are available for purchase, there is still a large quantity of food waste, therefore understanding the relationship between packaging and consumers is important. Many aspects of consumers attitude (awareness/perceptions, attitudes/feelings, and actions/behaviors) on how packaging affects food freshness are either underrepresented or has not been studied at all. For example, no study has examined how aware consumers are about the effects of RP and ASP on preserving food freshness, which can lower household food waste.

Furthermore, developing packaging solutions targeted at reducing HFW requires measuring and determining the composition of food waste and how it relates to packaging. Despite being

one of the nations with the highest rates of food waste, the US lacks federally implemented, routinely occurring quantitative measurements of food wasted at the household level. HWF is estimated to account for between 32% and 43% of household food (Smith & Landry, 2021; Yu & Jaenicke, 2020) and has been identified as the single largest source of food waste across the US food supply chain according to ReFED (2022). Although specific cross-sectional data set analyses have yielded some important insights into US household food waste (Landry & Smith, 2019; Smith & Landry, 2021; Yu & Jaenicke, 2020), a lack of data collected consistently over time makes it difficult to assess the trends of food waste and identify the factors that lead to this amount of waste.

Among the studies that have measured household food waste none of them have identified the packaging materials and formats associated with food waste. It is necessary to determine the point at which packaging and household food waste intersect, as packaging has been suggested as a potential means of lowering food waste in households. Finding this junction can assist in determining what modifications to make to the packaging used for specific food items that end up wasted in the homes of consumers.

1.2 Objectives

The goal of this project is to explore what role packaging can or does currently play in reducing household food waste and determine how aware consumers are of its value. In order to achieve these two goals in this study, a nationwide survey questionnaire has been designed based on four key objectives:

1) Assessing consumers perception of packaging formats and packaging materials and the relationship of those attributes to household food waste,

2) Assessing consumers' awareness of packaging features, technologies, function, purchase intentions after being educated, and willingness to pay for packaging designed to reduce household food waste.

3) Quantifying household food waste in the US for specific food categories and identifying its intersection with packaging, and

4) Assessing the impact of participants demographics and psychographics on the intersections between packaging and household food waste.

The results obtained from this study will fill numerous gaps in knowledge regarding packaging and household food waste to ensure new packaging strategies can be developed that are based on reliable data and can more effectively combat household food waste in the US.

1.3 Hypothesis

For the first objective of this study, it was hypothesized that there will be an inconstancy in US consumers knowledge of packaging attributes related to specific packaging formats and packaging materials used to maintain food freshness.

For the second objective of this study, it was hypothesized that US consumers are not aware of the impact of structural packaging designs and packaging technologies on food freshness, but their learning about it will increase their willingness to buy and pay for food in packaging that reduces food waste.

For the third objective of this study, it was hypothesized that the most wasted food category in US consumers households during an average week will be fruits and vegetables and the top corresponding packaging material for all food categories wasted in US consumers households will be plastic.

For the fourth objective in this study, it was hypothesized that there will be significant differences and two-way interactions identified for each question in the survey between population segments.

1.4 Structure Of Thesis

The rationale of this research has been introduced in the first chapter of the thesis. Chapter 2 is a literature review that gives a background about household food waste in the US, packaging's relationship to reducing food waste, and the relationship between consumers, packaging, and food waste. Chapter 3 describes the materials and methods of this study. Chapter 4 describes the demographic and psychographic breakdown of survey participants. Chapter 5 describes consumers awareness and perception of packaging formats and packaging materials and the relationship of those attributes to household food waste. Chapter 6 describes the results and discussions regarding US consumers use of packaging features, repackaging behaviors, awareness of packaging technologies, purchase intentions after education, and willingness to pay for packaging designed to reduce HFW. Chapter 7 describes the results and discussions regarding the quantification of US household food waste and its intersection with packaging. Chapter 8 is about the conclusion of the results obtained during this research and proposed future work.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 Food Packaging

Packaging is one of the household-level strategies that might significantly reduce food waste in the US (Wikström et al., 2019; Chan, 2022). Therefore, this section presents a thorough analysis of the literature on packaging aspects (e.g., structural design, features technologies), that extend food shelf life and/or maintain food freshness which can contribute to reducing HFW.

2.2 Packaging Design

Food quality, safety, processing, and shelf life are all preserved via packaging. Using the appropriate packing materials and formats help protect food from pathogens, chemicals, odor transmission, and mechanical damage when necessary. Packaging designs usually include a mix of structural, graphic, and language-related aspects. (Steenis et al., 2017). The structural components that have the biggest effects on household food waste are material and format, since they affect the shelf life of food. Food is packaged using specific materials (such as glass, metals, or plastic) and formats (such as cans, jars, or cartons) that match the intended shelf-life extension (short vs. long) with the material's inherent qualities (e.g., whether the material provides a good barrier to gases and vapors or not, the format has resistance to vacuum). Because of their exceptional barrier properties, chemicals and environmental contaminants seldom pass through glass and metal (Marsh and Bugusu, 2007). Fragile items are packaged in sturdy corrugated paperboard boxes and metal cans to provide protection from physical damage (Marsh and Bugusu, 2007).

2.3 Packaging Features

2.3.1 Resealability

In addition to structural designs (material + format), accessibility, handling, disposability, and resealability are a few packaging features that play a significant role in maintaining food freshness. These aspects are added with specific materials and formats to preserve food freshness, enabling them to aid in reducing food waste in consumers households. Reclosing a package reduces the amount of light and air that comes into touch with the food item, reducing its exposure to spores, moisture loss, and oxygen ingress - all of which are major outside agents that cause food to go bad (Almenar and Gonzalez-Buesa, 2024). As a result, resealable zippers, lids, and other closures enhance food freshness Soni et al. (2017).

2.3.2 Handling And Accessibility

Squeezable packaging offers several benefits, including the ability to remove the complete food product from the container and an extended shelf life without any signs of deterioration due to the airtight seal that prevents spores, moisture, and oxygen from getting into these pouches or bottles. The "upside-down" rigid bottle design gives consumers control over how much product comes out of the package and also keeps the product fresher longer by preventing air from entering the package when it is open for product dispensing (Lindh et al., 2016). This works similarly to squeeze flow control valves in that they control the amount of product that comes out of the package while eliminating exposure to air therefore, this design may also contribute to reducing household food waste.

Additional packaging features that have potential in prevention of consumer-level food waste include graphical aspects (e.g., illustrations, color, transparency), environmental aspects

(e.g., eco-friendly with the environment, recyclable) and communication aspects (e.g., date labeling, serving size, ingredient list etc.).

2.3.3 Sustainability

Over the past few years, consumers have placed a great deal of significance on sustainable packaging. More than half of US consumers are concerned about the environmental impact of packaging in general, according to a recent study by (Mckinsey & Company, 2020) study. As a result, more than 60% of the participants within the study expressed willingness to pay more money for sustainable packaging moving forward. Furthermore, consumers expressed nearly similar interest in recyclable and recycled plastic packaging as well as fiber-based alternatives when questioned in this same study. It is important to investigate the relationship between environmentally friendly packaging and food waste since consumers are concerned about the environmental impact of packaging and are interested in more novel sustainable packaging. After analyzing the findings of 22 publications, Zeng and Durif (2020) concluded that eco-design packaging, which includes resealable packaging, slender and minimalist design, and the use of recyclable materials, may have a favorable effect on consumers and aid in the reduction of HFW. To date, no research has investigated the importance that eco-friendly packaging plays in assisting consumers in minimizing HFW. Finding this intersection can help develop more innovative sustainable packaging aimed at reducing food waste and its negative environmental effects, which benefits everyone.

2.3.4 Communication

Providing information about the food inside the package is one of the primary purposes of food packaging. The recommended serving size, ingredients, price, expiration date, taste, nutritional content, net weight, volume, brand name, manufacturer's name, and any potential

risks (such as food containing egg, soy, dairy, or nuts) are just a few examples of the information that is included. Another method of informing consumers about the food's safety and quality is through smart or intelligent packaging (Barska and Wyrwa, 2016). Components used in smart or intelligent packaging monitor the state of the food being packaged or the surroundings in which it is stored in order to communicate the freshness of the food product. This is achieved by switching from a system of fixed "best-before" data to one of dynamic information about the actual state of the food (Poyatos-Racionero et al., 2018). Ripeness indicators, which indicate whether food is ready to eat, freshness indicators, which indicate food quality and safety, and time-temperature indicators, which more precisely indicate the length of the food's shelf life, are a few examples of smart/intelligent packaging.

Graphics are another popular means of communication when it comes to food packaging. According to Block et al. (2016), visually appealing packaging can influence impulsive consumers to acquire needless things. If graphical elements, such as color or illustrations, encourage people to buy unnecessary items, thus increasing food waste, it seems plausible that if those same elements, if properly designed, may also contribute to a decrease in food waste. Previous research (Lindh et al., 2016; Steenis et al., 2017) has concentrated on the graphic design used for labeling, packaging materials, and its impact on consumer perception of sustainable packaging. It is worthwhile to ascertain whether graphical elements like color and images contribute to aiding consumers in reducing HFW.

Another common form of communication is through date labeling. Regarding date labeling, various terms (e.g., "best-by", "best-before", "use-by", "sell-by", "freeze-by") are used. According to the NRDC (2013), the best-by or best-before dates indicate when food will no longer be at its peak quality (best flavor and texture, for example). From their definition, they are

related to the freshness and quality of the food and not about food safety. The sell-by date is intended for retailers and informs them of the date by which the product should be sold or removed from shelves. By definition, a sell-by date does not imply food safety; yet, roughly half of customers think that eating food after its sell-by date is unsafe, according to a survey by Ransom (2005). Food safety is one of the main causes associated with HFW (Neff et al., 2015), hence one of the main packaging-related causes of HFW is the lack of consistency in date labeling together with consumer confusion and misunderstanding (Williams et al., 2012). Providing consumers with the correct form of labeling may help reduce HFW.

2.4 Packaging Technologies

2.4.1 Modified Atmosphere Packaging

Modified atmosphere packaging (MAP) is a technology that replaces the interior ambient air in a package with a gas composition selected in accordance with the food product's needs for safety and/or freshness maintenance (Almenar, 2021). The shelf life of fresh or minimally processed food can often be prolonged by MAP. Thus, perishable commodities like meat, fish, fruit, and vegetables may have a longer shelf life thanks to MAP, which delays the physicochemical changes that lead to a product's quality being lost.

2.4.2 Active Packaging

Active packaging (AP) is a technology that enhances food quality and/or safety by adding certain additives, known as "active compounds," to the packaging material or putting them within the packing container (Almenar, 2020). Tiny packages, labels, and other items are examples of additives placed inside the container (Awalgaonkar et al., 2020). There may be a direct or indirect interaction between the perishable product and the active component. An active package enhances quality and safety of food products by either scavenging chemicals involved in

produce degradation processes or by releasing compounds that can minimize the influence of components involved in produce deterioration (Almenar, 2020).

2.4.3 Intelligent Packaging

Intelligent packaging (IP) is a technology that communicates information to support decision-making by tracking changes in the packaged food product's internal and exterior environments (Poyatos-Racionero et al., 2018). Food shelf life is not directly increased by intelligent packaging. Instead, the goal of intelligent packaging is to notify consumers, retailers, and other food supply chain participants on the item's quality or surrounding environment (Restuccia et al., 2010). For instance, an intelligent packaging system can use time-temperature indicators (TTIs) to display the food's temperature history (Robertson, 2005). Additionally, a barcode (QR code) on an intelligent package can provide broad product information (Almenar et al., 2020). Each of the aforementioned formats of IP can provide consumers with the means to monitor the shelf life of their products which can contribute to reducing food waste.

2.4.4 Retort Packaging

In order to render food sterile for use in commerce, Retort packaging (RP) entails placing it within a glass, plastic, or metal container (such as a pouch, can, or tray), closing it, and heating it to 121C or above for at least 10 minutes (Jeyapriya and Kantale, 2022). RP is a widely used preservation method in the food industry for low-acid, shelf-stable goods. RP for commercial use guarantees a sufficiently high level of spore-forming microbe reduction or inactivation to assure commercial sterility (Jeyapriya and Kantale, 2022).

2.4.5 Aseptic Packaging

According to Sanjana et al. (2019), Aseptic packaging (ASP) is the process of putting a sterile food product into sealed, sterilized containers within a commercially sterile setting. The

aseptic method helps food products have a longer shelf life by getting rid of harmful bacteria and spoiling. These containers, which are composed of paper, metal, and plastic, preserve food quality without requiring refrigeration.

2.4.6 Vacuum Packaging

By removing air from the package headspace and concentrating on removing oxygen, vacuum packing (VP) creates an anaerobic environment that inhibits the growth of spoilage bacteria, slows down oxidative processes that lead to product degradation, and lengthens shelf life (Almenar and Gonzalez-Busa, 2024). Additionally, because there is no package headspace, freezer burn is decreased. This enables food products to be frozen or stored for an extended period while also keeping them fresh for the consumer.

2.5 Consumers

This section encompasses research on the effects of consumers' attitude and their sociodemographic/psychographic factors on food packaging. Attitude is comprised of three components: awareness/perception, opinions/feelings, and actions/behaviors.

2.5.1 Awareness/Perception

2.5.1.1 Consumer Awareness Of Structural Packaging Designs Impact On Shelf-Life Extension

As previously mentioned, the structural elements, material and format, affect food shelf life and hence have the greatest impact on household food waste. When shelf-life extension is needed, consumers must be able to recognize the most effective packing materials and formats to empower them to reduce household food waste. Despite the significance of consumer awareness of the role structural packaging design plays in food shelf-life extension, which can greatly aid in making the proper choices when selecting packaging to reduce household food waste, there is

little to no information about it. The influence of structural packaging design (material type and/or shape/format) on consumers' perceptions of food's perceived quality, taste, safety, and healthiness has been the subject of previous studies (Bou-Mitri et al., 2021; Magnier et al., 2016; Steenis et al., 2017; Beker et al., 2011; van Rompay et al., 2016; Velasco et al., 2014). These studies, especially the ones concerning food quality, have nothing to do with extending the shelf life of food. Magnier et al. (2016) and Steenis et al. (2017), for instance, investigated the relationship between packaging sustainability and consumers' perceptions of food quality. There are merely two consumer behavior studies that discuss how structural packaging design and food shelf-life extension interact. According to one of them (Venter et al., 2011), South Africans associated the glass jar, carton box, and plastic pouch with long-term food storage since they observed these package designs conducting food products that are durable, regardless of whether these food products are perishable or not. According to the other study, after being shown multiple packaging designs, some Australians believe that packaging is essential to preserving food freshness, while others believe that packaging causes food to deteriorate more quickly (Langley et al., 2021). In order to develop and execute techniques that can considerably reduce household food waste, it is imperative to learn more about consumers' awareness of the role structural packaging design plays in food shelf-life extension.

2.5.1.2 Consumers Awareness Of Packaging Technologies Impact On Maintaining Food Freshness

Although the previously identified packaging technologies are readily available in the market, their major contribution to reducing household food waste will depend on consumers awareness of the role that each play in extending the shelf life of the food products. Knowing that these technologies exist on the market and how they affect food shelf life are two

components of consumer awareness about packaging technologies, as both are crucial for reducing household food waste. Previous literature has examined consumers recognition of VP, MAP, AP, and IP (**Table 1**). Although VP has been recognized by many (Chen et al., 2013; Bou-Mitri et al., 2021; Van Wezemael et al., 2011), reports for MAP, AP, and IP show much lower recognition rates of 16%, 4%–22%, and 17%–28%, respectively (Barska and Wyrwa, 2016; Grebitus et al., 2013a; Kocetkovs et al. 2019; O'Callaghan and Kerry 2016; Stoma and Dudziak, 2022). However, regarding ASP and RP there are no survey studies on consumers' recognition towards these two technologies in the literature despite their ability to increase the shelf life of many food products and decrease household food waste.

Consumers need to be aware of packaging technologies' capacity to prolong food shelf life, which can lower HFW, in addition to their ability to recognize them. Consumer awareness of the role that each packaging technology plays in extending food shelf life has only been investigated for (VP) (**Table 1**) (Bou-Mitri et al., 2021; Chen et al., 2013). In order to build future educational efforts for specific technologies consumers are unaware of and which can assist minimize HFW, it is necessary to ascertain consumers' overall awareness of each of the other packaging technologies (MAP, AP, IP, ASP, and RP), for which there is currently no available data.

Table 1. Details of the literature on consumer behavior towards packaging technologies that can reduce food waste that were gathered through surveys. The answers 'yes' and 'no' reflect whether the subject was covered in the manuscript. Survey studies about aseptic packaging and retort packaging providing such details are non-existent.

Inves tigate d PKG techn ology (PT)	Effe ct of the PT on self life, qual it, safe ty, or food was te red ucti on	Pac kage d food pro duct	Co unt ry wh ere the stu dy too k pla ce	Cons umer s' awar eness - Kno wled ge of PT prese nce in the mark etpla ce	Cons umer s' awar eness - Kno wled ge of PT impa ct on main taini ng food fresh ness	Cons umer s' accep tance of PT	Cons umer s' purc hase inten t of PT	Cons umer s' willin gness to pay extra for a PT that exten ds shelf life	Consu mers' demo graph ics	Consu mers' psycho graphi cs	Refe renc e
AP	Shel f life	Fres h- cut cant alou pe	US	No	No	Yes	No	Yes	Yes	No	Wils on et at., 2018

Table 1. (cont'd)

AP	Shelf life	Pita, bagged salad, salmon steaks, cheese and crackers snacks, and yoghurt	US	No	No	Yes	No	Yes	Yes	No	Just and Goddard, 2022
AP and IP	Quality and safety	Food in general	Poland	Yes	No	Yes	Yes	Yes	Yes	No	Barska and Wyrwa, 2016
AP and IP	Reduce HFW	Food in general	Italy	No	No	No	Yes	No	No	No	Cammarelle et al., 2021
AP and IP	Shelf life	Cheese	Ireland	Yes	No	Yes	Yes	Yes	Yes	No	O'Callaghan and Kerry, 2016
AP and IP	N/A	Food in general	Poland	Yes	No	No	No	No	Yes	No	Stoma and Dudziak, 2022
AP and IP	Shelf life	Food in general	Turkey	No	No	Yes	No	Yes	Yes	No	Aday and Yener, 2015
AP and IP	Freshness and quality	Food in general	Latvia	Yes	No	No	Yes	Yes	No	No	Kocetkovs et al., 2019

Table 1. (cont'd)

МАР	Shelf life and color	Ground beef	US	Yes	No	Yes	No	Yes	No	No	Grebitus et al., 2013a
МАР	Shelf life and color	Ground beef	US and Germany	No	No	Yes	No	Yes	No	No	Grebitus et al., 2013b
VP, MAP, and AP	Safety	Beef	Five European countries (France, Germany, Spain, Poland, and UK)	No	No	Yes	No	No	Yes	Yes	Van Wezemael et al., 2011
VP	Shelf life	Beef	Canada	Yes	Yes	Yes	No	Yes	Yes	No	Chen et al., 2013
VP	Quality	Cheese	Lebanon	No	Yes	No	No	Yes	Yes	No	Bou-Mitri et al., 2021
VP	Quality	Beef	US	No	No	Yes	No	Yes	Yes	No	Watson et al., 2005

2.5.2 Opinions/Feelings

Consumer preferences for important package aspects are crucial when designing packaging to reduce household food waste, however information on this is rather limited in literature. Three studies in the literature examined the importance of food packaging features for consumers (Bou-Mitri et al., 2020; Lindh et al., 2016; Venter et al., 2011) but this was not in relation to reducing household food waste. The food packaging sector may better adjust to consumer preferences and reduce household food waste by assessing the importance of packaging features that assist consumers in minimizing food waste.

2.5.3 Actions/Behaviors

To reduce food waste in households, it is essential to understand how consumers use food packaging in their daily lives before consumption and whether they are prepared to pay extra money for packaging aimed at reducing food waste.

2.5.3.1 Repackaging Behavior

Beyond safety, food packaging extends the shelf life of food. Some (but not all) of these functions are lost if food is removed from its packaging or transferred from its original packaging to a new one. Food waste can rise, and food shelf life can be drastically reduced as a result. How consumers handle the packaging while storing their food products before eating them is not well understood. Consumers' re-packaging behavior has been covered in two publications in the literature (Sealed Air, 2015; Avery Dennison, 2018). According to a Sealed Air (2015) survey, nearly 50% of US consumers take fresh food out of its container. Furthermore, 70% of US consumers surveyed by Avery Dennison claimed they store fresh products, such as fruits and vegetables, in zippered bags or other plastic containers after removing them from their original packaging. In this study, over 70% of customers repackaged various fresh products-notably deli meats and other protein sources-including cheese, from their original package. Discovering out how often consumers repackage can provide information about how much repackaging occurs in American households, what food categories are repacked the most, and what lists are repacked in the US, among other things. This information can be very helpful in creating educational programs that highlight the benefits of food packaging and alter current packaging to reduce.

2.5.3.2 Purchasing Behavior Regarding Packaging Features

As previously discussed, various packaging features such as Resealable zippers, lids, and other closures, upside-down rigid bottle, and squeezable packaging improve food freshness, which can contribute to reducing HFW. Determining whether consumers buy items with the above packaging features to preserve food freshness or for other reasons such as cost, convenience, brand loyalty, or others is vital. This can determine whether consumers recognize the value of packaging features ability to maintain food freshness which can help contribute to a reduction in HFW. Currently there is no literature that has explored this concept.

2.5.3.3 Purchase Intent Of Packaging Technologies

One important factor in reducing household food waste is consumers' intent to purchase the previously mentioned packaging technologies. Previous literature provides information on consumers' acceptance of most of these packaging technologies (MAP, VP, AP, and IP) (**Table 1**) (Aday and Yener, 2015; Barska and Wyrwa, 2016; Chen et al., 2013; Grebitus et al., 2013a and b; Just and Goddard, 2022; Van Wezemael et al., 2011; O'Callaghan and Kerry, 2016; Watson et al., 2005; Wilson et at., 2018). A packaging technology's acceptance by consumers does not ensure that it will be purchased. Therefore, in order to predict how each of these packaging technologies would position itself in the market, purchase intent information may be more reliable than acceptance information. Information of consumers purchase intent of AP and IP has been reported. Based on consumers' location, this purchase intent varied from 9% to 77%, and in general, IP received a higher percentage than AP (**Table 1**) (Barska and Wyrwa, 2016; Cammarelle et al., 2021; Kocetkovs et al. 2019; O'Callaghan and Kerry, 2016). The purchase intent of MAP, ASP, VP, and RP is currently unknown.

2.5.3.4 Willingness To Pay For Packaging Designed To Reduce Food Waste

While research on consumers' intentions to purchase various packaging technologies (has been conducted (**Table 1**)), there is a scarcity of studies on their willingness to pay extra packaging in general that is specifically designed to minimize food waste considering that this type of packaging usually comes at a higher cost. Only two studies have investigated consumers' willingness to pay extra for a reduction in food waste in general (Grant et al. 2019; InnovaLifestyle and Attitude study, 2021) however neither study related this to packaging. The first step in decreasing household waste is figuring out if consumers are prepared to pay more for packaging that has been created specifically to prevent food waste.

2.6 Food Waste

2.6.1 Household Food Waste Composition

Food waste in households is a major problem in the US (RTS, 2020), yet reducing it is very challenging to do since a great deal of the information available is merely an estimation. Two studies quantified food waste at the consumer level in US using estimates of food waste from the USDA Loss-adjusted Food Availability data series (LAFA) that included unusable parts of food (such as banana peels) but they omitted data on the percentage of edible food wasted at the plate level (Buzby et al., 2014; Conrad et al., 2018). Additionally, studies on food waste carried out in the United States have focused on different supply chain segments that produce food waste, such as retail (Lebersorger and Schneider, 2014), municipal solid waste (Thyberg et al., 2015), and the entire supply chain of a single state (Hawaii) (Loke and Leung, 2015). Present in **Table 2** is the majority of the data that is currently available regarding the quantification of food waste in households globally using different techniques, such as survey questionnaires. The majority of data on household food waste is provided by European countries, including Germany

(Hermanussen et al., 2022; Jörissen at al. 2015; Richter et al. 2017), Italy (Jörissen et al. 2015; Lanfranchi et al. 2016; Setti et al. 2016), and the United Kingdom (Langley et al. 2009; Martindale, 2014 WRAP, 2019). As shown in **Table 2**, only one study in the US has measured food waste at the household level (Li et al., 2023). The shortage of information in this field requires the development of a survey questionnaire intended to quantify and ascertain the makeup of household food waste in the US.

Averag e amount of HFW*	Count ry	Sample size	Collect ion method	Associa ted packagi ng materia l and/or format with HFW	Identif ied HFW state	HFW based on demograp hics	HFW based on psychograp hics	Refere nce
199 g/ person/ day	UK	33 respond ents	Diary	No	Yes	No	No	Langle y et al. 2009

Table 2. Publications detailing the amount of food waste generated by households in their respective nations.

Table 2. (cont'd)

243 g/household/day	Sweden	61 respondents	Diary	No	Yes	Yes	No	Williams et al. 2012
1,457 g/person/day	Canada	68 households	Household visit	No	Yes	Yes	Yes	Parizeau et al., 2015
18 g/ person/day	Italy	404 respondents	Online survey questionnaire	No	Yes	Yes	Yes	Jörissen et al. 2015
20 g/person/day	Germany	453 respondents						
Not Reported	Italy	1,403 respondents	Online survey questionnaire	No	No	Yes	Yes	Setti et al. 2016
Not Reported	Italy	500 respondents	Online Survey questionnaire	No	Yes	No	No	Lanfranchi et al. 2016

Table 2. (cont'd)

Not Reported		100	In-person					Ghinea and
	Romania	respondents	survey	No	No	Yes	Yes	Ghiuta, 2018
			questionnaire					
			Online					Aschemann-
Not Reported	Uruguay	540	Survey	No	Yes	Yes	Yes	Witzel et al.,
		households	questionnaire					2019
			In-person					Falasconi et
Not Reported	Italy	1,201	survey	No	No	Yes	Yes	al. 2019
		respondents	questionnaire					
6.6 million								
tones across	UK	2,199	Online survey	No	Yes	Yes	Yes	Wrap, 2019
all households		respondents	questionnaire					
210		115						Ilakovac et
g/person/day	Croatia	households	Dairy	No	No	Yes	Yes	al., 2020

Table 2. (cont'd)

			Combination					
8 514	German	727	of survey	N		Va	Va	Hermanusse
0,514	German	respondent	questionnair	11	No	10	10	n et al., 2022
g/person/day	У	-	-	0		S	S	
		S	e and FW					
			diary					
			Online					
		1,970	survey					
51.9 g/person/da	US	respondent	questionnair	Ν	Ye	Ye	Ye	Li et al.,
У	00	respondent	questionnan	0	s	S	S	2023
		S	e					

Regarding the makeup of food waste, Chan (2022) discovered that fresh fruits and vegetables, breads and cakes, dairy products, and meats and poultry were the commodities that consumers reported squandering the most. In a similar vein, fruits and vegetables were the food group that was wasted the most in a recent nationwide survey, according to Li et al. (2023). Fruits and vegetables have the highest percentage of food waste, according to AMERIPEN (2018). The outcome could be attributed to multiple reasons. Fruits and vegetables, for instance, have the least amount of packing among foods. Fruit and vegetable peels, which serve as a natural barrier of defense, may have some role in this. Additionally, since fruits and vegetables are comparatively less expensive than other perishable items, price has a significant influence on consumer behavior.

2.6.2 Food Waste States

Reducing household food waste requires identifying product food waste state. The literature on household food waste classifies food waste differently. WRAP (2012) listed fresh, frozen, canned/processed, leftovers from prepared meals or takeaway, and home-cooked meal leftovers as household food waste statuses. In their 2019 study, van Herpen et al. classified household food waste into four categories: unused, partially used, meal leftovers, and stored leftovers. Butler (2012) categorized and subcategorized HFW as follows: (1) unopened/whole and opened/partly used, (2) cooked: not served, left on dish. Nearly all research on household food waste has classified consumer household food waste by category **Table 1**. Williams et al. (2012) report that one-third of food waste originates from leftovers and storage. However, the relationship between food waste and packaging materials and formats is uncertain. As indicated, packaging has been recommended to reduce household food waste, but no study has specified the material or structure. Because of this, it is unknown how packaging affected previously documented household food waste (such as food that spoiled before being opened or partially consumed packed food). This information is necessary to create new packaging designs aimed at reducing household food waste.

2.6.3 Packaging And Household Food Waste

Packaging has been acknowledged as an essential strategy for reducing food waste (Chan, 2022; ReFED, 2016; The Rockefeller Foundation, 2017; Wikström et al., 2019) It is possible to reduce food waste going forward by making the appropriate changes to the packaging used for particular food products by identifying the packaging materials and formats associated with the food categories/groups discarded in consumer households. As shown in **Table 2** no study that has quantified household food waste has identified the packaging materials or formats

linked to the food categories/groups wasted in consumer households. It is noteworthy that the study conducted by Ghinea and Ghiuta, 2018, evaluated Romanian participants' trash to determine the types of waste included inside. The most common types of waste discovered in the trash of respondents, excluding food waste, were plastic, paper/paperboard, and glass. Additionally, lesser levels of metals and textiles were discovered. However, since the packaging materials found in the trash was not associated to consumers food waste, it was impossible to draw a direct connection between the two.

2.6.4 Socio-Demographic And Psychographic Factors

Given that most of the food waste in the US occurs at the consumer/household level (RTS, 2020), it is critical to investigate how consumers' sociodemographic and psychographic traits affect the way they generate waste. Previous studies have examined how consumers' waste-generation activities are influenced by their psychographic and sociodemographic traits. The association between food waste and household size was examined in two studies (Evans, 2014; Neff et al. 2015). Two studies evaluated the age distribution of household members and food waste (Neff et al., 2015; Stancu et al., 2016). Two studies examined the number of children in families (Evans 2011; Neff et al. 2015). Di Talia et al. (2019) examined consumers' places of residence (rural vs. urban areas). Additionally, Neff et al., 2015 investigated the following variables: gender, race, ethnicity, income, education level, employment, and whether or not the individual was raised in a U.S. or non-U.S. family. Finding variations in food waste among consumers' psychographic and sociodemographic characteristics can help develop educational initiatives aimed at reducing food waste in households by focusing on specific population segments.

2.6.5 Methodology In Measuring Household Food Waste

The most crucial step in reducing HFW is figuring out how to quantify the waste that occurs in consumer households. One major obstacle to measuring food waste, particularly at the household level, is the lack of standard approaches, which has resulted in the usage of several methodologies that differ greatly from one another (Bräutigam et al., 2014). Surveys, diaries, self-collection kitchen caddies, waste composition analysis, in-home observations, and photo coding are a few of the methods available for measuring HFW; each has advantages and disadvantages in terms of time and expense as well as accuracy, objectivity, and dependability (van Herpen et al., 2019). Waste composition analysis, for instance, yields precise data but is inapplicable to big sample quantities. On the other hand, surveys are less costly and may be conducted with huge sample sizes; however, they are highly dependent on the knowledge and recollection of respondents regarding food waste and may be influenced by social desirability. Thus, providing consumers with instructions in the questionnaire may be helpful in gathering reliable information while ensuring that the sample size is representative of the US population, both of which can contribute to the development of solutions for lowering HFW.

CHAPTER 3

MATERIALS AND METHODS

3.1 Participants

Qualtrics was utilized for both the design and implementation of the online survey questionnaire. Approximately 2,700 respondents from across the continental United States who were willing to take surveys in exchange of an economic reward and met the screening criteria (to be 18 years old or older, to be primary shoppers in their households, to purchase groceries at least once every other week, and not to be a packaging expert or related to one) were sent the survey from Qualtrics. Percentage splits from the US census-based on gender, age ranges, education levels, annual income, marital status, household size, those with a disability, and region (e.g., state you live in) were calculated. These splits were shared with Qualtrics to ensure that the survey participants were a fair representation of the US population (within \pm 2.0%). Participants were recruited by Ugam as per the agreement with Qualtrics. The number of responders was narrowed down to 1,000 based on the reliability of their responses.

3.2 Survey Questionnaire Development

3.2.1 Draft Questionnaire

A draft questionnaire and its associated files (screening questions and consent form) were developed and shared with the Michigan State University Institutional Review Board. The study was approved on February 07, 2022. The draft questionnaire which consists of 10 questions was shared with representatives from the Environmental Research and Educational Foundation (EREF), AMERIPEN, and others in the packaging industry for feedback. Feedback was collected through a zoom call and by written suggestions facilitated by EREF personnel. Following comments on the shared draft question, the following changes were made. Question

#3, which investigated the significance package features are to minimizing food waste at the household level, was moved up to question #1. To prevent participant fatigue, certain attributes from questions were eliminated (e.g., number of response choices). Technical packaging terminology was replaced with common terminology (e.g., good environmental footprint was changed to environmentally friendly). The verbiage used in various questions was changed. More photos of packages were taken and added when necessary to help consumers avoid confusion.

3.2.2 Pilot Test

Before launching the questionnaire, pilot testing took place. Approximately 50 people with different backgrounds (education level, gender, race, age, etc.) who met the inclusion requirements of the questionnaire, completed the consent form and took the online questionnaire. In addition, another packaging expert was asked to provide feedback. Minor mistakes such as spelling and excessive wording in questions and responses were highlighted by many participants. The questions designed to quantify HFW were modified to ask consumers to select their most wasted food category/group during an average week compared to an average month. Participants had trouble remembering the food they wasted during a month. Thus, servings were modified to reflect a week rather than a month.

3.2.3. Final Survey Design

A two-part questionnaire was administered to each participant. Before beginning the first part, participants responded to the screening criteria questions to ensure the fulfillment of the inclusion requirements. Next, participants read a brief introduction that explained the length of the questionnaire, the authors definition of household food waste (*"Household food waste is food that is fit for consumption but is discarded in the household including meal leftovers but*
excluding non-edible parts of food (e.g., banana peel, meat bones"), and examples of different states of food waste at the household level. Participants were additionally instructed to answer the questionnaire questions based on their own viewpoints or personal experiences in their respective households. Finally, participants were encouraged to respond "*I don't know*" if they were not aware of a specific interaction between packaging and household food waste.

The first part of the questionnaire consisted of a list of questions "choose one guide-type response" to collect participants demographic segments including age, race, education, ethnicity, gender, marital status, income, disability status, household size, and residency (state) as well as participants psychographic segments including grocery shopping frequency, grocery shopping method, and contribution to reducing household food waste along with the reasoning behind it. The second portion of the questionnaire consisted of 31 questions which include a list of ordinal scale and categorical questions (Likert scale and guide-type questions) that were designed in alignment with the objectives (1) assess consumers perception of packaging formats and packaging materials and the relationship of those attributes to household food waste, (2) assess consumers food waste-related package use, repackaging behaviors, awareness of packaging technologies, purchase intentions after education, and willingness to pay for packaging designed to reduce household food waste and (3) quantify household food waste in the US for specific food categories and determine its intersection with packaging.

Objective 1: Assessing consumers perception of packaging formats and packaging materials and the relationship of those attributes to household food waste.

Questions #1-4 were designed separately in alignment with objective 1 and the details are found below.

Question #1: Rate The Importance Of The Following Packaging Features In Reducing Food Waste In Your Household Using A 5-Point Scale From Very Important To Unimportant

Participants asked to rate the importance of the packaging features in reducing food waste in their respective household using a 5-point scale from very important to unimportant. The 15 packaging attributes were: 1) Transparency (food product visibility), 2) Material (paper, plastic, etc.), 3) Size, 4) Resealability/Closure type/Easy to open, 5) Dispensing feature/Easy to empty, 6) Easy to grip/Shape, 7) Eco Friendly with the environment, 8) Maintain food freshness, 9) Protection against physical damage/Strong (no breakage), 10) Graphics/Illustrations/Color, 11) Statements - Test/words other than expiration or best by dating, 12) Printed food product dating (best buy, sell by, coding dates and others, 13) An attachment that tells you about the safety of the food product, 14) An attachment that tells you how to use/cook of the food product, and 15) Other. This question includes one key basic function of packaging (protection against physical damage) This question also contains various other elements of packaging structural (material, format/shape, and size), graphical (color, labels, and illustrations/symbols) and verbal attributes. There is no literature that reports the relationship of some of the above packaging features to household food waste. Packaging format and packaging material were added to the list to determine how important they were to the participants before getting into the specifics for each of them. This question compiled all the packaging attributes that consumers could consider necessary to reduce household food waste. This was verified by the addition of "if other, please specify" to the list to help determining where packaging fails to meet consumer expectations in reducing food waste if the packaging attribute is not listed.

Question #2: Select All The Features From The List Below That You Associate With Each Packaging Material.

Participants were asked to select from the following packaging attributes and identify those associated with each packaging material. The packaging features included "Transparency (food product visibility)," "No chemicals move from the packaging material to the food product," "Dispensing feature/Easy to empty," "Maintain food freshness - Avoid changes in color and/or smell," "Maintain food freshness – Avoid texture changes," "Maintain food freshness – Avoid mold/bacteria to grow," and "Protection against physical damage/ Strong (no breakage)" and the packaging materials were paper/paperboard, plastic, metal, and glass.

Question #3: Select All The Features From The List Below That You Associate With Each Packaging Type.

Participants were asked to select from the following packaging attributes and identify those associated with each packaging format. The packaging features included "resealability/closure/easy to open," "dispensing features/easy to empty," "Easy to grip/Shape," "Eco friendly with the environment," "Protection against physical damage/Strong (no breakage). The packaging formats were bottle, can, pouch, and carton.

Question #4: Common Packages For (Food Product) Are Displayed Below. Compare The Packages Using The Following Choices "This Package Can Keep My Product Fresh The Least", "Neither The Freshest Nor The Least Fresh", "This Package Can Keep My Product Fresh The Most".

This topic consisted of one question with five parts that evaluated consumers' awareness of how different packaging designs (material + format) affect the shelf life of different food products. Participants were shown three common packages for the following food categories: Cherries, Milk, Bread, Chicken, and Peanut butter (**Table 3**). Participants are asked to compare the packages using the following choices "this package can keep my product fresh the least", "neither the freshest nor the least fresh", "this package can keep my product fresh the most". Both material and format were provided underneath each photo. The packages of each food product were shown on a different page of the online questionnaire. Participants were able to select only one out of the three possible choices for each package assigned to each food product. The selected choice was dropped for the remaining packages. There is no literature that reports the relationship between packaging design (format + material) and household food waste.

Table 3. Packages for cherries, milk, bread, chicken, and peanut butter shown to the survey participants.

Food product	Structural packaging designs		
Cherries	CHERRIES Output Metal can	CHERRIES Plastic clamshell container	CHERRIES Plastic pouch

Table 3. (cont'd)

Milk	Carton with or without easy opening feature (e.g., cap)	Plastic jug	Plastic bottle
Bread	Loose plastic bag	Paper bag with window	Loose plastic bag inside paper bag
Chicken	Plastic tray with a glued-on lid	CHICKEN Plastic air-tight packaging	Plastic tray with a wrap

Table 3. (cont'd)



Objective 2: Assessing Consumers' Awareness Of Packaging Features, Technologies, Function, Purchase Intentions After Being Educated, And Willingness To Pay For Packaging Designed To Reduce Household Food Waste.

Questions #5-8 were designed separately in alignment with objective 2 and the details of each question are found below.

Question #5 Please Select The Most Important Reason For Purchasing Food With The

Packaging Features Shown In The Photos.

Participants were asked "Please select the most important reason for purchasing food with the packaging features shown in the photos." Photos of food packages with different features were taken and edited. **Table 4.** complies the pictures of the packaging features shown to survey participants. The packaging features included: "packaging with zipper seal," "upside down rigid packaging," "packaging with a peelable and resealable lid," "packaging with squeeze flow control valve," "squeezable packaging," "multipack," and "upright bottle". The following reasons are: "convivence," "maintain freshness," "brand preference," "price," and "other". This question was formulated to learn about the most important reason consumers' purchasing food with specific

packaging features while assessing consumers' awareness of the value of packaging on extending food shelf life, which contributes to reducing household food waste.

Packaging feature	Photo of packaging feature
Packaging with zipper seal	Zipper seal
Upside down rigid packaging	Upside-down rigid packaging
Packaging with a peelable and resealable lid	Peelable and Resealable lid

 Table 4. Packages with specific packaging features that were shown to the survey participants.

 Packaging feature

Table 4. (cont'd)



Question #6: Please Select The Repacking Option That Better Represents Your Household For Each Food Category.

Participants were asked "Please select the repacking option that better represents your household for each food category." The food categories were: "Produce", "Protein," "Grains," "Baking ingredients, spices, and powders," "Dairy," "Potatoes and Onions," and "Fats and Oils". Participants were asked to select one of the following the repackaging options for each food category "the food product is kept in the package," "the food product is moved from its original packaging to a different one (e.g., Ziploc bag, Tupperware, Foil or plastic wrap) prior to being stored for easier storage, consuming the correct portion or serving size, or trying to ration out food based on household size," and "the food product is taken out its original packaging (e.g., fruit bowl or refrigerator drawer),". The goal of this question was to learn about the consumers' use of the package before the product is consumed as it relates to household food waste.

Question #7 (Part 1): Do You Think That Package A Or Package B Will Keep The Food Product Shown Fresh For Longer?

Consumers' knowledge of the impact of the packaging technologies modified atmosphere packaging (MAP), active packaging (AP), intelligent packaging (IP), retort packaging (RP), aseptic packaging (ASP), and vacuum packaging (VP) on food freshness was assessed. Two package pairs were displayed on each page of the questionnaire. One of the two packages showed the food product packaged in the packaging technology under assessment and the other one showed the same food product without the packaging technology. **Table 5** compiles these packages. Participants were asked to choose between the packaged products presented which one of the two alternatives in a pair keeps the food product fresh for longer. Participants were

provided with no information other than left (package A) and right (package B). The possible

responses to choose from were A, B, I don't know, and No difference.

Table 5. Packaging technologies including modified atmosphere packaging (MAP), active packaging (AP), intelligent packaging (IP), retort packaging (RP), aseptic packaging (ASP), and vacuum packaging (VP) presented to the survey panelists.

Packaging technology	Left (A); Right (B)
Modified Atmosphere Packaging	Lettuce Lettuce
Active Packaging	
Intelligent Packaging	FRUIT FRUIT

Table 5. (cont'd)



Question #7 (Part 2): How Often Would You Purchase The Food Product Shown Or Another Food Product In The Specific Packaging Technology (E.G. Modified Atmosphere Package) When Found In The Store?

Consumers' purchase intent of the packaging technologies after being educated was investigated in the second part of this question. Education consisted of showing the same pair of photos per technology as in section 2 along with a text that explained the difference between the two packages. Each text included the definition and advantages of the technology. These texts are compiled in **Table 6**. Then participants were asked to respond to the question: "How often

would you purchase food product A or another food product in technology X when found in the

store?" The possible responses to choose from were 'always', 'sometimes', and 'never'.

Table 6. Text provided for modified atmosphere packaging (MAP), active packaging (AP),
intelligent packaging (IP), retort packaging (RP), aseptic packaging (ASP), and vacuum
packaging (VP) to the participants.

Packaging		
technology	Definition	
Modified	Package A is a modified atmosphere package which means that package A is a	
Atmospher	hermetically sealed package that contains a safe gas that keeps the fresh-cut	
e	lettuce fresher. Package B is a not hermetically sealed which means the package	
Packaging	contains air which allows the fresh-cut lettuce to spoil faster	
Activo	Package A is an active package which means that package A contains an insert	
Active	(little packet that removes oxygen) to keep the beef jerky fresher. Package B	
Packaging	does not contain this inset so the product will spoil faster	
Intelligent	Package A is an intelligent package because it has an artifact (QR code) that	
Intelligent	provides you with information on the fresh-cut fruit (e.g., origin, freshness).	
Packaging	Package B does not have an artifact to provide this information.	
Datart	Packages A and B are both retort packages which means that the tuna is exposed	
Keton	to a high temperature while inside of the packages to kill any microorganisms	
packaging	present in order to maintain freshness.	
Acomtio	Package B is an aseptic package which means the orange juice has been	
Aseptic	packaged in an environment free of microorganisms to be kept fresher. Package	
packaging	A has not undergone the aseptic process".	

Table 6. (cont'd)

Vacuum	Package A is a vacuum package which means the air has been eliminated from
Packaging	the package before sealing to keep the salmon fresher. Package B is not vacuum
	packaged which means it contains air that will spoil the salmon faster.

Question #8 Would You Be Willing To Pay Extra For Food Products In Packages Designed To Help Reduce Food Waste?

This question was designed to determine consumers' willingness to pay extra for food products in packages designed to help reduce food waste was obtained by asking participant exactly this and asking them to select 'yes', 'no', or 'maybe' as possible responses.

Objective 3: Quantify Household Food Waste In The US For Specific Food Categories And Determine Its Intersection With Packaging

The quantification of household food waste section was designed to determine the largest food category that is wasted in the American households during an average week, the largest food group that is wasted in the American households during an average week, identify the packaging material(s) of the largest food group that is wasted in the American households during an average week, identify packaging format(s) with the largest food group that is wasted in the American households during an average week, distribution of states of food waste, and determine and quantify the most wasted food groups and fresh whole fruits and vegetables in American households. This was determined through different questions. Below is the overall breakdown of each question.

Question #9A: Top Food Category That Is Wasted In American Households During An Average Week

The top food category wasted in American households during an average week was determined by asking participants to select one of the following food categories produce, protein, grains, beverages, baking ingredients, spices, and powders, dairy, prepared foods, potatoes and onions, and fats and oils.

Question #9B: Top Food Group That Is Wasted In American Households During An Average Week

The top food group wasted in American households during an average week was determined by asking participants to select the specific food group based on their previously selected food category. For each food category, main food groups were presented to the participants for them to select the correct one (e.g., Fresh whole fruits and vegetables, Milk, etc.).

Question #9C: Packaging Material Of The Top Food Group That Is Wasted In American Households During An Average Week

The packaging material associated with the top food group that is wasted in American households during an average week was determined by asking participants to select the packaging in which the food product is commonly sold in by taking into consideration its material (e.g., metal, glass, plastic, etc.). If the previously chosen food product was not packaged participants were instructed to select the option "no packaging."

Question #9D: Packaging Format Of The Top Food Group That Is Wasted In American Households During An Average Week

The packaging format associated with the top food group that is wasted in American households during an average week was determined by asking participants to select the packaging format (e.g. can, bottle, clamshell container, etc.) in which the food product is commonly sold based on their previously selected material.

Question #10A: Food Waste States Based On Participants' Most Wasted Food Group

The food waste states associated with participants' most wasted food group was determined by asking participants to select one of the following food waste states: half-eaten packaged food product, food without packaging that spoiled before it was eaten, not eaten meal leftovers, food that spoiled before the package was opened, and food that was thrown away because the wrong product was purchased.

Question #10B: Quantification Of Household Food Waste

Using a visual reference **Figure 1** participants were asked to select the number of servings they discarded of their selected food group during an average week. Similar to what is done in food waste references, each food group was linked to a hand portion that denoted a serving size. The number of serving varied from 1 to >9 and each serving was correlated to a specific number of ounces.



Figure 1. Parts of the human hand that represent a specific servings size for food groups.

Question #11: Distribution Of Fresh Whole Fruits And Vegetables Wasted In US Consumers Households During An Average Week

If participants selected fresh whole fruits and vegetables as their most wasted food group then they were asked to select from a list the specific most wasted fresh whole fruit and/or vegetable (e.g., bananas, lettuce, strawberries) wasted in their household along with the number of units that are discarded in their respective household during an average week. This question was not included in the quantification of food waste; rather, it's only purpose was to ascertain the amount of fresh, whole fruits and vegetables that were wasted.

3.3 Data Collection

To identify any inconsistencies or problems with the quality of the data, the Questionnaire first had a soft launch that gathered responses from 200 participants in November of 2022. A few inconsistencies were identified within the soft launch. A particular question aimed at evaluating consumers' perceptions of packaging attributes (e.g., maintain food freshness, eco-friendly, etc.) associated with packaging materials (e.g., glass, plastic, metal, paper/paperboard), yielded results. Of the 117 participants, 50% chose metal and paper/paperboard as transparent. To determine the packaging material and format associated with consumer's most wasted food group, they were directed to select the packaging material and format in which their most wasted food group was typically sold in. The responses to this question during the soft launch revealed that some consumers chose eggs as their most wasted food group and glass jar as the as packaging material and format. For a number of reasons, eggs are not offered in this material and/or format. Therefore, these responses were a clear indication that the data collected was not trustworthy. As a result, several termination points were designed for various questions to avoid these results. For example, in question 2, if participants selected metal for the packaging attribute "transparency", if the

participant selected the same material for each attribute, if the participant didn't select more than 1 attribute for any of the materials. In question 3, if the participants selected "can" for "resealability", if the participant selects the same format for each attribute, if the participant doesn't select more than one attribute for any of the formats. In question 6, if participants select "the food product is taken out of its original packaging and stored without packaging (e.g., fruit bowl or refrigerator drawer)" for fats and oils, grains and any other food category that cannot be stored without packaging. After meeting with Qualtrics, a new panel of participants were recruited. Overall, 2,697 responses were collected when combining the responses collected before and after the new panel was recruited. The data was scrubbed simultaneously throughout the collection process until 1,000 completed surveys were collected matching the demographics of the U.S. census.

3.4 Statistical Analysis

Principal Component Analysis (PCA) was performed to examine the data from questions #4 and #7 (part 1 and 2) for potential correlations between the factors in each of these three question blocks using SPSS (IBM[®] Statistics 29, Armork, New York, NY, USA). The PCA results for question #4 and part 1 of question #7 showed that factor correlation was not appropriate, indicating a significant variation in consumers' knowledge about the effects of packaging technologies and structural designs on food freshness (referred to as the "KNOWLEDGE_TECH" and "KNOWLEDGE_STR" variables) between food products. Based on the findings of the pilot test, which indicated that knowledge depended on the type of food product, the inappropriateness of PCA was anticipated. The Kaiser–Meyer–Olkin estimate for the PCA conducted for question #7 (part 2 purchase inten) was 0.753, indicating that the consumer, rather than the food, is primarily responsible for consumers' willingness to purchase food products in packaging that preserves their freshness for a longer period (referred to as the "PURCHASE INTENT" variable). It was inappropriate to extract Cronbach's Alpha for "KNOWLEDGE_STR" and "KNOWLEDGE_TECH" because food itself has a significant influence on the consumer's understanding of how structural packaging designs and packaging technologies affect food freshness. The retrieved Cronbach's Alpha for "PURCHASE INTENT" was within an acceptable range (0.657), and this was expected due to the dependence of the data on the consumer, rather than the food.

Participant data were analyzed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). The categorical responses were analyzed using a chi-square test of independence for each individual population segment (i.e., age, gender, education, ethnicity, etc.) with PROC FREQ procedure. The ordinal responses were analyzed using a chi-square test of independence for each individual population segment (i.e., age, gender, education, ethnicity, etc.) and two-way interactions between these population segments with PROC LOGISTIC procedure. The chi-square test p-value < 0.05 indicated a significant association between the response and the population segments. For binary responses, the model used was binary logistic regression and for other ordinal responses with more than 2 levels, the method used was cumulative logistic regression model. Power analysis (PROC POWER procedure in SAS 9.4) was used to compare the proportions of responses, a power greater than 0.8 is needed to conclude that people choose one choice significantly over another. Since each question was analyzed individually to produce a certain outcome, the participant data were analyzed separately.

A cumulative logistic regression was used to determine whether there are any associations between people's rating for each feature and demographic and psychographic segments in question #1. A significance test (chi-square test) was utilized for questions #2 and #3 to compare the percentage of respondents who selected each option.

A chi-square test was used to examine how many participants answered each question correctly compared to incorrectly for question #4. A Binary Logistic regression was utilized to find significant differences and two-way interactions with demographic and psychographic data.

A frequency technique and the chi-square test were used to determine the choice distribution for each packaging type for Question #5. A significance test was also utilized to determine whether particular reasons were chosen considerably more often or less frequently than others when purchasing each packing function. A logistic regression was utilized to find significant differences and two-way interactions with demographic and psychographic data.

A frequency technique and Chi square test were performed with the null hypothesis that individuals chose evenly among the five options for Question #6 to determine whether people have a preference in re-packaging choices. Additionally, a significant test was done to establish whether specific re-packaging alternatives for food categories were utilized much more often than others. A logistic regression was utilized to find significant differences and two-way interactions with demographic and psychographic data.

A chi-square test was utilized for Question #7 to examine the proportion of respondents who chose the right answer as opposed to the wrong one; with the null hypothesis that respondents chose both the right and the wrong answer equally. A logistic regression was utilized to find significant differences and two-way interactions with demographic and psychographic data.

A chi-square test was used for Question #8 to determine whether more people chose "Yes" than "No" or "maybe," with the null hypothesis being that respondents chose evenly among the three options. A power analysis was carried out to compare the percentages of yes to no and yes

to maybe. To determine whether there are any correlations between people's choices and demographic/psychographic factors, a cumulative logistic model for all the demo/psych components was created.

A chi-square test and significance test were carried out for Question #9A (food categories) to determine the top three food categories and significant differences between the total number of responses for top 1-3 food categories. A Cumulative logistic regression was used to identify significant differences and two-way interactions between the top three food categories and demographic and psychographic characteristics.

A chi-square test and significance test were carried out for Question #9B (food groups) to determine the top three food groups and significant differences between the total number of responses for the top 1-3 food groups. A Cumulative logistic regression was used to identify significant differences and two-way interactions between the top three food groups and demographic and psychographic characteristics.

A chi-square test and significance test were carried out for Question #9C (packaging materials) to determine the top three packaging materials and significant differences between the total number of responses for top 1-3 material. A Cumulative logistic regression was used to identify significant differences and two-way interactions between the top three food groups and demographic and psychographic characteristics. Using a chi-square test, the top three food categories' demographic/psychographic groups related with plastic packaging formats were examined separately for Question #9C (format). An additional comparison between each material and format for each food category was made using a multinomial proportion test.

A chi-square test and significance test between the top three waste states were performed for Question #10A in order to determine the top three waste states based on all 982 responses. The

significant differences and two-way interactions between food waste states and demographic/psychographic segments were also determined using the chi-square test. Additionally, associations between food waste states and packaging materials—no packaging, plastic, paper, or other—and plastic formats—bottle, jar, bag, and tray—were analyzed with the chi-square test.

CHAPTER 4

DEMOGRAPHIC AND PSYCHOGRAPHIC BREAKDOWN

4.1 Consumers Demographics

A total of twelve demographic segments were gathered from the survey participants (section 3.2.3). The demographic breakdown of the survey participants is presented in **Table 7**. The dominant groups within the demographic breakdown were Caucasians, non-disabled, and non-Hispanic, Latino, or Spanish participants. This demographic distribution matched that of Just and Goddard (2022), who also carried out a national survey in the US on AP, quite closely. In contrast, in earlier studies, female participants made up the majority of the demographic breakdown (O'Callaghan and Kerry, 2016; Wilson et al., 2018; Cammarelle et al., 2021). This might be accounted for by the fact that these studies did not focus on a demographic distribution similar to their censuses.

4.2 Consumers Psychographics

Participants were asked to answer the following psychographic questions: "How do you most often buy your groceries," "How often do you grocery shop," "Do you contribute to reducing food waste in your household," and "Why do you try to throw away less food".

The psychographic breakdown of survey participants is also presented in **Table 7.** Most participants bought their food at physical stores, and more than half of them frequently do so once a week. Approximately 90% of the participants helped cut down on home waste and did so because either they do not believe in wasting food or they spent money on it. Therefore, some participants viewed throwing away food as equivalent to throwing away money.

Population segments	Population groups	Participants (%)
		N = 1,000
	Demographics	
Gender	Male	46.9
	Female	53.0
	18-25	6.3
Age	26-41	27.8
	42-57	28.5
	58+	37.4
	White	76.5
	Black or African	13.2
	American	10.2
Race	American Indian or	3.8
	Alaska Native	
	Asian	5.6
	Native Hawaiian or	0.9
	Other Pacific Islander	0.9
Income	> \$20,000	13.0
	\$20,000-\$49,999	27.9
	\$50,000-\$74,999	19.9
	\$75,000-\$99,999	10.3
	< \$100,000	28.9

 Table 7. Participants' demographic and psychographic breakdowns.

Table 7. (cont'd)

	Some school	2.1
	High school diploma	22.1
	or GED	22.1
	Some college	28
Educational	Associate's degree or	11.9
background	2-year degree	11.7
	Bachelor's degree or	21.9
	4-year degree	21.7
	Graduate degree or	14.0
	more	14.0
	Married	45.6
	Never married	34.1
Marital Status	Separated	2.1
	Divorced	11.8
	Widowed	6.4
Household size	1 person	26.1
	2 persons	35.9
	3 persons	15.6
	4 persons	13.3
	5 persons	6.2
	6 person and up	2.9
Disability	Yes	18.5

Table 7. (cont'd)

	No	84.8
Ethnicity	Hispanic, Latino, or Spanish origin	18.5
	Not Hispanic, Latino, or Spanish origin	81.5
	Northeast	17.9
Region	Midwest	21.8
region	West	22.2
	South	38.1
	Psychographics	
Grocery method	Buy items online then go and pick them up	6.9
	Buy items online and have them delivery to you	12.1
	Buy at a physical store	81.0
Grocery frequency	Every other week	22.4
	Once per week	52.5
	More than once per week	25.1
Reduce waste	Yes	90.3

Table 7. (cont'd)

	No	9.7
	I spent money on that food	33.1
Why do you try to	I do not believe in wasting food	56.9
throw away less food?	I don't want it to negatively impact the environment	9.4
	I am not sure	0.5

CHAPTER 5

ASSESSING CONSUMERS PERCEPTION OF PACKAGING FORMATS AND PACKAGING MATERIALS AND THE RELATIONSHIP OF THOSE ATTRIBUTES TO HOUSEHOLD FOOD WASTE

5.1 Importance Of Packaging Features In Reducing Household Food Waste





Figure 2 presents the importance that 16 different packaging features have in reducing

household food waste for the survey participants.

"Maintain food freshness" was rated the most important packaging feature in reducing household food waste (Likert score = 4.3 out of 5) (Figure 2). This score resulted from approximately 91% of the survey participants rating this feature as either important or very important. While "maintain food freshness" was rated as the most important packaging feature for reducing household food waste, the packaging feature "material (paper, plastic, etc.)"—which is essential for a package to maintain food freshness—was rated as one of the least important aspects for maintaining food freshness according to survey participants.

Second highest was "Printed food product dating (best buy, sell by, coding dates and others)". (Figure 1—Likert = 4.1/5). This score came from 82% of participants ranking this feature as either important or very important. In a food waste survey, Patra et al. (2022) discovered that many respondents were confused about how to interpret food date labels, which contributed to food waste. Depending on the printed food product dating, it helps retailers decide how long to display packaged food products, manufacturers identify the date and time of production, and does not indicate food shelf life or safety (Food Safety and Inspection Service, 2019). While "printed food product dating" was rated as an important packaging feature in reducing household food waste, "transparency", "an attachment that tell you about the freshness of the food product", and "an attachment that tell you about the safety of the food product" were neither important nor unimportant. This suggests that people are unaware that these packaging elements better indicate food shelf life. Intelligent packaging can warn consumers about food waste, but they seem ignorant. This suggests that consumers might accept intelligent packaging if they were informed about how this unique packaging technology can reduce household food waste. Intelligent packaging can give consumers the information they need to reduce food waste.

The third most important packaging feature in reducing household food waste was "protection against physical damage/strong (no breakage)" (Likert score = 4.0 out of 5) (Figure 2). This score resulted from approximately ~78 % of participants rating this feature as either important or very important. The fourth most important packaging features in reducing food waste was "Resealability/ Closure type/Easy to open" (Likert score = 3.9 out of 5) (Figure 2).

This score resulted from approximately 73 % of participants rating this feature as either important or very important. The fifth most important packaging feature in reducing food waste was "size" (Likert score = 3.8 out of 5) (Figure 2). This score resulted from approximately 76 % of participants rating this feature as either important or very important. More participants rated "Resealability/ Closure type/Easy to open" as very important which resulted in a higher Likert score compared to size. The lowest rated packaging feature was Graphics/ Illustrations/ Color (Likert score = 2.5 out of 5). This score resulted from approximately 48% of participants rating this feature as either unimportant or of low importance. About half of participants did not see any value graphics or illustrations play in reducing household food waste.

Some common findings for the three major packaging elements and various group behaviors in some population subgroups are worth mentioning. Participant involvement in minimizing household food waste affects the importance of all three packaging features rated as important in this regard differently depending on the population segment. Maintain food freshness, "printed food product dating" and "protection against physical damage" were less important to Gen Z (18 to 25), participants with incomes under \$99,999, and people with disabilities who reduce food waste in their household. They may already reduce food waste in their families, making package characteristics that reduce food waste less significant. In contrast, college graduates, divorcees, and grocery shoppers who decrease food waste within their homes valued packaging characteristics like "printed food product dating" and "protection against physical damage" more. Due to their greater education, these consumers may be aware of how specific packaging characteristics reduce home food waste. Participants who shop every other week understand the importance of food dates and quality. Appendix A shows two-way interactions between population segments on the importance of packaging features such as

"Maintain freshness," "Printed food product dating (best buy, sell by, coding dates)," and "protection against physical damage/strong (no breakage)" regarding household food waste reduction (P < 0.05).





Figure 3. Participant's perception of packaging materials associated with packaging features. Today's consumers want transparent containers to monitor food freshness. Transparent materials include plastic, glass, and certain paper/paperboard forms. Plastic and glass were judged as far more transparent than paper (p < 0.0001). This is likely because transparent paper or paperboard is rare. Bakery products like bread are usually packaged in windowed paper bags.
Plastic packaging was perceived as transparent to 89% of participants (Figure 3). This may be because beer and wine bottles contain a pigment that reduces transparency. Based on the above, participants correctly perceive "transparency" in packaging.

Food products can absorb chemical substances from packaging which is known as migration (FDA, 2023). More participants chose glass for "no chemicals move from packaging

material to food product" than paper/paperboard, plastic, or metal (p < 0.0001). In addition, participants did not view metal, plastic, or paper as being different when it came to the transfer of chemicals from them to food products. Although 59% of participants chose glass for "no chemicals move from the packaging material to the food product" (Figure 3), only 20% chose metal, which also has minimal migration (Marsh and Bugusu, 2007). Plastic, which encourages migration, was chosen by 30% of participants as a chemical-resistant material. Most food-packaging interactions involve low-molecular-weight compounds such stabilizers, plasticizers, antioxidants, monomers, and oligomers migrating from plastic packaging materials into food (Arvanitoyannis and Bosena, 2004). The above indicates that participants misperceive some packaging materials as more or less prone to migration which can contribute to more household food waste.

Dispensing and emptying packaging features affect food waste, according to research. Easy-to-empty features make food accessible and reduce residue. Lindh et al. (2016) define this as "the ability to access the product, to pour or, in another way, take out the product from the package without loss of product." "Not easy to empty" is the second most common packagingrelated food waste explanation (Williams et al., 2012). Participants chose plastic for "Dispensing feature/Easy to empty" significantly more compared to glass, metal, and paper/paperboard (p < 0.0001). Roughly 63% of consumers chose plastic while 42%, 40%, and 21% chose glass, paper/ paperboard, and metal, respectively (**Figure 3**). Despite the lower number of participants who chose metal, the difference was not enough for participants to show a perceived difference among glass, paper/paperboard, and metal for "Dispensing feature/Easy to empty" (p > 0.05). The ability of plastic to create endless container designs has led to several dispensing features and shapes (Selke et al., 2021). This type aids dispensing and emptying. Squeezable, flexible

packets with many dispensing methods allow consumers to empty the full container. Plastic may have been chosen over other materials because of this.

Participants perceived paper/paperboard and glass as "eco-friendly with the environment" significantly more compared to plastic and metal (p < 0.0001). There were no significant differences (p > 0.05) between these two packing materials or plastic and metal, although 72% of individuals preferred paper/paperboard compared to 44, 20, and 16% who chose glass, metal, and plastic. The results of this study were in close agreement with a study conducted in Sweden, which found that consumers thought paper-based packaging had the least negative environmental effects, followed by glass, plastic, and metal (Lindh et al., 2016). Additionally, these results concurred with a study that found that when it came to sustainable packaging, more US customers favored glass, paperboard, and paper over plastic and metal. Consumers classified each material as highly or extremely sustainable packaging more closely than in our survey. 57–60% of US consumers considered glass, paperboard, and paper highly or extremely sustainable packaging more closely than in our survey. 57–60% of US consumers considered glass, paperboard, and paper highly or extremely sustainable packaging substrates, while 53–57% and 48% did so for plastic and metal. Compostable and recycled plastic makes the difference. However, ecofriendly materials take longer to extend food shelf life (Duguma et al., 2023) and consequently, reduce food waste.

Main food changes that result from spoilage include discoloration, off-flavor development, softening/hardening, and mold/bacteria growth (Almenar and Gonzalez-Buesa, 2023). Packaging can minimize these changes thereby extending food shelf life (Almenar, 2020; Almenar, 2021; Almenar et al., 2023). The type of material contributes significantly to this minimization (Joo et al., 2011). When participants were asked to choose packaging materials that maintain food freshness, they chose glass and plastic significantly more compared to metal and paper/paperboard (p < 0.0001). Regardless of the type of food changes resulting from spoilage,

the ranking was the same: glass, plastic, metal, and paper. 65% of respondents knew glass keeps food fresh (Figure 3). Glass' exceptional barrier to gases and vapors keeps food fresh and flavorful for longer (Marsh and Bugusu, 2007). Many participants showed a lack of awareness by choosing plastic over metal for food-fresh packaging. Similar results were seen for the packaging attribute migration when plastic and metal were switched. Metal-based packaging materials are employed in food packaging applications that require a long shelf life due to their better barrier qualities over plastic. The results suggest that consumers should be educated about how packing materials keep food fresh.

Physical damage protection in packaging extends food shelf life and reduces food waste (Williams et al., 2012). Packaging materials protect food from physical damage differently (Spruit and Almenar, 2021). Metal is used in numerous food applications because of its physical protection (Marsh and Bugusu, 2007). Plastics have replaced glass in soda bottles to avoid shattered glass (Marsh and Bugusu, 2007). Thus, traditional and e-commerce supply chains offer liquid food goods mostly using metal and plastic (Spruit and Almenar, 2021). Participants significantly selected metal and plastic packaging materials for protection against physical damage and strength (no breaking) compared to glass and paper (p < 0.0001). At least 65, 45, 29, and 16% of individuals chose metal, plastic glass, and paper/paperboard. Thus, participants understood how packing materials protect food or not from physical damage, especially nondamaging materials. Only 45% of participants chose plastic for "protection against physical damage /Strong (no breakage)"; perhaps they thought about the format (e.g., flexible packaging) rather than the material. There is no justification for the low metal participation (65%) as metal is the best material among the others in providing protection against physical damge. (Figure 3). These findings and the fact that participants ranked protection against physical damage as the

third most important packaging feature for reducing household food waste in section 5.2 support if the appropriate packaging material is selected for food products, then food waste can be reduced in the homes of consumers.





Figure 4. Participant's perception of packaging formats associated with packaging features. Resealability decreases environmental exposure and prolongs food preservation, reducing food waste. Food categories that need freshness may benefit from resealable zippers, lids, or other closures (Sustainable Packaging Coalition, 2021). Consumers seek packaging conveniences including resealability and quick opening (Marsh and Bugusu, 2007). Participants preferred bottles, jars, and pouches over cans and cartons based on resealability, closure type, and simplicity of opening (p < 0.0001). About 75, 75, 66, 43, and 4% of participants chose bottle, jar, pouch, carton, and can (Figure 4). Since bottles and jars have twist-off lids or tops, they are the greatest resealable packages. Mason jar foods and bottled drinks are examples. Since cans rarely seal in this form, they ranked lowest. Consumers understand that packaging formats affect resealability, which can reduce food waste.

Since almost all packaging takes force to break a seal, screw a cap, or unload the contents, it can be difficult to use and cause food splits. Having trouble accessing the contents may lead to unhappiness, poor product delivery, or not eating all of it (Blakey et al., 2009). Splits and uneaten food increase household food waste. When asked about "dispensing feature/easy to empty," participants frequently chose bottles and cartons above cans, jars, and pouches (p < p0.0001). Approximately 72, 71, 56, 43, and 43% of participants selected bottle, carton, jar, can, and pouch, respectively (Figure 4). The bottle's top rating may be related to participants' assessment of squeezable bottles. For consumer safety, ease of use, and better access to contents, food packaging businesses utilize "squeezy" bottles for fluid foods. Participants may have considered the "upside-down" bottle design (e.g., ketchup), which stores the content on its lid for faster retrieval. Milk and drink cartons are stiff and easy to open, making content delivery easier. Carton and bottle were likely tied as the top format for dispensing/easy to empty because of the above. By choosing these two, 75% of participants showed that they can identify packaging formats with more frequent dispensing characteristics and easier emptying, which could reduce household food waste.

Opening packages requires different grips and forces based on the packaging type and consumer ability. Food accessibility and reducing food throwing before eating depend on package shape and customer handling. Silayoi and Speece (2004) and Hassan et al. (2012) discovered container shape affects purchasing. Participants significantly selected bottles over cans, cartons, jars, and pouches when asked to correlate packaging formats with "Easy to grip/Shape" (p < 0.0001). Participants chose bottle, pouch, jar, can, and carton in proportions of 75, 54, 53, 52, and 49% (**Figure 4**). Thus, the bottle was the most grippable packaging format. Wenk et al. (2016) used focus group research to determine seniors' demands and the force

needed to open selected food packaging options. This study's focus group found that the PET bottle's bigger screw top was easier to hold and turn due to its slightly larger diameter and deeper grooves. Pouches were the second most grippable packing format. Wenk et al. (2016) found that peelable packaging like pouches was user-friendly and enjoyable by both active and weak senior citizens because the indentations were clearly marked and opening required only a simple grasp and moderate strength. By appealing to consumer desires and creating new, easy-to-grasp container styles, household food waste can be reduced.

Participants significantly chose jar, carton, and bottle over can and pouch when asked to associate packing formats with "Eco Friendly with the environment" (p < 0.0001). The percentage of participants who chose jar, carton, bottle, can, and pouch, respectively, was approximately 57, 54, 43, 31, and 22% (**Figure 4**). When participants were asked to associate materials with the feature of being environmentally friendly earlier in this section, the results showed that 72% of participants chose paper/paperboard and glass as their top two choices for this feature (**Figure 4**). This could have contributed to jar, carton, and bottle being more selected as environmentally eco-friendly formats since they are made of either paper/paperboard or glass. Another possible reason is participants' awareness of recycling practices since jar, carton, and bottle are accepted as part of the recycling stream.

When participants were asked to evaluate packaging formats with "Protection against physical damage/Strong (no breakage)," the can was selected significantly more frequently than the carton, jar, bottle, and pouch (p < 0.0001). Approximate percentages of participants who chose can, pouch, carton, bottle, and jar were 77, 35, 29, 28, and 15 (**Figure 4**). Considering that "metal" was the best material for physical damage protection, the can was likely the top choice for this function. Metal cans are common. Why only 35% of participants selected the pouch may
be because only 45% chose earlier plastic for "protection against physical damage/Strong (no breakage)". This validates the assumption made in section 5.3, which stated that participants associated plastic with flexible packaging like pouches. These results support the appropriate choice of particular packaging formats if food waste reduction in consumers' homes is indented, as does the fact that participants ranked protection against physical damage as the third most important packaging feature for reducing household food waste in section 5.2.

5.4 Consumers' Awareness Of The Impact Of Structural Packaging Design On Food Freshness

Consumers' awareness of the role different packaging designs (format + material) play in extending food shelf life can significantly contribute to reducing household food waste.



Figure 5. Consumers' awareness (green) of the impact of structural packaging designs commonly found in US supermarkets (bottom) on maintaining the freshness of cherries, milk, bread, chicken, and peanut butter.

5.4.1 Consumers' Awareness Of The Impact Of Structural Packaging Design On The

Freshness Of Cherries

Figure 5 shows consumers' awareness of the role different structural packaging designs play in extending the shelf life of cherries. Common packaging designs found in US supermarkets for produce include metal cans, plastic clamshell containers, and plastic stand-up pouches (Table 3). Canning is commonly used to preserve fruits and vegetables for extended periods of time (Almenar, Wilson, Bayer, and Kubicki, 2024). Plastic clamshell containers have been used to commercialize produce for more than two decades since they offer protection, air flow to prevent condensation, and stackability. Lately, plastic stand-up pouches have grown in use because of the usage of less plastic compared to the clamshell aiming for sustainability. However, they provide less protection and allow for less air to flow. Approximately 64% of participants selected correctly metal can as the structural package design that can keep cherries fresh the most (p < 0.0001). Only ~35% and 30% of participants were able to identify the plastic clamshell container as neither the best nor the worst in terms of extending cherry shelf life (p <0.0001) and the plastic pouch as the packaging design that keeps cherries fresh the least (p <0.0001), respectively. The above shows that American consumers' assessment of structural packaging designs for cherries is not quite correct. This most likely applies to other fresh produce with similar packaging and hence significantly contributes to household produce waste. These results could be explained by the significant number of American consumers who do not care about produce packaging (Wilson et al., 2018). Comparing our results with Langley et al. (2021)'s results, more Australian consumers feel that plastic packaging does not extend food shelf life than American consumers.

Significant differences among population segments were found only for educational background and ethnicity in the case of cherries in the metal can. Participants with a high school diploma, some college, an associate's degree, and a bachelor's degree selected that the metal can will keep cherries fresh the most significantly more than participants with a different educational background (p < 0.0317). Participants who are not Hispanic, Latino, or of Spanish origin selected that the metal can will keep cherries fresh the most significantly more than those who are of Hispanic, Latino, or Spanish origin (p < 0.0500).

5.4.2 Consumers' Awareness Of The Impact Of Structural Packaging Design On Milk Freshness

Figure 5 shows consumers' awareness of the role different structural packaging designs play in extending the shelf life of milk. In the US, extended shelf-life (ESL) or ultra-pasteurized or ultra-high temperature (UHT) milk is sold in cartons and plastic bottles covered with an opaque plastic sleeve all trough while high temperature short time (HTST) milk is sold in plastic jugs (Table 3). This is because when milk is treated at different temperatures (high (Elwell and Barbano, 2006) vs. ultra-high (Sujata et al., 2022) it differs in shelf life and hence packaging requirements. The carton and plastic bottle are better barriers to oxygen and light than the plastic jug due to the different materials they are made of. Consequently, packaged UHT milk has a shelf life of several months and does not require refrigeration until the package has been opened (Wani et al., 2014) while packaged HTST milk has a shelf life of 2-3 weeks if refrigerated (International Dairy Federation, 2016). Less than 20% of participants were able to correctly select carton as the structural package design that can keep milk fresh the most (p < 0.0001) and plastic jug as the packaging design that can keep milk fresh the least (p < 0.0001). Approximately ~45% of participants were able to identify the plastic bottle as neither the best nor the worst in terms of extending milk shelf life (p < 0.0001). The above shows that consumers' assessment of structural packaging designs for milk is not correct, which can significantly contribute to household milk waste. In fact, it is worse than in the case of produce. Contrary to Americans, South Africans were able to associate the carton box with long-term food storage (Venter et al., 2011). Our results also show that participants do not read the label in the package, which announces the processing conditions milk and packaging underwent or not (ultra-pasteurized vs. pasteurized), or if they do, they do not know the implications of the

terminology in milk shelf life. Hence, educating consumers to read labels or to learn about packaging technologies could contribute to reducing household milk waste. There is a study in the literature that covers consumers' perception of milk packaging, however, this does not correlate different structural packaging design with the perceived shelf life of the milk and/or household milk waste (Lien, Groen, and Van Kleef, 2022).

The selection of the correct responses for milk in the carton and plastic jug was significantly different based on population segments. For both carton and plastic jug, female participants responded significantly better than male participants in selecting the carton as the best packaging design for maintaining milk's freshness and the plastic jug as the worst packaging design for doing so (p < 0.0169 and p < 0.0167, respectively). Additionally, Black or African American, American Indian or Alaska Native, and Native Hawaiian or Other Pacific Islander participants selected the plastic jug as the worst packaging design in maintaining milk's freshness significantly more than participants of a different race (p < 0.0041).

5.4.3 Consumers' Awareness Of The Impact Of Structural Packaging Design On Bread Freshness

Figure 5 shows consumers' awareness of the role different structural packaging designs play in extending the shelf life of bread. The bread loaf is commonly found in US supermarkets packaged in a loose plastic bag made of a polyolefin which can minimize stalling in order to maintain freshness (Pasqualone et al., 2019) (Table 3). The paper bag is also used because it brings enough protection for products expected to be consumed quickly like bread (Table 3). Additionally, a combination of plastic and paper bags have been used to increase bread shelf life when needed (e.g., loaf bread not sold earlier in the day) (Table 3). Half of the participants selected correctly loose plastic bag inside the paper bag as the package design that can keep

bread fresh the most (p = 1). Also, half of the participants (46.6%) were able to identify the paper bag with window as the packaging design that keeps bread fresh the least (p < 0.0315). Only 30% of participants were able to identify the loose plastic bag as neither the best nor the worst in terms of extending bread shelf life (p < 0.0001). The above shows that consumers' assessment of packaging designs for bread is not quite correct, but much better than for cherries and milk. These findings also indicate that approximately half of the participants knew that a paper bag extends bread shelf life less than a plastic bag.

The selection of the correct response for bread packaged in a paper bag and bread packaged in loose plastic bag inside the paper bag was significantly different based on population segments. Regarding bread packaged in a paper bag, participants with some school, some college, and a bachelor's degree, those who were not of Hispanic, Latino, and/or Spanish origin, and those with incomes of at least \$50,000 selected the paper bag as the packaging design that keeps bread fresh the least significantly more than participants from other groups within each respective population segment (p < 0.0339, p < 0.0005, and p < 0.0116). Regarding bread packaged in loose plastic bag inside the paper bag, participants who shop for groceries once a week or more selected the loose plastic bag inside the paper bag as neither the best nor worst for maintaining bread freshness significantly more than participants who grocery shop every other week (p < 0.0113).

5.4.4 Consumers' Awareness Of The Impact Of Structural Packaging Design On Chicken Freshness

Figure 5 shows consumers' awareness of the role different structural packaging designs play in extending the shelf life of chicken. Fresh chicken is frequently sold in plastic airtight packaging, trays with glued-on lids, and trays with wraps in US supermarkets (Table 3). The meat

industry has regularly been commercializing chicken using plastic airtight packaging to reduce air/oxygen in the package headspace to slow down oxidation and growth of aerobic microorganisms (Wani et al., 2015). In contrast, plastic trays with glued-on lids and plastic trays with wraps contain air in their headspaces. They differ in their barrier properties, with the trays with airtight packaging presenting a higher barrier. Many participants (77%) correctly identified air-tight packing as the most effective packaging design for maintaining chicken freshness (p < 0.0001). Nearly half of the participants (45 and 46%) recognized the tray with a glued-on top as neither the best nor the worst format (p < 0.019) and the tray with a wrap as the least effective packaging design when it came to maintaining chicken freshness (p < 0.0228). Consumers' awareness about packaging designs for chicken was better than consumers' awareness about packaging designs for cherries, milk, and bread. This higher awareness could be attributed to advertisements of devices that remove air from pouches containing food to extend food shelf life on television and other media.

The selection of the correct response for each packaging design was significantly different based on population segments. Regarding plastic air-tight packaging, participants over the age of 41, participants who were not of Hispanic, Latino, or Spanish origin, married, divorced, and widowed participants, participants who buy items at a physical store, and participants who contribute to reducing household food waste selected air-tight packaging as the most effective design for maintaining chicken freshness significantly more than participants from other groups within each respective population segment (p < 0.0006, p < 0.0001, p < 0.0160, and p < 0.0240, and p < 0.0014). Regarding the tray with a wrap, participants who identified as Asian, American Indian or Alaska Native, those with non-Hispanic, Latino, or Spanish origin and those who grocery shop at least once per week selected the tray with a wrap as the least effective packaging design for maintaining chicken freshness significantly more than participants from other groups within each respective population segment (p < 0.0009, p < 0.0238, and p < 0.0006). Regarding the plastic tray with a glued-on top, American Indian or Alaska Native and Asian participants selected this packaging as neither the best nor the worst format for maintaining chicken freshness significantly more than participants of a different race (p < 0.0308).

5.4.5 Consumers' Awareness Of The Impact Of Structural Packaging Design On Peanut Butter Freshness

Figure 5 shows consumers' awareness of the role different structural packaging designs play in extending the shelf life of peanut butter. Peanut butter is frequently offered for purchase in flexible pouches, glass jars, and plastic jars in US supermarkets (Table 3). Glass jars contrary to plastic jars have been used to package food for extended periods of time due to glass advantages of being environmentally safe, chemically inert, odorless, and impermeable to gases and vapors (Chadha et al., 2022). Stand-up pouches with dispensing devices are growing in popularity due to convenience. These pouches are frequently constructed of plastic, metal foil, and occasionally paper. Sometimes the metal foil is replaced with a metallized film. Either the aluminum layer or the metallized film increases the odor, moisture, oil, water, and oxygen barrier of the multilayer structure (Marsh and Bugusu, 2007) resulting in a package that can extend food shelf life longer compared to the plastic jar. The glass jar was recognized by more than half of the participants (61%) as the most effective packaging design for maintaining peanut butter freshness (p < 0.0001). According to research by Venter et al. (2011) on consumers' perceptions of food packaging, participants believed that certain food products stored in glass packaging had a long shelf life due to their perceptions of glass being an expensive packaging. Less than 16% of participants correctly identified the pouch as neither the best nor the worst option (p < 0.0001)

and the plastic jar was identified by 17% of participants as the least effective packaging design for maintaining peanut butter freshness (p < 0.0001). The information above demonstrates that consumers' perceptions of peanut butter packaging designs in terms of freshness maintenance are not entirely accurate. The similar number of correct responses for both plastic bag and plastic jar could be attributed to participants' perception of plastic without taking into consideration the metallized film that is within the pouch which enhances its barrier qualities thereby helping prolong the peanut butter shelf life in comparison to the plastic jar.

The selection of the correct response for each of these packaging designs was significantly different based on population segments. Regarding the glass jar, participants 25 and under, 58 and over, and Caucasian, American Indian or Alaska Native and Asian participants, selected the glass jar as the best packaging design for maintaining the freshness of peanut butter significantly more than participants from other groups within each respective population segment (p < 0.0026 and p < 0.0053). Regarding the plastic jar, participants with some college, an associate's degree, a bachelor's degree, participants who identify as Hispanic, Latino, or Spanish, participants with an income above \$50,000, and participants who grocery shop more than once per week selected the plastic jar as the least effective packaging design for maintaining the freshness of peanut butter significantly more than participants from other groups within each respective population segment (p < 0.0198, p < 0.0480, p < 0.0044, and p < 0.0303). Regarding the plastic pouch, participants with an income of >\$20,000 and \$50,000-\$99,999 and those who shopped for groceries more than once a week and every other week rated the plastic pouch as neither the best nor the worst option for maintaining the freshness of peanut butter significantly more than participants from other groups within each respective population segment (p < 0.05, p < 0.0101).

CHAPTER 6

ASSESSING CONSUMERS' AWARENESS OF PACKAGING FEATURES, TECHNOLOGIES, FUNCTION, PURCHASE INTENTIONS AFTER BEING EDUCATED, AND WILLINGNESS TO PAY FOR PACKAGING DESIGNED TO REDUCE HOUSEHOLD FOOD WASTE

6.1 Consumers' Awareness Of Packaging Features As They Relate To Household Food

Waste When Making Purchase Decisions



Figure 6. Consumers' most important reason for purchasing food in packages with features that can contribute to reducing household food waste.

Reclosing a package reduces light and air contact with food, reducing exposure to spores, moisture, and oxygen, which deteriorate food (Almenar and Gonzalez-Buesa, 2024). Food preservation reduces waste. Consumers like packaging preservation and value resealability (Neff et al., 2015). Zippered plastic pouches, resealable zippers, lids, or other secure closures are valued (Soni et al., 2017). Participants prioritized convenience and food freshness over brand preference, price, and other factors when purchasing "packaging with a zipper seal" and "packaging with a peelable and resealable lid" (p < 0.0001; p < 0.0001). Nearly half of participants (49 and 41%) picked zipper seal packaging for convenience and food freshness (**Figure 6**). Peelable and resealable lid packaging was preferred by 45 and 27% of participants for convenience and food freshness (**Figure 6**). A statistical comparison of convenience and food freshness found that participants prioritize convenience over freshness for packaging designs with waste prevention measures (p < 0.05). Many participants believe "packaging with a zipper seal" can keep food fresher than "packaging with a peelable and resealable lid." Different reclosing properties and individuals' experiences may explain this. The participants who chose "packaging with a zipper seal" and "packaging with a peelable and resealable lid" to maintain food freshness helped rank "Resealability/Closure type/Easy to open" as the fourth most important packaging feature for reducing household food waste.

The "upside-down" bottle design, which holds the bottle content on its cover, controls how much product comes out and keeps the product fresher by preventing air from entering the package in the open position. Controlled product distribution and airtightness reduce food waste. Participants significantly chose convenience over food freshness, brand choice, price, and other variables when purchasing "upside down rigid packaging" (p < 0.0001). Sixty percent of individuals bought this packaging feature for convenience, compared to 14% for brand preference and food freshness (**Figure 6**). Statistical analysis revealed no significant differences between brand preference and food freshness (p > 0.05). Flexible inverted packages offer consumers the ability to remove more product and control how much comes out, which may have contributed to convenience being the main reason they buy them. Few participants saw the "upside-down" bottle's food freshness benefits.

With squeeze flow control valves, consumers can avoid overconsuming a product by controlling how much they pour out of packaging. This valve also reduces the amount of air (spores, moisture, oxygen) from entering the packaging during food product consumption. Controlled product distribution and airtightness reduce food waste. Participants significantly chose convenience and food freshness over brand preference, price, and other considerations when choosing "Packaging with squeeze flow control valve" (p < 0.0001) (**Figure 6**). Based on a statistical comparison, consumers significantly chose convenience over food freshness as their primary reason for purchasing this packaging feature (p < 0.05). This may be because packaging with a squeeze flow control valve allows customers to pour out the exact amount of product they desire with simply a squeeze, unlike alternative lids that may spill more product. One quarter of interviewees recognized squeeze flow control valve packaging for food freshness.

Squeezable packaging is usually supplied in pouches, which last longer and allow all the food to be removed. These pouches also block air (spores, moisture, oxygen). The following helps maintain food quality at home, decreasing food wastage. Participants significantly chose convenience over food freshness, brand choice, price, and other considerations when buying "Squeezable packaging" (p < 0.0001). In a statistical comparison, participants significantly preferred maintaining food freshness over brand preference (p < 0.05), with over 80% power. 16% bought this packaging feature to maintain food freshness, whereas 11% bought it for price (**Figure 6**). Participants choosing convenience as the top reason for purchasing this packaging feature may explain why food packaging manufacturers use "squeezy or squeezable" pouches and bottles for fluid foods to ensure ease of use and access.

Multipacks comprise multiple individually packaged commodities sold together. Multipacks often offer the same package in several serving-size packaging so consumers may eat

it all at once. Opening one packet keeps the rest of the multipack's food fresh. The above considerably reduces food deterioration and household food waste (Lindh et al., 2016). Participants significantly chose convenience and price over food freshness, brand choice, and other variables when purchasing a "Multipack" (p < 0.0001). Approximately 37% of participants chose convenience, 23% chose price, and 20% chose to retain food freshness (**Figure 6**). Participants significantly preferred maintaining food freshness over brand preference (p < 0.05) in a statistical comparison (power > 80%). These findings contrast with a study that investigated a technique to optimized consumer packaged goods (CPG) multipacks and found that price was the main factor influencing consumers' purchases (Bloommark, 2021). Saving money was a "very important" or "extremely important" consideration for 82% of multipack buyers. Our findings may be due to participants prioritizing a multipack's easy access and ability to consume a particular amount over pricing.

Convenience was the top reason participants bought packaging with features that can contribute to maintain food fresh and reduce food waste. Consequently, individuals avoid certain package features to prevent household food waste. Maintaining food freshness was the second most important reason for buying zipper seal, peelable and resealable lid, squeeze flow control valve, and squeezable packaging, but not upside down rigid or multipack packaging. Approximately 41, 27, 26, and 16% of participants chose maintain food freshness for zipper seal, peelable and resealable lid, squeeze flow control, and squeezable packaging.

6.2 Food Categories Kept In The Original Packaging, Repacked, Or Stored Without

Packaging At The Household



The food product is kept in the package

The food product is moved from its original packaging to a different one

 $\hfill\square$ The food product is taken out of its original packaging and stored without packaging

Figure 7. Amounts of food kept in the original packaging, repacked, or stored without packaging at the household.

6.2.1 Consumers Re-Packaging Behavior Of Produce Before Consumption

Figure 7 presents the amounts of produce kept in their packaging, repacked, or stored without packaging in consumers households. Packaging benefits some produce products more than others. It depends on commodities respiration rate, transpiration, ethylene production or sensitivity, microbial growth susceptibility, and others (Almenar, 2020). Participants significant preferred storing fruits and vegetables in their original packaging or without packaging, rather than switching to a new package (p < 0.0003). The similar number of participants (36.3%) either store fruits and vegetables in their original packaging or without (p > 0.05) (Figure 7). 27.4% of consumers repackage their produce. In an Avery Dennison online survey, more than 70% of respondents stated they remove fresh products like fruits and vegetables from their packaging and store them in a zippered bag or other plastic container. Taking a product out of its original

packing can diminish its shelf life and increase food waste, however this varies by item, container, and environment.

6.2.2 Consumers Re-Packaging Behavior Of Protein Before Consumption

Figure 7 presents the amounts of proteins kept in their packaging, repacked, or stored without packaging in consumers households. Protein foods include meats, shellfish, lentils, eggs, seeds, etc. This food group's shelf life is lowered by oxygen, light, moisture, microbes, and mechanical damage (Almenar and Gonzalez-Buesa, 2023). All protein foods benefit from packaging (Almenar and Gonzalez-Buesa, 2023). Participants significantly preferred to store protein products in their original packaging or in a new container, rather than storing them without packaging (p < 0.0001). 53% of individuals leave protein meals in their original packaging, while 46% repackage them (Figure 7). More than 80% power showed that participants prefer keeping protein in its original packaging versus repackaging it (p < 0.05). This study found fewer consumers repackaging protein items than Avery Dennison's 70% online survey of 1,000 individuals. Participants may repackage these foods for easier storage, portion size, or to freeze for a long period of time.

6.2.3 Consumers Re-Packaging Behavior Of Grains Before Consumption

Figure 7 presents the amounts of grains kept in their packaging, repacked, or stored without packaging in consumers households. Bread, pasta, cereals, and other grains are prone to lipid oxidation, moisture gain, microbiological development, and staling (Almenar and Gonzalez-Buesa, 2024). Packaging slows all these breakdown processes, benefiting this food group (Almenar and Gonzalez-Buesa, 2024). Many participants preferred to store grains in their original packaging rather than store them without packaging or in a new package (p < 0.0001). Participants prefer repackaging grain to storing it without packaging (p < 0.05), as shown by a

statistical analysis with above 80% power. Only 23.5% of participants keep grains in new packaging, 1% store them without packaging, and 75.5% store them in their original container (**Figure 7**). The significant number of participants who kept the grains in the original package shows that they recognized packaging extends grain shelf life.

6.2.4 Consumers Re-Packaging Behavior Of Baking Ingredients, Spices, And Powders Before Consumption

Figure 7 presents the amounts of baking ingredients, spices, and powders kept in their packaging, repacked, or stored without packaging in consumers households. Baking ingredients, spices, and powders all degrade from dampness. Some products in this group's shelf life depend on oxygen. Thus, packaging greatly improves this food type. Participants preferred storing baking ingredients, spices, and powders in their original packaging, rather than storing them without packaging or in a new package (p < 0.0001). Participants prefer repackaging baking materials, spices, and powders to storing them without packaging (p < 0.05), as shown by a statistical analysis with above 80% power. Similar to grains, 76% of participants keep baking ingredients, spices, and powders in their original package whereas 20.5% repackage them (**Figure 7**). Participants may repackage these foods for storage, use, or portion size.

6.2.5 Consumers Re-Packaging Behavior Of Dairy Before Consumption

Figure 7 presents the amounts of dairy kept in their packaging, repacked, or stored without packaging in consumers households. Lipid oxidation, non-enzymatic browning, syneresis, proteolysis, lipolysis, microbiological development, and discolouration are the principal dairy product deterioration mechanisms (Almenar and Gonzalez-Buesa, 2024). Packaging slows several of these processes, extending shelf life and minimizing food waste (Almenar and Gonzalez-Buesa, 2024). Thus, if not immediately consumed, these products should not be repacked or stored without

packaging. Participants significantly preferred keeping dairy food products in their original packaging as opposed to taking them out of it and storing them without packaging or taking them out of it and storing them in a new package. (p < 0.0001). Participants prefer repackaging dairy products over storing it without packing, as shown by a statistical analysis with above 80% power (p < 0.05). 91% of participants preserve dairy products in their packaging, 6% repackage (**Figure 7**). Repacking is substantially lower than in an Avery Dennison study. This study indicated that more than 70% of customers removed fresh commodities like cheese from their packaging and stored them in a plastic bag or other container, but it is unclear if dairy products other than cheese were included. Participants demonstrated that they recognized how packaging might improve dairy products' shelf life by keeping them in their original packaging.

6.2.6 Consumers Re-Packaging Behavior Of Potatoes And Onions Before Consumption

Figure 7 presents the amounts of potatoes and onions kept in their packaging, repacked, or stored without packaging in consumers households. If not eaten soon or stored properly, potatoes profit more than onions from packaging. Light and airflow must be blocked to prevent potato greening and moisture loss. Storing potatoes in their original container extends shelf life and reduces food waste. Without processing (peeled, sliced, or diced), onions provide little utility. Participants significantly preferred to keep potatoes and onions in their original packaging or remove them and store them without packaging than to put them in a new food package (p < 0.0001). 44% of consumers keep their potatoes and onions in their original packing, and 41% do not repackage them (**Figure 7**). No significant differences existed between the two options (p > 0.05). Nearly half of participants keep potatoes and onions without packaging because they know they last three months in a well-ventilated location.

6.2.7 Consumers Re-Packaging Behavior Of Fats And Oils Before Consumption

Figure 7 presents the amounts of fats and oils kept in their packaging, repacked, or stored without packaging in consumers households. Lipolysis, hydrolysis, and oxidative rancidity ruin oils and fats. Oxidative rancidity requires oxygen and light, while hydrolytic and lipolytic rancidity require water (Almenar and Gonzalez-Buesa, 2023). To lengthen the shelf life of this food group and decrease food waste, light, moisture, and oxygen exposure must be reduced. Commercial fats and oils are packaged to reduce environmental impact. Many participants preferred to store fats and oils in their original packaging rather than without packaging or in a new package (p < 0.0001). Participants prefer repackaging fats and oils to storing them without packaging, as shown by a statistical analysis with above 80% power (p < 0.05). Like dairy products, 91% of customers keep fats and oils in their packaging (**Figure 7**). For convenience or storage, 8.5% of consumers presumably repack margarine and butter. By retaining fats and oils in their packaging, participants showed they recognized how packaging might extend this food group's shelf life.

Based on the above findings, more than 90% of dairy products, oils, and fats and 76% of grains, baking ingredients, spices, and powders are kept in the original package. The protein group is the food group that is most repacked (46%) followed by produce (27%), grains (24%), and baking ingredients, spices, and powders (21%). Potatoes and onions (41%) and Fruits and vegetables (36%) are the food groups that are removed from their original packaging the most often without being repackaged. Comparing the above results with the need for keeping the food in the original packaging to extend its shelf life, the more prejudiced food group is the protein group.



6.3 Consumers' Awareness Of The Impact Of Packaging Technologies On Food Freshness

■ A ■ B ■ I don't know □ No difference

Figure 8. Consumers' awareness of the ability of different packaging technologies to maintain food freshness or to provide information about the food product. Participant responses are presented in different colors: A (green), B (blue), I don't know (dark gray), and no difference (light gray). A and B correspond to the left and right packages of each photo in Table 5. The correct response for each packaging technology is highlighted using a red rectangle.

Currently the same food product can be found at the marketplace in packages that differ in ability to extend food shelf life or to provide information about the food product. Modified atmosphere packaging (MAP), active packaging (AP), retort packaging, aseptic packaging, and vacuum packaging (VP) are all packaging technologies used to maintain food freshness. In contrast, intelligent packaging (IP) is a packaging technology that provides information on the food product. **Figure 8** presents consumers' awareness of the ability of these packaging technologies to maintain food freshness longer.

6.3.1. Consumers' Awareness Of The Impact Of MAP On Food Freshness

MAP is a technology where the ambient air inside the package is replaced with a gas composition selected based on the needs of the food product for freshness maintenance and/or safety (Almenar, 2021). After showing participants fresh-cut lettuce in a sealed pouch (MAP) and in a tray with a snap-fit lid (not MAP) (**Table 5**) and asking them to identify the packaging that keeps the fresh-cut lettuce fresher for longer, they significantly selected the incorrect response (tray with a snap-fit lid, No difference, I don't know) more than the correct response (MAP) (p < 0.0001). Tray with a snap-fit lid as the package that can keep the lettuce fresher for longer was the highest response (54% of participants) and only 27.6% of participants selected the correct response (Figure 8). Therefore, participants were unaware of the effect that MAP plays on maintaining the freshness of food, specifically fresh-cut lettuce. The US consumers' lack of MAP recognition of 84% reported in the literature (Grebitus et al., 2013) may have contributed to the low number of correct responses. Consumers cannot be aware of the capacity of a technology to maintain food freshness if they are not familiar with such technology. The knowledge about MAP impact on maintaining food freshness was significantly different based on gender only, with male participants being more knowledgeable than female participants (p < 0.0001). 2-way interactions between population segments were found for MAP. These are available under appendix B.

6.3.2. Consumers' Awareness Of The Impact Of AP On Food Freshness

AP is a technology where certain additives, referred to as "active compounds," are added to the packaging material or placed inside the packaging container to improve food quality and/or safety (Almenar, 2020). Additive placement inside the container occurs in the form of tiny packets, labels, or others (Awalgaonkar et al., 2020). When participants were shown beef jerky

in two different bags: one including a tiny packet (AP) and the other not containing a tiny packet (not AP) Table 5 and asked to identify the one that keeps the beef jerky fresher for longer, they significantly selected the incorrect response (bag without tiny packet, No difference, and I don't know) more than the correct response (bag with tiny packet) (p < 0.0001). The highest response (63% of participants) was "No difference" (Figure 8). Only 23% of participants selected the correct response. Hence participants were unaware of the effect AP plays on extending the shelf life of food products, specifically beef jerky. There is no information on consumers' knowledge of the effect of AP on food shelf life that could be used for comparison (**Table 1**). The literature has focused on consumers' recognition of AP only (**Table 1**). Specifically, Barska and Wyrwa (2016) found that 42% and 16% of Polish consumers recognized AP when asked about packaging with scavengers to remove harmful gases to extend product durability and emitters to restrict microorganism growth, respectively. O'Callaghan and Kerry (2016) reported that only 22.4% of Irish consumers recognized AP. These and other studies (Stoma and Dudzia, 2022; Kocetkovs et al., 2019) revealed that European consumers do not generally recognize AP. This lack of recognition could be also happening in US consumers and be the reason why only 23% of them selected the correct response. If consumers are not able to recognize a packaging technology, it seems unlikely that they can know about its effect on food shelf life. The selection of the correct response (AP keeps the beef jerky fresher for longer) was significantly different based on only participants contribution to reducing household food waste. Participants who contribute to reducing household food waste were more aware of the effect AP plays on extending the shelf life of food products than participants who do not contribute to reducing household food waste (p < 0.0019). 2-way interactions between population segments were found for AP. These interactions are available under appendix B.

6.3.3. Consumers' Awareness Of The Impact Of IP On Food Freshness

IP is a technology that monitors changes in the internal and external surroundings of the packed food product and conveys that information to facilitate decision-making (Poyatos-Racionero et al., 2018). Furthermore, an intelligent package can give general information about the product through a barcode (QR code) (Almenar et al., 2020). When participants were shown fresh-cut fruit in a container with a QR code (IP) and in a container without a QR code (not IP) Table 5 and asked to identify the one that provides them with information about the fresh-cut fruit (e.g., origin, freshness), they significantly selected the incorrect response (not IP, No difference, and I don't know) more than the correct response (IP) (p < 0.0001). Only 32% of participants selected the correct response (Figure 8). The highest response (55% of participants) was "no difference". Therefore, participants were unaware of the effect IP (specifically QR code) plays on informing about the food (e.g., origin, freshness), specifically fresh-cut fruit. Like MAP and AP, consumers have little recognition of IP based on the literature, which most likely explains our result of no knowledge about a QR code providing information about the fresh-cut fruit. O'Callaghan and Kerry (2016) found that 71.6% of customers have never heard of "intelligent packaging". Barska and Wyrwa (2016) found that only 17% of Polish survey respondents knew about IP. When questioned about packaging with temperature and atmosphere composition indications, Polish consumers' recognition increased to 53% and declined to 5%. The awareness of IP informing on food freshness was significantly different based on participants race, buying platform, grocery frequency, and contribution to reducing household food waste. Participants who identify as Caucasian and American Indian or Alaska Native, who buy items online and pick them up or have them delivered, who grocery shop every other week or more than once a week, and who contribute to reducing household food waste where more

aware of the effect IP (specifically QR code) plays in informing about the food (e.g., origin, freshness) than participants from other groups within each respective population segment (p < 0.0452, p < 0.0333, p < 0.0495, and p < 0.0347). 2-way interactions between population segments were found for IP. These interactions are available under appendix B.

6.3.4. Consumers' Awareness Of The Impact Of RP On Food Freshness

RP involves packaging food into a glass, plastic, or metal container (pouch, can, tray), sealing it, and then heating it to a temperature of 121 °C or higher for at least 10 min to make the product sterile for use in commerce (Jeyapriya and Kantale, 2022). One of the main benefits of retorted packages is that the food and container are both thermally treated simultaneously, making the filled packages commercially sterile and with an extended shelf life. When participants were shown tuna in a pouch (retorted package) and canned tuna (retorted package) (**Table 5**) and asked which of the two packages can keep the tuna fresher for longer, they significantly selected the incorrect response (tuna in a pouch, canned tuna, and I don't know) more than the correct response (No difference) (p < 0.0001). Only 9% of participants selected the correct response and 68% of participants selected that can keeps the tuna fresher for longer compared to the pouch (Figure 8). Based on these results, participants were aware that canned tuna has a long shelf life, but they didn't know that tuna retorted in plastic pouches and cans possesses the same shelf life. This shows that participants associated the long shelf life of the tuna to the packaging design can. Awareness of tuna having the same freshness in can and plastic pouch was significantly different based on participants' disability status. Participants with a disability were more aware that the same shelf life for tuna is possible in both can and plastic pouch than participants without a disability (p < 0.0453). The difference in knowledge may be due to the need of Americans with specific disabilities for learning about packaging alternatives

to cans that offer easier opening. 2-way interactions between population segments were found for retorting packaging. These interactions are available under appendix B.

6.3.5. Consumers' Awareness Of The Impact Of ASP On Food Freshness

ASP involves the packing of a sterilized food product into sterilized containers that are sealed in a commercially sterile environment (Sanjana et al., 2019). The aseptic process eliminates spoilage and pathogenic microorganisms, which helps to extend the shelf life of food products. These containers maintain the quality of the food product without the need for refrigeration because they are made of paper, aluminum, and plastic. When participants were shown juice in a plastic jug (not an aseptic package) and in a carton (aseptic package) Table 5 and asked which of the two packages can keep the juice fresher for longer, they significantly selected the incorrect response (plastic jug, No difference, I don't know) more than the correct response (carton) (p < 0.0001). Only 16% of participants selected the correct response and 62% of participants selected the plastic jug as the better package to keep the juice fresher compared to the carton (**Figure 8**). Thus, participants were unaware of the effect aseptic packaging plays in extending the shelf life of food products, specifically juice. No differences within the same population segment were observed for aseptic packaging.

6.3.6. Consumers' Awareness Of The Impact Of VP On Food Freshness

VP is a technology that removes the air from the package headspace to eliminate oxygen creating an anaerobic environment that prevents the growth of spoilage bacteria and decreases the pace of oxidative processes that cause product degradation to increase shelf life (Almenar and Gonzalez-Buesa, 2024a). It also increases food shelf life by reducing freezer burn because of the absence of package headspace (Almenar and Gonzalez-Buesa, 2024a). When participants were shown both fresh salmon in an air-tight package (VP) and non-air-tight package (not VP)

Table 5 and asked which of the two packages can keep salmon fresher for longer, they significantly selected the correct response (air-tight package) more than the incorrect response (non-air-tight package, no different, I don't know) (p < 0.0001). Most participants (78%) chose the correct response (Figure 8). Therefore, the impact of VP on maintaining food freshness was acknowledged throughout the participants. Likewise, Bou-Mitri et al. (2021) reported that most Lebanese consumers thought that vacuum packaged cheese had the greatest quality when asked to compare different types of packaging for cheese. In addition, Chen et al. (2013) reported that 76% of Canadian consumers said they had heard of vacuum packaging and understood its function. The selection of the correct response was significantly different based on participants age, gender, race, marital status, and educational background. Participants who were 42+ years old, female participants, Caucasian and American Indian/Alaska Native participants, married, separated, divorced, widowed participants and those who's educational background included possessing a high school diploma, some college experience, and an associate's degree were more aware of VP on maintaining food freshness than participants from other groups within each respective population segment (p < 0.0001, p < 0.0020, p < 0.0001, p < 0.00010, and p < 0.00010, p < 0.00000, p < 0.000000, p < 0.00000, p < 0.000000, 0.0419). 2-way interactions between population segments were found for VP. These interactions are available under appendix B.

6.4 Assessing Consumers' Purchase Intent Of Packaging Technologies After Being



Educated

Figure 9. Consumers' purchase intent of food commercialized in MAP, active packaging, intelligent packaging, retort packaging, aseptic packaging, and vacuum packaging after learning about these packaging technologies.

6.4.1. Consumers' Purchase Intent Of MAP

Figure 9 presents participants' purchase intent of food commercialized in MAP after being shown the same images as in section 3.3 (**Table 5**) along with the corresponding definition of the technology (**Table 6**). As shown in the figure, participants significantly chose always and sometimes compared to never (p < 0.0001). 55% of participants selected sometimes and 38% of participants selected always. Therefore, 93% of participants were willing to buy food product s commercialized in MAP after getting to know what the packaging technology consists of. After highlighting the benefits of the MAP's safety features, Van Wezemael et al. (2011) explored if European customers would accept it to improve the safety of beef. Only 55% of survey respondents indicated that they accepted MAP, however, it is important to note that this study focused on safety and did not examine consumers purchasing intentions but acceptance.

Significant differences in the purchase intent of fresh-cut lettuce and another food product in MAP within the same population segment were observed. Younger participants (> 41 years old), those who have never been married, those who are divorced, and those who go grocery shopping one or more times per week reported they would purchase MAP always and sometimes significantly more than participants from other groups within each specific population segment (p <0.04, p < 0.02, and p < 0.01). 2-way interactions between population segments were not found for MAP.

6.4.2. Consumers' Purchase Intent Of AP

Figure 9 presents participants' purchase intent of food commercialized in AP after being shown the same images as in section 3.3 (**Table 3**) along with the corresponding definition of the technology (**Table 4**). Participants significantly selected always and sometimes (p < 0.0001). Specifically, 50% of participants selected always and 36% of participants selected sometimes. Thus, 86% of participants were open to purchasing food products commercialized in AP when found in the store after getting to know what the packaging technology consists of. Comparing the purchase intent of AP by Americans with other nationalities (**Table 1**), Barska and Wyrwa (2016) found a significant number of Polish consumers (68%) willing to purchase food in AP after receiving a brief explanation of the packaging technology. More than half of these consumers selected "decrease in food waste," and "growing food awareness" as significant contributors to AP's growth. O'Callaghan and Kerry (2016) reported a much lower purchase intent (10%) of cheese when packaged in AP by Irish consumers after learning about it. The lack of control Irish customers have over cheese when it is present in this packaging technology was one factor in this. Significant differences in the purchase intent of beef jerky and another food product in AP within the same population segment were observed. Participants between the ages of 18 and 57 responded they would purchase active packaging always and sometimes significantly more than participants above the age of 57 (p < 0.0001). Likewise, O'Callaghan and Kerry (2016) found that older participants were more inclined to desire no technological interference. Male participants responded they would purchase active packaging always and sometimes significantly more than female participants (p < 0.0008). This could be attributed to American males liking AP more than American females (Wilson et al., 2018). Caucasian and Black or African American participants and participants who grocery shop more than once per week also responded they would purchase active packaging always and sometimes significantly more than participants of a different group within the same population segment (p < 0.0049 and p < 0.0328). Several two-way interactions between population segments were identified (p < 0.05) and the details can be found in appendix B

6.4.3. Consumers' Purchase Intent Of IP

Figure 9 presents participants' purchase intent of food commercialized in IP after being shown the same images as in section 3.3 (**Table 5**) along with the corresponding definition of the technology (**Table 6**). Participants significantly selected always and sometimes compared to never (p < 0.0001). Specifically, 51% of participants selected sometimes and 35% of participants selected always. Thus, 86% of participants were open to purchasing food products commercialized in IP when found in the store after getting to know what the packaging technology consists of. Previous research conducted in other countries has shown positive IP buying intentions, supporting our findings. Barska and Wyrwa (2016) found that 67% of Polish

consumers were open to purchase IP after learning about it. O'Callaghan and Kerry (2016) reported that Irish consumers were more open to purchase IP than AP and other technologies after getting information because it interfered least with cheese, and they appreciated inspecting products without opening the container. Similarly, Cammarelle et al. (2021) reported Italian customers were more open to purchasing IP than AP to reduce household food waste since it provided real-time use-by or expiration information. Our findings indicate that US consumers behave differently since they were more willing to buy AP than IP. Significant differences in the purchase intent of fruit and another food product in an IP within the same population segment were observed. All races except for Caucasians and Asians and Hispanic, Latino, or Spanish participants responded they would purchase IP always and sometimes significantly more than participants of a different group within the same population segment (p < 0.0052 and p < 0.0306). Several two-way interactions between population segments were identified (p < 0.05). These can be found in appendix B.

AP and IP were the two technologies with the highest number of "never" responses after retort packaging. This finding is supported by several studies that highlight that consumers' lack of trust/skepticism toward new packaging technologies is another issue impeding their functionality in food-saving. These studies include Realini and Marcos (2014) for skepticism toward supplementary sachets and pads such as oxygen scavengers and moisture absorbers, Pennanen et al. (2015) for skepticism toward time-temperature indicator technology, Aday and Yener (2015) and Barska and Wyrwa (2016) for skepticism toward both IP and AP.

6.4.4. Consumers' Purchase Intent Of RP

Figure 9 presents participants' purchase intent of food commercialized in flexible RP after being shown the same images as in section 3.3 (**Table 3**) along with the corresponding

definition of the technology (Table 4). Participants significantly selected sometimes (p < 0.0001). 49% of participants selected sometimes and 24% of participants selected always. The lower percentage of always and higher percentage of never compared to other packaging technologies may be because consumers are accustomed to storing food with an extended shelf life in cans and find it difficult to accept the notion that a pouch is capable of doing the same. This finding may indicate that U.S. consumers have a strong attachment to certain packaging designs and are unwilling to make changes them. Significant differences in the purchase intent of tuna and another food product in retort pouches opposed to retort cans within the same population segment were observed. Participants under the age of 58 responded they would purchase food in retort pouches always and sometimes significantly more than participants 58 and older (p < 0.0002). This could be justified by the growth in difficulty of opening packages with age. Participants who contribute to reducing household food waste also responded they would purchase food in retort pouches always and sometimes significantly more compared to participants who do not contribute to reducing household food waste (p < 0.0109). The details of each of the numerous two-way interactions that were identified between population segments can be found in Appendix B

6.4.5. Consumers' Purchase Intent Of ASP

Figure 9 presents participants' purchase intent of food commercialized in ASP after being shown the same images as in section 3.3 (**Table 5**) along with the corresponding definition of the technology (**Table 6**). Participants significantly selected always and sometimes (p < 0.0001). 46% of participants selected always and 46% of participants selected sometimes. Thus, 92% of participants were very willing to buy food products commercialized in ASP after getting to know what the packaging technology consists of. Considering that just a small portion (16%)

of the participants were aware of the technology's ability to extend food shelf life (**Figure 8**), this is a considerable number. Significant differences in the purchase intent of orange juice and another food product in an aseptic package within the same population segment were observed. Caucasian and Black or African American participants responded they would purchase ASP always and sometimes significantly more than participants of a different race (p < 0.0196). Participants who buy items online and have them delivered responded they would purchase ASP always and sometimes significantly more compared to participants who buy items online and then pick them up or that buy items at the physical store (p < 0.0472). Furthermore, one two-way interaction between age and income was identified and can be found in Appendix B

6.4.6. Consumers' Purchase Intent Of VP

Figure 9 presents participants' purchase intent of food commercialized in VP after being shown the same images as in section 3.3 (**Table 5**) along with the corresponding definition of the technology (**Table 4**). Participants selected "always" and "sometimes" significantly more than "never" (p < 0.0001). 58% of participants selected always and 35% of participants selected sometimes. The reason why almost all participants were willing to purchase food commercialized in VP is their awareness of the positive impact of the technology on maintaining food freshness. This is shown in section 3.2 where most participants selected VP as the packaging that can maintain salmon's freshness for a longer period. **Table 1** shows that prior research on VP (Waston et al., 2005; Van Wezemael et al., 2011; Chen et al., 2013) did not capture consumers' purchase intentions, simply their willingness to pay for VP's capacity to increase the shelf life of various food products. Chen et al. (2013), who study Canadian consumers' acceptability of vacuum-packaged beef steak, reported an increase in acceptability of VP after consumers were fully informed about the advantages and disadvantages of the

technology. Similarly, our findings about US consumers' purchase intent of VP must have been influenced by the information consumers got about VP since the number of participants who declared a purchase intent of VP was higher (93%) (**Table 6**) than those who recognized VP as a technology able to extend shelf life (78%) (Figure 5). Significant differences in the purchase intent of salmon and another food products in VP within the same population segment were observed. Participants with some college experience or a bachelor's degree responded they would purchase food in vacuum packaging always and sometimes significantly more than participants with a different educational background (p < 0.0398). Likewise, Chen et al. (2013) found that consumers with a reasonably high level of education were more supportive of VP because they were already aware of and familiar with it. Non-disable participants responded they would buy food in VP "always" and "sometimes" significantly more compared to participants with a disability (p < 0.03). This could be because of the difficulty of opening VP compared to a tray wrapped with a film. Furthermore, participants who contribute to reducing household food waste responded they would buy food in VP always and sometimes significantly more compared to participants who do not contribute to reducing household food waste (p < 0.0233). 2-way interaction were not found for vacuum packaging.

6.5 Willingness To Pay Extra For Food Products In Packages Designed To Help Reduce Food Waste

The literature reports that consumers find price to be one of the most important aspects of food purchase decisions (Koutsimanis et al., 2012; Van Birgelen et al., 2009; O'Callaghan and Kerry, 2016). Price also plays an important role in consumers' food waste behavior. According to AMERIPEN (2018), one of the reasons why vegetables and fruits are the foods with the highest rate of waste is their lower cost compared with other perishable foods. While several

studies have been performed to determine if consumers are willing to pay extra for specific packaging technologies that can extend food shelf life (**Table 1**), to the best of the authors' knowledge, nothing is known about consumer willingness to pay extra for food in packages designed to help reduce food waste. In this study, this willingness was determined by directly asking about it and participants significantly responded more "yes" or "maybe" than "no" to the question (p < 0.0001). Specifically, 47% and 38% of participants selected "yes" and "maybe", respectively. "Yes" was significantly more chosen than "maybe" (P < 0.05). The expected higher price of food packaged in novel packaging technologies (Barska and Wyrwa, 2016) may explain the 15% of "No" replies in this study. The amount of "Yes" replies is consistent with findings from previous research on consumers' willingness to pay to reduce food waste. According to Grant et al. (2019), US consumers would be willing to pay more for a product that had a few extra days of shelf life along with less food waste. Furthermore, the 2021 Innova Lifestyle & Attitude survey found that 62% of US consumers were willing to pay more for food and beverage products in environmentally friendly packaging mainly because they thought this type of packaging could help reduce food waste. Consumer willingness to pay extra for specific packaging technologies intended to increase the shelf life of food products (Grebitus, 2013b; Barska and Wyrwa, 2016; Wilson et at., 2018; Just and Goddard, 2022; Bou-Mitri et al., 2021) also aligns with the 85% of US consumers who are willing to pay extra for food in packages designed to help reduce food waste.

This willingness to pay extra was different based on participants disability status and contribution to reducing household food waste. Participants with a disability were more willing to pay extra for food products in packages designed to help reduce food waste compared to non-disable participants (p < 0.05). Participants who contribute to reducing household food waste

were more willing to pay extra for food products in packages designed to help reduce food waste compared to participants who do not contribute to reducing household food waste (p < 0.0001). Furthermore, the willingness to pay extra was different between population segments shown by several 2-way interactions found in this study. The details can be found in the Appendix C.

CHAPTER 7

QUANTIFICATION OF US HOUSEHOLD FOOD WASTE AND ITS INTERSECTION WITH PACKAGING

7.1 Top Three Food Categories, Food Groups, And Distribution Of Whole Fresh Fruits And Vegetables That Are Wasted In Participant Household During An Average Week.



Figure 10. Distributions of (A) the top food category, (B) the top 3 food groups, and (C) the whole fresh fruits and vegetables that are wasted in participant household during an average week.

As shown in Figure 10A, the top three food categories wasted most commonly in

American households during a normal week are fruits and vegetables, prepared foods, and dairy (selected by 48.4%, 18.3%, and 8.4% of participants, respectively). Participants significantly wasted produce and prepared foods compared to any other food category (p < 0.0001). When comparing participants most wasted food category against the 2nd and 3rd most wasted food categories statistically, participants significantly selected fruits and vegetables as top food

category that is wasted in their households compared to prepared foods and dairy (p < 0.05). Furthermore, when comparing the 2nd and 3rd most wasted statistically, participants selection of prepared foods was significantly higher than that of dairy (p < 0.05). Previous food waste studies have reported similar results. Fruits and vegetables make up 39% and 40% of household waste according to FAO (2011) and WRAP (WRAP, 2008), respectively. Similarly, Conrad (2020) reported that "fruits and vegetables" were one of two top categories of waste in the United States. Fresh, natural produce is perishable and has a shorter shelf life than dried produce and other food groups, which may be the cause of this outcome. Based on the breakdown of the top three categories into the food groups that cause the greatest waste within each of them, fresh whole fruits and vegetables accounted for 77% of fruits and vegetables wasted in participants households, fresh ready-made meals accounted for 74% of prepared foods wasted in participants households, and milk accounted for 68% of dairy products wasted in participants households (Figure 10B). A further breakdown in the case of the fresh whole fruits and vegetables shows that the top three fresh whole fruits and vegetables that participants threw away the most were bananas, lettuce, and strawberries (chosen by 32%, 25%, and 8% of participants, respectively) (Figure 10C). Differences between population segments for the selected most wasted food categories were found and are explained in Appendix D.
7.2 Top Food Group That Is Perceived To Be Wasted In American Households During An

Average Week

Food group	%	Food group	%	Food group	%	Food group	%
Fresh whole fruits and vegetables	38.0	Bakery products	1.02	Juice	0.31	Frozen ready- made meals	4.89
Fresh cut fruits and vegetables	10.4	Small bakery products other than bread	0.10	Wine, Beer, other alcoholic beverages	0.51	Oil	3.57
Canned fruits and vegetables	0.51	Pasta	0.71	Carbonated drinks	2.34	Butter	0.71
Frozen fruits and vegetables	0.31	Cereals	0.71	Other	0.20	Potatoes	3.67
Other	0.10	Snack food	0.10	Powdered milk	0.31	Sweet potato	0.10
Fresh red and white meats	2.55	Milk	5.81	Instant Coffee	0.10	Garlic	0.31
Cooked red and white meats	1.43	Dairy products other than milk and cheese	1.94	Sugar, salt	0.51	Onion	2.65
Fresh fish and seafood	0.41	Soft cheese	0.71	Other	0.31	Leftovers	0.51

Table 8. Distribution of the top food group that is wasted in participants household during an average week.

Table 8. (cont'd)

Cooked fish				Fresh ready-		
and seafood	0.31	Hard Cheese	0.10	made meals	13.8	
				indu o iniculo		

As shown in **Table 8**, fresh whole fruits and vegetables, chosen by 38% of participants, fresh ready-made meals, chosen by 14% of participants, and fresh-cut fruits and vegetables, chosen by 10% of participants, were the top three food groups that are wasted most frequently in American homes during a typical week. A statistical analysis revealed that participants selected fresh whole fruits and vegetables over fresh ready-made meals and fresh-cut fruits and vegetables (p < 0.05). Statistical analysis showed no significant difference between the 2nd and 3rd most wasted food groups (p > 0.05). Differences between population segments for the selected most wasted food groups were found (p > 0.05) and are explained in Appendix D.

7.3 Packaging Material And Format Associated With The Top Food Group That Is Perceived To Be Wasted In American Households During An Average Week



Figure 11. (A) Distribution of the packaging material and packaging format associated with the most wasted food category in participant household during an average week. (B): Distribution of the packaging material and packaging format associated with the most wasted food group in participant household during an average week.

7.3.1 Top Three Packaging Materials Associated With The Perceived Most Wasted Food

Group In Participants' Household During An Average Week

Figure 11A (top) shows that the top three packaging materials associated with the most wasted food group in participants' household during an average week were plastic (chosen by 50% of participants), no packaging (chosen by 23% of participants), and paper/paperboard (chosen by 6% of participant). As discussed previously, fresh whole fruits and vegetables were the most frequently chosen food group that is wasted in participant household and these are commonly sold in plastic packaging (e.g., berries) or no packaging (e.g., bananas). Differences between population segments for the participants selection of the packaging material of their most wasted food category were found (p < 0.05) and are explained in Appendix E.

7.3.1.2 Packaging Material Associated With The Top Food Group That Is Perceived To Be Wasted In American Households During An Average Week

Figure 11A (bottom) shows the materials used to package fruits and vegetables, the food category most Americans waste each week. No packaging and plastic made up 52% and 35% of the packaging materials, respectively, while paper/paperboard, metal, and textile made up the remaining 3%. 10% of responders were unsure of the material utilized to sell their most wasted fresh product. Since plastic is the primary packaging materials. Many fruits and vegetables lack packaging to protect them from mechanical damage, microorganisms and gases, which may be why fresh whole produce is the top food group wasted in American households each week. There is evidence that supports packaging produce (Almenar, 2020; 2021; Awalgaonkar, Beaury, and Almenar, 2020).

7.3.1.3 Packaging Format Associated With The Most Wasted Food Group In American Households During An Average Week

Figure 11B presents the packaging format associated with participants' previously selected packaging material. **Figure 11B** (**top**) shows that the top three packaging formats associated with the most wasted food group in participants' household during an average week were "No packaging" (chosen by 23% of participants), "Bag/Pouch" (chosen by 21% of participants), and "tray with wrap, film, or snap fit lid" (chosen by 20% of participants). This is consistent with our earlier findings that "no packaging" was the second most selected packing material wasted and fresh whole fruits and vegetables were the top food group selected. The 2nd and 3rd selected styles, bag/pouch and tray, are the most prevalent packing formats for whole

and fresh-cut produce (Figure 10C), the 1st and 3rd most wasted food groups. Many of Figure 3A's food products are likewise sold in these two package types.

7.3.1.4 Packaging Format Associated With The Top Food Group That Is Perceived To Be Wasted In American Households During An Average Week

Figure 11B (bottom) shows the format used to package fruits and vegetables, the food category most Americans waste each week. Bags and pouches accounted for 64.3% of fruit and vegetable waste **Figure 11B (bottom).** Tray with wrap, film, or snap fit lid" accounted for 33.3% of fruit and vegetable waste. Jars accounted for 2.2% of fruit and vegetable waste. Differences between population segments for packaging formats for fruits and vegetables (top food category) were found (p < 0.05) and are explained in Appendix E.



7.4 Food Waste States Based On Participants' Most Wasted Food Group

Figure 12. (A) Distribution of food waste states that correspond with the food group participants chose as the most wasted in their household in an average week. (B) Distribution of food waste states for fresh whole fruits and vegetables, the top food group participants chose as the most wasted in their household in an average week.

Figure 12A shows about 35% of participants chose half-eaten packaged food, 28% chose

food without packaging that spoiled before it was eaten, 20% chose not-eaten meal leftovers,

15% chose food that spoiled before the package was opened, and 2% chose food that was thrown

away because the wrong product was purchased. Half-eaten packaged food and unpackaged food that spoiled before consumption were more popular among participants than leftovers, spoilt food, and food thrown away due to incorrect purchasing (p < 0.0001). Participants significantly selected half-eaten packaged food over unpackaged food that spoiled before consumption and unconsumed meal leftovers (p < 0.05) when comparing their top food waste state to the 2nd and 3rd states. Participants significantly chose unpackaged food that spoiled before consumption over unconsumed meal leftovers (p < 0.05) when comparing the 2nd and 3rd food waste statuses. In the top wasted food category, participants chose fruits and vegetables without packaging that spoiled before consumption, and half-eaten produce packages over leftovers, spoiled produce, or incorrect purchases (p < 0.0001) (Figure 12B). In a statistical analysis of the top two food waste states, participants chose unpackaged fruits and vegetables over half-eaten packaged produce (p < 0.05) with over 80% power. Based on these findings, various food products, particularly produce, might be packed to lengthen shelf life and reduce food waste. Packaging produce can preserve its overall quality and shelf life (Almenar, 2020, 2021). Correlations between waste states and population segments were found (p > 0.05) and are explained in Appendix Correlations between packaging materials and formats and food waste states were found (p > 0.05) and are explained in Appendix G.

7.5 Quantification Of Household Food Waste



Figure 13. Amount of wasted food in g/person/day for selected food categories and food groups in America in 2023.

In 2023, US food waste per person per day averaged 57 g. Figure 13 illustrates the variation in this amount by food group and category. These findings were consistent with those of (Li et al., 2023) who calculated that between 2021 and 2022, US consumers squandered 363.47 g/person/week, or around 52 g/person/day. On the other hand, according to ReFED data from 2021, 43.6 million tons of household food were wasted by Americans. With 331.9 million people living in the United States in 2021, each person will squander 0.72 pounds (~370 grams) of food each day when eating at home. Furthermore, the results of Conrad et al. (2018), who found that from 2007 to 2014, US consumers wasted an average of 422 g of food per person per day, and Buzby et al. (2014), who reported that the average American wasted an even higher amount of food in 2010 (530 g daily), are significantly higher than this study's results along with Li et al. (2023). As literature supports (e.g., Ventour, 2008, Herpen et al., 2019), consumers often

severely underestimate their HFW due to a variety of reasons, including lack of awareness about the true meaning of food waste (e.g., consumers do not count foods fed to their pets or composted as food waste), lack of awareness about their household food waste, and lack of clear food waste memory to report the previous week/month. To compare our results with those in the literature, however, more is required than just a final number. The study's methodology for quantifying household food waste (HFW) relied on the most wasted food categories and groups among consumers, rather than accounting for the total amount of food wasted in a typical week. Consumers probably eat and waste a wide variety of food categories and groups on a daily basis, thus measuring this could make the results more comparable to previous research. Additionally, nonsensical responses (e.g., eggs in glass bottles) were rejected as these results were not seen as trustworthy. Similar methods may not have been used in other studies. Food prices are higher than two years ago, which may have reduced food waste. Furthermore, the quantification of HFW in this study was based on consumers most wasted food category/group which does not take into consideration all the food they waste during an average week. The above results are from 1,000 people with little variance.

Figure 13 shows that grams per person per day, beverages, fruits and vegetables, and dairy products were the most wasted food categories. Participants wasted 82 g/day of liquids, 79 g/day of fruits and vegetables, and 56 g/day of dairy. Onions, potatoes, and fats and oils were the least wasted in American households. This may have been due to the fact that certain food groups' goods have a shelf life longer than 2-3 weeks and are more likely to be eaten. According to grams per person per day, canned juice, and fresh produce were the most wasted food types. Participants wasted 121 g/day of canned fruit and vegetables, 97 g/day of juice, and 84 g/day of fresh produce. Milk was the third-largest food group wasted in participant households, but it did

not waste as much as other food categories. The tiny sample size (< 5 people) of participants who chose canned fruits and veggies, and juice may not be representative of the American population. Whole fresh fruits and vegetables and fresh-cut fruits and vegetables created the most waste (each with 80-319 participants). Two-way interactions between populations segments for the quantification of the top three most wasted food categories during an average week were found (p > 0.05) and are explained in greater detail in Appendix H.



7.6.1 Food Waste Based On Demographic Segments

Figure 14. Differences in food waste, measured in g/person/day the various population segments that correspond to the US's demographics: age, race, ethnicity, gender, income, education level, household, disability, marital status, and geographical location in the US.

Figure 14 shows that food waste in the US in 2023 varies by demographic segments. **Figure 14** shows that younger generations threw away more food than older ones. Food may have been more accessible in the last 30 years. The biggest gap was between Millennials and Boomers. Baby boomers wasted 37.9 g of food every day, but millennials wasted 56.3 g. Figure 14 also showed that Caucasians and Black or African Americans discarded more food (46.7 g/person/day and 45.3 g/person/day, respectively) than other races. The biggest difference was between Caucasians and Native Hawaiians or other Pacific Islanders. Caucasians wasted 22g more food per day than Native Hawaiians or other Pacific islanders (46.7 vs. 24.3). Although similar to the US census, Native Hawaiians made up a smaller percentage of survey participants than Caucasians. Figure 14 also shows that non-Hispanic, Latino, and Spanish participants threw away a little more food than those who were (46.2 g/person/day vs. 43.3 g/person/day) and that male participants threw away more food than female participants (48.7 g vs. 43.0 g). Figure 14 demonstrates that college-educated participants threw away more food than others. Participants with college experience differed most from those with school experience. Participants with college experience wasted 30g/day more food than those with some education (51.9 g/day vs. 21.6 g/day). The lower income of school-educated participants may explain this. Figure 14 indicates that households with six or more persons waste the most food. The highest disparity was between six-person and one-person households. Households with six or more persons disposed of 24 g/person/day more food than those with one person (66.3 vs. 42.3). In contrast, Yu and Jaenick (2020) found that larger households waste less food. Figure 14 demonstrates that people with earnings over \$100,000 threw away more food than those beneath \$100,000. Participants earning \$100,000 and those earning less than \$20,000 differ most. Those earning \$100,000 discarded 10 g more per person per day than those earning under \$20,000 (48.7 g vs.

38.6 g). Higher-income people can buy more food, so losing food is like wasting money, so they may not care as much. Yu and Jaenick (2020) agreed that higher-income people waste more food. **Figure 14** reveals that disabled participants discarded 46.4 g/person/day more food than non-disabled participants (45.5 g/person/day). **Figure 14** shows that widowers threw away more food than any other marital status. Food waste differed most between widowed and separated people. Widows threw out about 42 g/person/day more food than people who are separated (53.2 vs. 11.4 g/day). West Coasters threw away more food than any other US region. West and northeast exhibited the largest disparity. Participants in the western US threw out 10 g/person/day more food than those in the northeast (50.9 vs. 40.5). In the West region of the US, increased availability of whole fruits and vegetables (from farmers' markets and independent farmers selling year-round food) may lead to increased consumption.



7.6.2 Food Waste Based On Psychographic Segments

Figure 15. Differences in food waste, measured in g/person/day, among the groupings of the population segments that represent psychographics associated with food waste, such as buying platform, purchase frequency, contribution to reducing food waste, and motivation to reduce food waste.

As in **Figure 15**, online grocery shoppers waste more food than regular buyers. The most differences were between online grocery shoppers who had them delivered and those who picked them up. Online consumers who had their groceries delivered discarded 13 g/person/day more than those who picked them up (55.9 vs. 42.7). This may be because food delivery is easier than picking it up. People who buy for groceries more often throw away more food, as shown in **Figure 15.** More frequent grocery shoppers and those who buy every other week showed the biggest difference. Participants who went food shopping more than once a week wasted 6 g/person/day more than those who went every other week (47.5 vs. 41.7 g/day). Ostergaard and Hanssen (2018) discovered that bread wasters buy more of it and in larger quantities. By contrast, Di Talia et al. (2019) found that households that buy less waste more food. **Figure 15**

shows that individuals who were willing to reduce household food waste disposed of more food (46.3 g/person/day versus 39.3 g/person/day). Our findings may have been influenced by the fact that over 90% of participants indicated they limit household food waste, which increases food waste. **Figure 15** reveals that "I don't want it to negatively impact the environment" motivated people to throw away more food than any other factor. Two reasons, "I don't want it to have a negative impact on the environment" and "I'm not sure," wasted the most food. Participants who chose I don't know tossed 30.8 g/day, whereas those who chose not to harm the environment disposed 51.9 g/day.

CHAPTER 8

CONCLUSION AND FUTURE WORK

8.1 Conclusion

The findings of this study have generated new and deeper understanding about the consumer relationship between packaging and household food waste that can generate solutions critical to reduce household food waste, these being mainly consumer education and need for new packaging designs. This study shows the little knowledge American consumers have about packaging features, materials, formats, designs, and technologies, all of which play a key role in maintaining food freshness thereby reducing household food waste. The value of packaging is not recognized by consumers since they are unaware of the function it can play in maintaining food freshness thus reducing household food waste. Education should be targeted to specific population segments if a fast intervention is desired since some population segments waste more food than others. This study shows that participants are open to buy food in packaging that can extend shelf life if they learn about such packaging. Based on the main food waste states, and packaging materials and formats associated to household food waste, there is a need for: (1) designing packaging for produce that is not currently packaged, (2) designing packaging that can extend the use life of food (once the package has been opened), mainly for dairy products, and (3) designing packaging that can indicate the shelf life of the food product. This shows the need for active packaging and intelligent packaging to reduce household food waste. Based on the findings of these study, packaging does fail to meet consumers expectations in reducing food waste on the above. There is also a need for appropriate systems to recruit and work with a large number of reliable survey participants to better quantify food waste.

8.2 Future Work

If a quick intervention to reduce HFW is sought, packaging for produce that is not currently wrapped must be designed because fresh whole fruit and vegetables are the food group that US consumers lose the most due to these products not being packaged. This can be accomplished by utilizing a variety of packaging technologies (e.g., MAP, AP), materials and formats. Determining consumer acceptance and purchase intent for the innovative packaging for fresh whole fruits and vegetables would be crucial because many of these products are already sold without packaging. The study's findings indicated that more than 80% of US consumers are willing to buy food products with packaging meant to reduce food waste. Therefore, there is a market segment that would be receptive to adding packaging to un-packaged produce.

Designing packaging that can prolong the shelf life of food (after it has been opened) is also necessary, especially for dairy products, particularly milk. Among all the dairy-based products included in this category, milk was the one that was wasted the most in US consumers' homes. Intelligent packaging, particularly in the form of an indication, is a crucial packaging technology that, in my opinion, should be applied to milk. The product's freshness can be monitored via the indicator, which can alert consumers to the remaining time before the milk spoils.

There is a need to identify consumers re-packaging behavior impact on HFW. Although this study did determine consumers re-packaging behavior for several main food categories this was not related to HFW. The survey found that over half of the consumers repackaged protein items, which will significantly reduce the shelf life of this food category. It can be helpful to determine how this relates to food waste (e.g., leads to more or less waste) in order to modify the packaging for these products as needed.

Furthermore, it is imperative for marketers to educate consumers about the ways in which packaging materials, formats, features, and technology impact the preservation of food freshness. Many times, consumers in this survey shown a lack of understanding regarding the part each of them play in preserving food freshness. One way to assist reduce HFW is to develop innovative teaching initiatives that target customers who are the primary shopper in their family through various types of mass media (e.g., TV). Each research participant was the household's primary shopper. After learning about the advantages of different packaging technologies, participants were willing to buy them if found in the supermarket.

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APPENDIX A

TWO-WAY AND THREE-WAY INTERACTIONS BETWEEN POPULATION SEGMENTS REGARDING THE TOP THREE MOST IMPORTANT PACKAGING FEATURES IN REDUCING HFW

Maintain Food Freshness

Several two-way interactions between population segments regarding how important the packaging feature "Maintain freshness" is to reduce household food waste were found (P < 0.05). Two-way interactions between age and contribution to reducing household food waste, income, marital status, education, grocery frequency, and gender were found. The Gen Z participants (18-25 years old) who contribute to reducing household food waste rated the feature maintain food freshness less important than the Gen Z participants who do not contribute to reducing household food waste. The Millennials participants (26-41 years old) with an income between \$50,000 and \$74,999 rated the feature maintain food freshness more important than the millennials participants with a different income. Furthermore, the married or never married millennials rated the feature maintain food freshness more important than the separated, divorced, or widowed millennials. The Gen X participants (42 - 57 years old) with some college experience rated the feature maintain food freshness more important than the Gen X participants with a different educational background. Also, the Gen X participants who grocery shopping every other week rated the feature maintain food freshness more important compared to the Gen X participants who grocery shop once per week or more often. The Male Gen X rated the feature maintain food freshness more important than the female Gen X.

Three two-way interactions between race and marital status were found. Caucasian participants who are married or have never been married rated the feature maintain food freshness less important than separated, divorced, or widowed Caucasian participants. The

divorced participants rated the feature maintain food freshness more important than the separated and widowed participants. In contrast, married American Indian or Alaska Native participants rated the feature maintain food freshness more important than American Indian or Alaska Native participants who have never been_married, separated, divorced, or widowed.

Two-way interactions between disability and grocery shopping frequency, contribution to reducing household food waste, and marital status, were found. Disable participants who grocery shop once per week rated the feature maintain food freshness more important compared to the ones with a different grocery shopping frequency. In contrast, disable participants who contribute to reducing household food waste rated the feature maintain food freshness less important compared to the ones who do not contribute to reducing household food waste. Furthermore, disable participants who have never been married rated the feature maintain food freshness less important important than married, separated, divorced, and widowed disable participants.

Two-way interactions between education and income, marital, and grocery method were found. Participants with either an associate degree or bachelor's degree who earn between \$20,000 and \$49,999 annually rated the feature maintain food freshness less important than participants with the same educational background who have a different income. Participants with a bachelor's degree that have never been married rated the feature maintain food freshness less important than graduates with a different marital status. Participants with a high school diploma or GED, some college experience, an associate degree, or bachelor's degree that buy items online and have them delivered rated the feature maintain food freshness more important than the participants with the same education level who utilize a different grocery shopping method.

Two-way interactions between income and grocery shopping method, and grocery shopping frequency were found. Participants with an income between \$50,000 and \$74,999 who grocery shop every other week or once per week rated the feature maintain food freshness less important than participants with the same income who grocery shop more than once per week. Comparing the two groups, participants who grocery shop every other week rated this feature less important than participants who grocery shopping once per week. Participants who earn either < \$20,000 or between \$75,000 and \$99,999 annually and buy items online and pick them up rated the feature maintain food freshness less important compared to participants with the same income but a different grocery shopping method.

One two-way interaction between grocery frequency and contribute to reducing food waste was found. Participants who grocery shop every other week and contribute to reducing household food waste rated the feature maintain food freshness more important compared to participants with the same grocery frequency who do not contribute to reducing household food waste.

Six two-way interactions between marital status and grocery frequency were found. Participants who are either married, have never been married, or are divorced and grocery shop every other week rated the feature maintain food freshness less important than participants with the same marital status but a grocery shopping frequency higher than once per week. Participants with the same marital status as above who grocery shop once per week rated this feature less important than the ones with a different grocery shopping frequency.

Only one three-way-interaction was found for maintain freshness. This was between age, education, and grocery frequency.

Printed Food Product Dating "(Best Buy, Sell By, Coding Dates And Others)"

Several two-way interactions between population segments regarding how important the packaging feature "Printed food product dating" is to reduce household food waste were found (P < 0.05). Two-way interactions between education and marital status, income, and contribution to household food waste, and age were found. Nine two-way interactions based on education and marital status were found. Participants who have either completed some college, or have earned an associate degree, or a bachelor's degree and are married, have never been married, or divorced rated the feature printed food product dating less important compared to participants with the same educational background who are separated, or widowed. Participants with a high school diploma or GED who earn between \$50,000 and \$74,999 annually rated printed food product dating less important than participants with the same educational background but a different income. Likewise, participants with some college experience that earn between \$20,000 and \$74,999 annually rated this feature less important compared to participants with the same educational background but a different income. Similarly, participants with an associate degree that earn between \$20,000 and \$49,999 annually rated printed food product dating less important compared to participants with the same educational background but a different income. Furthermore, participants with a bachelor's degree that earn between \$20,000 and \$74,999 annually rated this feature less important compared to participants with the same educational background but a different income. In contrast, participants with a bachelor's degree who contribute to reducing household food waste rated printed food product dating more important compared to participants with the same educational background who do not contribute to reducing household food waste. Similarly, Gen X participants (42-57 years old) with a high

school diploma or GED rated the feature printed food product dating more important compared to participants in the same age group with a different educational background.

Two-way interactions between income and marital status, contribution to reducing household food waste, grocery shopping method, ethnicity, and disability were found. Participants who earn < \$20,000 annually and have never been married rated the feature printed food product dating more important compared to participants with the same income but a different marital status. Participants who earn between \$20,000 and \$49,999 and contribute to reducing household food waste rated the feature printed food product dating less important compared to participants with the same income who do not contribute to reducing household food waste. Participants who earn between \$75,000 and \$99,999 annually buy items online then go and pick them up rated printed food product dating less important than participants with the same income level who utilize a different grocery shopping method. Similarly, participants who make between \$50,000 and \$99,999 annually and are of Hispanic, Latino, or Spanish origin rated printed food product dating less important than participants of the same ethnicity with a different income. Disable participants who earn between \$50,000 and \$74,999 rated the feature printed food product dating more important compared to disable participants with a different income.

Two-way interactions between gender and income, and grocery shopping frequency were found. Male participants who make between \$20,000 and \$74,999 annually rated printed food product dating more important than male participants with a different income. Likewise, male participants who grocery shop once per week rated printed food product dating more important compared to male participants with a different grocery shopping frequency.

Two two-way interactions between race and grocery shopping method were found. Caucasian and American Indian or Alaska Native participants who buy items online then go and

pick them up rated the feature printed food product dating more important than participants of the same race who utilize a different grocery shopping method.

Two-way interactions between contribution to reducing household food waste and grocery shopping frequency, and marital status were identified. Participants who contribute to reducing household food waste and grocery shop every other week rated printed food product dating more important compared to participants with the same shopping frequently who do not contribute to reducing household food waste. Participants who contribute to reducing household food waste and are divorced rated the feature printed food product dating more important compared to participants with the same marital status who do not contribute to reducing household food waste.

Only one 3 way-interaction was found for dating. This was between age, gender, and race.

Protection Against Physical Damage/Strong "(No Breakage)"

Several two-way interactions between population segments regarding how important the packaging feature "protection against physical damage/strong (no breakage)" is to reduce household food waste were found (P < 0.05). Two-way interactions between age and marital status, ethnicity, income, and contribution to reducing food waste were found. Gen Z participants (18-25 years old) who contribute to reducing food waste in their respective household rated the feature protection against physical damage less important compared to participants in the same age group that do not contribute to reducing household food waste. Millennials (26-41 years old) who are either married or have never been married rated the feature protection against physical damage more important than participants in the same age group with a different marital status. Likewise, Millennials who earn between \$50,000 and \$74,999 annually rated the feature

protection against physical damage more important compared to participants in this same age group with a different income. In contrast, millennials who identify as Hispanic, Latino, or Spanish rated the feature protection against physical damage less important compared to non-Hispanic, Latino, or Spanish participants in the same age group.

Two-way interactions between race and marital status, education, and grocery method were found. American Indian or Alaska Native participants who are married rated the feature protection_against physical damage less important compared to participants of the same race with a different marital status. Likewise, American Indian or Alaska Native participants with a bachelor's degree rated the feature protection against physical damage less important compared to participants of the same race with a different education level. In contrast, American Indian or Alaska Native participants who buy items online then go and pick them up rated the feature protection against physical damage more important than participants of the same race with a different grocery shopping method. Regarding ethnicity, two two-way interactions between ethnicity and marital status were found. Hispanic, Latino, or Spanish origin participants who have never married or are divorced rated the feature protection against physical damage more important compared to participants with the same ethnicity but a different marital status.

Two-way interactions between gender and race, and grocery shopping method were found. Male American Indian or Alaska Native participants rated the feature protection against physical damage less important compared to males of a different race. Likewise, male participants who buy items online and pick them up rated the feature protection against physical damage less important compared to male participants with a different grocery shopping method.

Two-way interactions between education and grocery shopping method, contribution to reducing household food waste, disability, income, and marital status were found. Participants

who completed some college and either buy items online then go and pick them up or buy items online and have them delivery to them rated the feature protection against physical damage more important than participants with the same educational background who buy items at a physical store. Similarly, participants who obtained a bachelor's degree and buy items online then go and pick them up rated the feature protection against physical damage more important than participants with the same educational background who utilize a different grocery shopping method. Participants that completed some college or obtained an associate's degree and contribute to reducing food waste in their respective household rated the feature protection against physical damage more important compared to participants with the same educational backgrounds who do not contribute to reducing household food waste. Disable participants with either a high school diploma or GED, some college experience, or a bachelor's degree rated the feature protection against physical damage more important compared to non-disabled participants with the same educational backgrounds. Participants with a bachelor's degree who earn between \$50,000 and \$74,999 rated the feature protection against physical damage less important compared to participants with the same educational background but a different income. Participants who earned a bachelor's degree and are divorced rated the feature protection against physical damage less important compared to participants with the same education level but a different marital status.

Two-way interactions between income and marital status, grocery shopping method, and contribution to reducing household food waste were found. Participants who make < \$20,000 annually and are either married or have never been married rated the feature protection against physical damage more important compared to participants with the same income but a different marital status. Participants who also earn < \$20,000 or between \$75,000 and \$99,999 annually

and buy items online and pick them up rated the feature protection against physical damage less important compared to participants with the same earnings who use a different grocery shopping method. Participants who earn < \$99,999 and contribute to reducing household food waste rated the feature protection against physical damage less important than participants with the same income level who do not contribute to reducing household food waste.

Two-way interactions between disability and marital status, and contribution to reducing household food waste were found. Participants who identified themselves as disable and contribute to reducing food waste in their respective household rated the feature protection against physical damage less important compared to disabled participants that do not contribute to reducing household food waste. Likewise, disable participants who are married rated the feature protection against physical damage less important compared to disable participants with a different marital status.

Three two-way interactions between marital status and grocery shopping frequency were found. Participants that are either married or have never been married who grocery shop every other week rated the feature protection against physical damage less important compared to participants with the same marital status but a different grocery shopping frequency. Furthermore, the never been married participants who grocery shop once per week rated this feature less important compared to participants with the same marital status who buy groceries more than once per week.

Two two-way interactions between grocery shopping frequency and contribution to reducing household food waste were found. Participants who grocery shop every other week and contribute to reducing household food waste rated the feature protection against physical damage more important compared to participants with a similar shopping frequency who do not

contribute to reducing household food waste. Likewise, participants who grocery shop once per week and contribute to reducing household food waste rated this feature more important compared to participants with a similar shopping frequency who do not contribute to reducing household food waste.

APPENDIX B

TWO-WAY INTERACTIONS BETWEEN POPULATION SEGMENTS REGARDING THE PURCHASE INTENT OF PACKAGING TECHNOLOGIES

AP Purchase Intent Two-Way Interactions

Two-way interactions between gender and education and income were found. Male participants with some college experience responded they would purchase active packaging always and sometimes less than male participants with a different educational background. Male participants who earn between \$75,000 and \$99,999 responded they would purchase active packaging always and sometimes more than males with a different income level. Two-way interactions between age and grocery shopping frequency and income were found. Millennials (26 to 41 years old) who grocery shop every other week or once per week responded they would purchase active packaging always and sometimes less than millennials who grocery shop more than once per week. Likewise, Gen X (42 to 57 years old) participants that grocery shop every other week or more than once per week responded they would purchase active packaging always and sometimes less than gen Z participants who grocery shop once per week. Millennials (26 to 41 years old) participants who earn between \$75,000 and \$99,999 responded they would purchase active packaging always and sometimes more than millennials with a different income level. One two-way interaction between ethnicity and income was found. Hispanic, Latino, or Spanish who earn between \$50,000 and \$99,999 responded they would purchase active packaging always and sometimes less than participants of this ethnic group with a different income.

Two two-way interactions between education and grocery shopping frequency and reduce waste were found. Participants with a high school diploma, an associate degree, and/or bachelor's
degree who grocery shop every other week responded they would purchase active packaging always and sometimes less than participants with the same educational background but a different grocery shopping frequency.

Three two-way interactions between income and grocery shopping frequency were found. Participants who earn between \$50,000 and \$74,999 while grocery shop every other week responded they would purchase active packaging always and sometimes less than participants with the same income with a different grocery shopping frequency. Likewise, participants who earn between \$75,000 and \$99,999 and grocery shop every other week or once per week responded they would purchase active packaging always and sometimes less than participants with the same income with a different grocery shopping frequency. Two-way interaction between contribution to reducing household food waste and education and grocery shopping frequency were found. Participants with some college experience who contribute to reducing household food waste responded they would purchase active packaging always and sometimes less than participants with the same educational background who do not contribute to reducing household food waste. Likewise, participants who grocery shop once per week while contributing to reducing household food waste responded they would purchase active packaging always and sometimes less than participants with the same grocery shopping frequency who do not contribute to reducing household food waste.

IP Purchase Intent Two-Way Interaction

Two two-way interactions between age and gender and education were found. Male Gen X (42 to 57) participants responded they would purchase intelligent packaging always and sometimes more than female gen Z participants. Furthermore, Gen X participants with some college experience responded they would purchase intelligent packaging always and sometimes

more than Gen z participants with a different educational background. Two two-way interactions between education and income and grocery shopping frequency were found. Participants with some college experience who earn between \$50,000 and \$74,999 annually responded they would purchase intelligent packaging always and sometimes less than participants with the same educational background with a different income. In contrast, participants with a high school diploma or some college experience who grocery shop once per week responded they would purchase intelligent packaging always and sometimes more than with the same educational background with a different grocery shopping frequency. Participants who earn between \$75,000 and \$99,999 annually and grocery shop once per week responded they would purchase intelligent packaging always and sometimes with the same income with a different grocery shopping frequency. One two-way interaction between disability and grocery shopping frequency was found. Disable participants who grocery shop once per week responded they would they would purchase intelligent packaging always and sometimes some disability and grocery shopping frequency was found. Disable participants who grocery shop once per week responded they would purchase intelligent packaging always and sometimes less than participants with the same income with a different grocery shopping frequency. One two-way interaction between disability and grocery shopping frequency was found. Disable participants who grocery shop once per week responded they would purchase intelligent packaging always and sometimes less than disable participants with a different grocery shopping frequency.

RP Purchase Intent Two-Way Interactions

Caucasian and Black or African American participants with a bachelor's degree responded they would purchase RP always and sometimes less than participants who belong to the same races with a different educational background. Two-way interaction between education and income, marital status, and contribution to reducing household food waste were found. Participants with a high school diploma and/or some college experience who earn between \$20,000 and \$49,999 & \$75,000 and \$99,999 responded they would purchase RP always and sometimes less than participants with same educational but a different income. Similarly, participants with an associate's degree who earn between \$75,000 and \$99,999 responded they

would purchase RP always and sometimes less than participants with same educational but a different income. Participants with high school diploma, some college experience, or a bachelor's degree who are divorced responded they would purchase RP always and sometimes more than participants with the same educational background but different marital status. Participants with some college experience who contribute to reducing household food waste responded they would purchase RP always and sometimes more than participants with the same educational background who do not contribute to reducing food waste. One two-way interaction between ethnicity and income was found. Hispanic, Latino, or Spanish participants who earn between <\$20,000 and between \$50,000 and \$99,999 responded they would purchase RP always and sometimes more than participants of the same ethnic group with a different income. One twoway interaction between disability and income was found. Disable participants who earn less than \$20,000 responded they would purchase RP always and sometimes less than disable participants with a different income. Three two-way interactions between income and marital status, grocery shopping method, and contribution to reducing household food waste were found. Participants that earn between \$20,000 and \$49,999 and are divorced responded they would purchase RP always and sometimes less than participants with the same income but a different marital status. Likewise, participants who earn this same income and contribute to reducing household food waste responded they would purchase RP always and sometimes less than participants that do not contribute to reducing household food waste. Participants who earn between \$50,000 and \$74,999 and buy items online and have them delivered responded they would purchase RP always and sometimes less than participants with the same income with a different grocery shopping method. Two two-way interactions between gender and grocery shopping method and contribution to reducing household food waste were found. Male

participants who buy items online and pick them up responded they would purchase retort packaging always and sometimes less than male participants with a different grocery shopping method. In contrast, male participants who contribute to reduce household food waste responded they would purchase retort packaging always and sometimes more than male participants that do not contribute to reducing household food waste. One two-way interaction between grocery shopping method and grocery shopping frequency was found. Participants who buy items online and have them delivered while grocery shopping once per week responded they would purchase retort packaging always and sometimes more than participants with the same grocery shopping method but a different grocery shopping frequency. Several two-way interactions between age and education, ethnicity, income, grocery shopping method, and grocery shopping frequency were found. Millennial (26-41 years old) participants with a high school diploma, some college experience, and/or an associate's degree responded they would purchase retort packaging always and sometimes more than millennials with a different educational background. Gen Z (18-25 years old) participants who identify as Hispanic, Latino, or Spanish responded they would purchase retort packaging always and sometimes less than non-Hispanic, Latino, or Spanish Gen Z participants. Likewise, Gen Z participants who earn less than \$20,000 responded they would purchase retort packaging always and sometimes less than Gen Z participants with a different income. Millennials (26-41 years old) who earn between less than \$20,000 and \$49,999 responded they would purchase retort packaging the always and sometimes less than millennials with a different income. Likewise, millennials who earn between \$75,000 and \$99,999 responded they would purchase retort packaging the always and sometimes less than millennials with a different income. Millennials who buy items online and have them delivered responded they would purchase retort packaging always and sometimes more than millennials with a

different grocery shopping method. Gen X (42-57 years old) participants who buy items online and pick them up and/or buy items online and have them delivered responded they would purchase retort packaging always and sometimes more than Gen X participants who buy items at the physical store. Gen X participants who grocery shop every other week responded they would purchase retort packaging always and sometimes less than Gen X participants with a different grocery shopping frequency.

ASP Purchase Intent Two-Way Interactions

One two-way interaction between age and income was identified. Gen X (18-25 years old) participants who earn between \$50,000 and \$74,999 responded they would purchase aseptic packaging always and sometimes more than Gen X participants with a different income.

APPENDIX C

TWO-WAY INTERACTIONS BETWEEN POPULATION SEGMENTS FOR THE WILLINGNESS TO PAY EXTRA FOR PACKAGING DESIGNED TO REDUCE HFW Two-Way Interactions Based On The WTP Extra

The Gen Z participants (18-25 years old) who identify as Hispanic, Latino, or Spanish were more willing to pay extra compared to non-Hispanic, Latino, or Spanish Gen Z participants. In contrast, Gen X participants (42-57 years old) who identify as Hispanic, Latino, or Spanish were less willing to pay extra compared to non-Hispanic, Latino, or Spanish Gen X participants. Gen Z participants who contribute to reducing household food waste were more willing to pay extra compared to participants in the same age group who do not contribute to reducing household food waste. In contrast, Gen X participants who contribute to reducing household food waste were less willing to pay extra compared to Gen X participants who do not contribute to reducing food waste. The above results show how groups of generations X and Z differ from each other in the willingness to pay extra, which was not the case for other age generations. Wilson et al. (2018) reported that participants under the age of 25 were willing to spend more money on packaging that can extend the usage of a food product while respondents over the age of 25 were not. Based on the above findings, two population segments with a similar age split for willingness to pay extra or not for food products in packaging intended to assist reduce food waste were identified: Hispanic, Latino, or Spanish, and participants who help reduce food waste.

Black or African American participants who earn <\$20,000 were more willing to pay extra compared to participants of the same race with a different income. In the case of the Hispanic, Latino, or Spanish participants, the ones who earn between \$20,000 and \$49,999 were

less willing to pay extra compared to Hispanic, Latino, or Spanish participants with a different income. Furthermore, Gen X participants who earn between \$75,000 and \$99,999 were less willing to pay extra compared to participants in the same age group with a different income. Therefore, the effect income on willingness to pay extra varies depending on population segments (group age, race, and ethnicity). According to multiple studies (Ganglbauer et al., 2013; Stancu et al., 2016), higher-income households waste more food. Therefore, people with high annual incomes should not see value in spending more money on food items in packaging that can decrease food waste. However, our findings do not support such a relationship.

Black or African American participants who are married were less willing to pay extra compared to Black or African American participants who have never been married, separated, divorced, or widowed. In contrast. married participants who contribute to reducing household food waste were more willing to pay extra compared to married participants who do not contribute to reducing household food waste.

Disable participants who buy items online and pick them up were less willing to pay extra compared to disable participants with a different grocery shopping method. In contrast, Hispanic, Latino, or Spanish participants who buy items online and pick them up were more willing to pay extra compared to Hispanic, Latino, or Spanish participants who buy items online and have them delivered or buy items from a physical store. Male participants who buy items online and have them delivered were less willing to pay extra compared to male participants with a different grocery shopping method. Similarly, Gen X who buy items online and have them delivered were less willing to Gen X participants with a different grocery shopping method. Based on the above results, the willingness to pay extra is different between population segments if the food purchase occurs online but not if this occurs at a physical store.

Participants with an associate's degree who grocery shop once per week were more willing to pay extra compared to participants with the same educational background who grocery shop every other week or more often. In contrast, Black or African American participants who grocery shop once per week were less willing to pay extra compared to Black or African American who grocery shop every other week or more often. Gen Z participants who grocery shop every other week were less willing to pay extra compared to participants of the same age group with a different grocery shopping frequency. Participants that grocery shop every other week or once per week who contribute to reducing household food waste were willing to pay extra compared to participants with the same grocery shopping frequency that do not contribute to reducing household food waste. Previous household food waste studies have reported that families who shop more regularly typically waste less food (Jörissen et al., 2015; Smith and Landry, 2020). In principle, families who shop less regularly should be more willing to pay extra. However, our findings show that such willingness varies depending on the population group. The above findings show that the groups among population segments that differ in the willingness to pay extra are generations Z and X, Hispanic, Latino, or Spanish, Black or African American, married, male, buyers with an associate's degree, buyers of items online, and grocery shopper at once per week or less. Also, our findings show that groups of the population segments related to household size did not show any differences in willingness to pay extra.

APPENDIX D

EFFECT OF POPULATION SEGMENTS ON PARTICIPANTS TOP THREE MOST WASTED FOOD CATEGORIES AND FOOD GROUPS DURING AN AVERAGE WEEK Fruits And Vegetables

Significant differences in the selection of fruits and vegetables leading to the most waste in participants households were found among population segments (p < 0.05). When compared to participants from other groups within each particular population segment, Millennials, Baby Boomers, males, Caucasians, people who declare themselves to be non-Latino, Latino, or Spanish, those with bachelor's or graduate-level degrees, who earn \$75,000 or more, who are married, who are divorced, who are widowed, who are disabled, who buy items online and pick them up in person and who buy items online and have them delivered, dispose more fruit and vegetables during an average week (p < 0.05).

Prepared Foods

Significant differences in the selection of prepared foods leading to the most waste in participants households were found among population segments (p < 0.05). When compared to participants from other groups within each particular population segment, Gen X participants, Baby Boomers, males, Black or African Americans, American Indians or Alaska Natives, Asians, people who declare themselves to be non-Latino, Latino, or Spanish, people with incomes over \$75,000, who are married, who are separated, who buy items online and pick them up and buy at a physical store, and who grocery shop more than once per week, dispose more prepared foods during an average week (p < 0.05).

Dairy

Significant differences in the selection of dairy leading to the most waste in participants households were found among population segments (p < 0.05). When compared to participants

from other groups within each particular population segment, Males, those who possess a high school diploma, those with some college experience, people who declare themselves to be non-Latino, Latino, or Spanish, who earn between \$20,000 and \$49.999, who have never been married, who are separated, who are divorced, who buy items online and have them delivered, who buy at a physical store, who grocery shop every other week and once per week, dispose more dairy products during an average week (p < 0.05).

Effect Of Population Segments On The Top Three Most Wasted Food Group During An Average Week

Significant differences in the selection of fresh whole fruits and vegetables leading to the most waste in participants households were found among population segments (p < 0.05). Millennials, Generation Xers, Caucasians, Black or African Americans, American Indians or Alaska Natives, those with a high school diploma, some college experience, a graduate degree, who are not of Spanish, Latino, or Hispanic origin, who earn \$50,000 or more, those who have never been married, are widowed, are not disable, who buy items online and pick them up, onceper-week grocery shoppers, and those that do not contribute to reducing household food waste discarded more fresh whole fruits and vegetables than participants from other groups within each specific population segment (p < 0.05).

Significant differences in the selection of fresh ready-made meals leading to the most waste in participants households were found among population segments (p < 0.05). Generation Xer, Baby boomers, Males, Black or African Americans, Asians, those who possess a high school diploma, an associate's degree, who are not of Spanish, Latino, or Hispanic origin, who earn less than \$20,000 and at least \$75,000, those who have never been married and are widowed, who are non-disable, who buy items at the physical store, grocery shop more than once

a week, discarded more fresh ready-made meals than participants from other groups within each specific population segment (p < 0.05).

Significant differences in the selection of fresh-cut fruits and vegetables leading to the most waste in participants households were found among population segments (p < 0.05). Males, Caucasians, those who possess a bachelor's degree or higher, who are not of Spanish, Latino, or Hispanic origin, who earn above \$100,000, who are married, who are divorced, who buy items online and pick them up and/or have them delivered, who grocery shop every other week, and who do not contribute to reducing household food waste, discarded more and fresh cut fruits and vegetables than participants from other groups within each specific population segment (p < 0.05). One three-way interaction between age, gender, and grocery frequency was identified as well.

APPENDIX E

EFFECT OF POPULATION SEGMENTS ON PARTICIPANTS THE PACKAGING MATERIAL AND FORMAT ASSOCIATED WITH PARTICIPANTS MOST WASTED FOOD PRODUCT

Food In Plastic Packaging

Gen Zers, Xers, and Millennials, Caucasians, American Indians or Alaska Natives, and Asians, those with some education, some college experience, an associate's degree, and a bachelor's degree, who earn between \$20,000 and \$49,999 and \$100,000+, who have never been married and are widowed, who buy items and have them delivered, who grocery shop more than once a week, discarded more food in plastic packaging than participants from other groups within each specific population segment (p < 0.05).

Food Without Packaging

Millennials, Baby boomers, male, Caucasian, with some college, a bachelor's degree, and graduate degree, Hispanic, Latino, or Spanish, who earn \$50,000 or more, who are married or are divorced, disable, who buy items and have them delivered, who grocery shop every other week or once a week, those who contribute to reducing household food waste participants discarded more food without packaging than participants from other groups within each specific population segment (p < 0.05)

Food In Paper/Paperboard

Millennials, Gen X, male, Black or African American, with an associate's degree, and a bachelor's degree, who earn between \$75,000+, who have never been married and are widowed, disable, who buy items and have them delivered and/or pick them up, who grocery shop more than once a week, those who contribute to reducing household food waste participants discard

more food in paper/paperboard than participants from other groups within each specific population segment (p < 0.05)

Packaging Associated With Fruits And Vegetables

Significant differences between the selection of packaging formats associated with fruits and vegetable waste (top food category) and population segments were found (p < 0.05). Gen Z, Millennials, and Gen X, Female, African American and Native Hawaiian, who earn between \$20,000 and \$49,999 and \$100,000+, who are married and are divorced, non-disable, who buy at a physical store, who grocery shop once a week, and those who contribute to reducing household food waste discarded fruits and vegetables in a tray more than participants from other groups within each specific population segment (p < 0.05)

Participants over the age of 26, Male, Caucasian, with a high school diploma, a bachelor's degree, and a graduate degree, Non- Hispanic, Latino, or Spanish, who earn less than 20,000, between 50,000 and 74,999 and 100,000+, who are married or have never been married, who buy at a physical store, who grocery shop every other week and more than once a week, discarded fruits and vegetables in a bag/pouch more than participants from other groups within each specific population segment (p < 0.05)

Gen Z and Millennials, Asian and Native Hawaiian, with some school and some college, who earn between \$75,000 and \$99,000, who are divorced and are widowed, who buy online and pick them up, who grocery shop once a week, and those who contribute to reducing household food waste discarded fruits and vegetables in a jar more than participants from other groups within each specific population segment (p < 0.05). One three-way interaction between age, race, and education was found. Additionally, one three-way interaction between gender, race, and education was found.

APPENDIX F

CORRELATIONS BETWEEN FOOD WASTE STATES AND POPULATION SEGMENTS

Age And Food Waste State

Correlations between population segments and food waste states were found (p < 0.05). Correlations between age and food waste state were identified (X^2 (12, N = 1000) = 22.6, p < 0.0312). Participants under the age of 42 threw away more food because the wrong product was purchased than older participants. Millennials threw away more food without packaging that spoiled before it was eaten than other age groups. Participants under the age of 58 threw away more food that spoiled before it opened than older participants. Gen Z, Gen X, and Baby boomers threw away more leftovers than millennials. Participants 42 and older threw away more half-eaten packaged food products than younger participants.

Education, Ethnicity, And Food Waste State

Correlations between education and food waste state were identified (χ^2 (20, N = 1000) = 39.1, p < 0.0065). Participants with some school, a high school diploma, and an associate's degree threw away more food because the wrong product was purchased than participants with a different educational background. Participants with some college, a bachelor's degree, and a graduate degree threw away more food without packaging that spoiled than participants with a different educational background. Participants with some school, a high school diploma, and an associate's degree threw away more food that spoiled before being open than participants with a different educational background. Participants with some school, a high school diploma, and some college threw away more leftover food than participants with a different educational background. Participants with some school, a high school diploma, and some college threw away more leftover food than participants with a different educational background. Participants with some school, a high school diploma, and some college threw away more leftover food than participants with a different educational background. Participants with a massociate's degree, bachelor's degree, and graduate degree threw away more half-eaten packaged food than participants with a different educational

background. Correlations between ethnicity and food waste state were identified (X^2 (4, N = 1000) = 10.5, p < 0.0329). Hispanic, Latino, or Spanish participants threw away more food because the wrong food product was purchased, spoiled before being opened, and leftover food than non-Hispanic, Latino, or Spanish participants. Non-Hispanic, Latino, or Spanish participants threw away more food without packaging that spoiled and half-eaten packaged food products than Hispanic, Latino, or Spanish participants.

Income And Food Waste State

Correlations between income and food waste state were identified (X^2 (16, N = 1000) = 26.6, p < 0.0456). Participants who earn between \$20,000 and \$74,999 threw away more food because the wrong product was purchased than participants with a different income. Participants who earned between \$50,000 and \$74,999 and \$100,000+ threw away more food without packaging that spoiled than participants with a different income. Participants who earned less than \$50,000 threw away more food that spoiled before being opened than participants with a higher income. Participants who earn less than \$49,999) and between \$75,000 and \$99,999 threw away leftovers than participants with a different income. Participants who earn more than \$50,000 threw away more half-eaten packaged food than participants with a lower income.

Grocery Shopping Method And Food Waste State

Correlations between grocery shopping method and food waste state were identified (X^2 (8, N = 1000) = 26.6, p < 0.0169). Participants who buy items online and pick them up and buy items online and have them delivered threw more food away because the wrong product was purchased and food that spoiled before being opened than participants who buy at the physical store. Participants who buy items online and have them delivered threw away more food without packaging that spoiled than participants with a different grocery shopping method. Participants who buy items at the physical store threw away more leftover food than participants with a different grocery shopping method. Participants who buy items online and pick them up and buy at the physical store threw away more half-eaten packaged food than participants who buy items online and have them delivered. Female participants discarded more half-eaten packaged food products, leftovers, and food that spoiled being open compared to male participants. In contrast, male participants discarded more food without packaging that spoiled and food that is purchased wrongly than female participants. Black or African American participants threw away more food because the wrong product was purchased than participants of a different race. Caucasian participants threw away more food without packaging that spoiled than other race. Black or African American and American Indian or Alaska Native threw away more food that spoiled before being opened than other race. American Indian or Alaska Native, Asian, and Native Hawaiian or other Pacific islander participants discarded more meal leftovers than other races. Caucasian and Black or African American discarded more half-eaten packaged food products than other races. Married participants discarded more half-eaten packaged food products and food products that were thrown away because the wrong product was purchased than participants with a different marital status. Participants who have never been married and are widowed discarded more food without packaging that spoiled than participants with a different marital status. Participants who have never been married and are divorced or widowed discarded more packaged food that spoiled before being opened than participants with a different marital status. Participants who are married, separated, and divorced discarded more meal leftovers than participants with a different marital status. Disable participants discarded more meal leftovers, packaged food that spoiled before being opened, and food without packaging that spoiled than non-disable participants. In contrast, non-disable participants discarded more half-eaten

packaged food products and food that was thrown away because the wrong product was purchased than disable participants. Participants who grocery shop every other week discarded food that was thrown away because the wrong product was purchased more than participants with a different grocery shopping frequency. Participants who grocery shop every other week and once per week discarded more food that spoiled without packaging than those who grocery shop more than once per week. Participants who grocery shop every other week and more than once per week discarded more packaged food that spoiled before being opened than those who grocery shop once per week. Participants who grocery shop once per week and more than once per week discarded more meal leftovers and half-eaten packaged food products than those who grocery shop every other week. Participants who contribute to reducing household food waste discarded more meal leftovers, packaged food that spoiled before being opened, and food without packaging that spoiled than participants that do not contribute to reducing household food waste. In contrast, participants who do not contribute to reducing household food waste discarded more half-eaten packaged food products and food that was thrown away because the wrong product was purchased than those who contribute to reducing household food waste.

APPENDIX G

CORRELATIONS BETWEEN PACKAGING MATERIALS AND FORMATS AND FOOD WASTE STATES

Significant correlations between packaging materials and food waste states were identified $(X^2 (12, N = 1000) = 545, p < 0.0001)$. Plastic packaging is discarded more frequently than paper or other packaging when it comes to packaged food products that have been half-eaten. If the food product is in paper or another non-plastic package, more meal leftovers are thrown out. Food products that spoiled before the package was opened are discarded more if the packaging is made of plastic than another material. Food products that are thrown away because the wrong product was purchased are discarded more if the packaging is made of plastic packaging.

Correlations between packaging formats and food waste states were identified. Half-eaten packaged food products are discarded in a bottle more than in a bag, tray, or jar. When the food product is in a jar, tray, or bottle rather than a bag, more leftover meals that have not been consumed are thrown away. If the packaging is in the form of a bag or jar as opposed to a bottle or tray, more food products that went bad before the container was opened are thrown away. When packaged in a bottle rather than a bag, jar, or tray, food that was thrown away because the wrong food product was purchased is wasted more frequently.

APPENDIX H

TWO-WAY INTERACTIONS BETWEEN POPULATIONS SEGMENTS FOR THE QUANTIFICATION OF THE TOP THREE MOST WASTED FOOD CATEGORIES DURING AN AVERAGE WEEK

Dairy

Two-way interactions between age and race, marital status, ethnicity, income, disability, and education were found. Millennial participants who identify as Caucasian wasted less ounces of dairy products during an average week than millennials of a different race. Millennial participants who grocery shop every other week wasted more ounces of dairy products than millennials with a different grocery shopping frequency. Millennial participants who earn between (\$50,000-\$99,999) wasted more ounces of dairy products during an average week than millennials with a different income. Millennials who earn between (\$20,000-\$49,999) wasted less ounces of dairy products during an average week than millennials with a different income. Millennial participants with a disability wasted more ounces of dairy products during ana average week than non-disable millennials. Millennials with an educational background outside of some school and a graduate degree wasted less ounces of dairy products during an average week than millennials with a different educational background. Gen X participants who identify as Caucasian wasted more ounces of dairy products during an average week than gen x participants of a different race. Gen X participants who earn less than \$20,000 annually wasted more ounces of dairy products than gen x participants with a different income. Gen X participants who earn between (\$20,000-\$49,999) wasted less ounces of dairy products than gen x participants with a different income. Gen X participants with a disability wasted less ounces of dairy products during and average week than non-disable gen x participants. Gen X participants with a high school diploma, some college, and

a graduate degree wasted less ounces of dairy products during ana average week than gen x participants with a different educational background. Millennial and Gen X participants who are married wasted less ounces of dairy products during an average week than participants of these age groups with a different marital status. Millennial and Gen X participants who identify as Hispanic, Latino, or Spanish wasted less ounces of dairy products during an average week than participants of these age groups who are not Hispanic, Latino, or Spanish. Gen Z participants with a high school diploma wasted more ounces of dairy products during an average week than gen z participants with a different educational background. Two-way interactions between race and gender, income, education, ethnicity, and disability were found. Caucasian and Black or African American male participants wasted more ounces of dairy products during an average week than male participants of a different race. Caucasian and Black or African American participants who earn less than \$50,000 annually wasted less ounces of dairy products during an average week than participants of the same race with a different income. Black or African American participants with an associate degree wasted more ounces of dairy products than participants of the same race with a different educational background. Caucasian with some college, an associate degree, and a bachelor's degree wasted more ounces of dairy products during an average week than participants of the same race with a different educational background. Male participants with a disability wasted less ounces of dairy products during ana average week than male participants without a disability. Two-way interactions between gender and income and education, and ethnicity were found. Male participants who earn less than \$50,000 annually wasted less ounces of dairy products during an average week than males with a higher income. Male participants with a high school diploma and some college wasted more ounces of dairy products during an average week than male participants with a different educational background. Male Hispanic, Latino, or Spanish

participants wasted less ounces of dairy products during an average week than male participants that do not belong to this ethnic group. Two-way interactions between ethnicity and disability and education were found. Hispanic, Latino, or Spanish participants with a disability wasted less ounces of dairy products during ana average week than Hispanic, Latino, or Spanish participants without a disability. Hispanic, Latino, or Spanish participants with a high school diploma and some college experience wasted more ounces of dairy products during an average week than Hispanic, Latino, or Spanish participant with a different educational background.

Prepared foods

Two-way interactions between age, gender, race, education, ethnicity, disability, income, grocery shopping method and grocery shopping frequency were found. Two-way interactions between age and gender were found. Gen Z male participants wasted less ounces of prepared foods during an average week. In contrast, Millennial male participants wasted more ounces of prepared foods during an average week. Millennial participants that are Caucasian, Black or African American, and American Indian or Alaska Native wasted less ounces of prepared foods than participants of a different race. Gen X participants that are Black or African American, and American Indian or Alaska Native wasted less ounces of prepared foods during an average week than participants of a different race. Millennial participants with some college, an associate degree, and a bachelor's degree wasted more ounces of prepared foods during an average week than millennial participants with a different educational background. Gen X participants with some school wasted less ounces of prepared foods during an average week than Gen X participants with a different educational background. Millennial participants who are Hispanic, Latino, or Spanish wasted more ounces of prepared foods during an average week than millennial participants who are not Hispanic, Latino, or Spanish. Millennial and Gen X participants with a disability wasted

more ounces of prepared foods during an average week than millennial and Gen X participants without a disability. Millennial participants who earn between (\$20,000-\$49,999) wasted less ounces of prepared foods than millennials with a different income. Millennial participants that buy items online pick them up and buy items online and have them delivered wasted less ounces of prepared foods during ana average week than millennials who buy at the physical store. Millennial participants who grocery shop every other week wasted more ounces of prepared foods during an average week. Two-way interactions between gender and race, education, ethnicity, income, marital status, grocery shopping method, and disability were found. Male participants that are Caucasian and Black or African American wasted less ounces of prepared foods during an average week than male participants of a different race. Male participants with a high school diploma, some college, an associate degree, and a bachelor's degree wasted less ounces of prepared foods during an average week than male participants with a different educational background. Male Hispanic, Latino, or Spanish participants wasted more ounces of prepared foods during an average week than non- Hispanic, Latino, or Spanish male participants. Male participants who earn less than \$20,000 wasted more ounces of prepared foods during an average week than male participants with a different income. Male participants who are married wasted less ounces of prepared foods during an average week than male participants with a different marital status. Male participants that buy items online pick them up wasted less ounces of prepared foods during an average week than male participants with a different grocery shopping method. Male participants with a disability wasted less ounces of prepared foods during an average week than male participants without a disability.

Two-way interactions between race, education, ethnicity, disability, and income were found. Caucasian with a bachelor's degree wasted more ounces of prepared foods during an

average week than Caucasian participants with a different educational background. Caucasian Hispanic, Latino, or Spanish participants wasted more ounces of prepared foods during an average week than Caucasian participants not a part of this ethnic group. Caucasian participants with a disability wasted more ounces of prepared foods during an average week than Caucasian participants without a disability. Caucasian participants who earn between \$20,000-\$99,999 wasted more ounces of prepared foods during an average week than Caucasian participants with a different income. Two-way interaction between ethnicity and education, disability, and income were found. Hispanic, Latino, or Spanish participants with a high school diploma, some college, an associate degree, and a bachelor's degree wasted more ounces of prepared foods during an average week than non- Hispanic, Latino, or Spanish participants with the same educational background. Hispanic, Latino, or Spanish participants with a disability wasted less ounces of prepared foods during an average week than participants of the same ethnic group without a disability. Hispanic, Latino, or Spanish participants who earn between \$20,000-\$49,999 wasted more ounces of prepared foods during an average week than participants of the same ethnic group with a different income. Two-way interactions between education and disability, income, and grocery shopping method were found. Participants with a high school diploma, and some college who are disable wasted less ounces of prepared foods during an average week than non-disable participants with the same educational background. Participants with a high school diploma that buy items online pick them up wasted less ounces of prepared foods during an average week than participants with the same educational background who utilize a different grocery shopping method. Participants with a high school diploma who earn less than \$20,000 wasted more ounces of prepared foods during an average week. In contrast, participants with a high school diploma who earn between \$20,000-\$74,999 wasted less ounces of prepared foods during an average week.

Participants with some college experience who earn between less than \$20,000 and \$50,000-\$74,999 wasted more ounces of prepared food during an average week. In contrast, participants with the same educational background who earn between (\$20,000-\$49,999) wasted less ounces of prepared foods during an average week. Participants with an associate degree and bachelor's degree who earn between (\$75,000-\$99,999) wasted less ounces of prepared foods during an average week. One two-way interaction between disability and income was found. Disable participants who earn less than \$20,000 wasted more ounces of prepared foods during an average week.