The Value of Flexible Packaging in Extending Shelf Life and Reducing Food Waste

A Flexible Packaging Association Report

Prepared for FPA by McEwen Associates

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Flexible Packaging

FPA

Flexible Packaging Association

1 Executive Summary

As the voice of the flexible packaging industry, FPA is exploring opportunities to communicate the advantages of flexible packaging in reducing food waste. This study follows up on another FPA study, "The Role of Flexible Packaging in Reducing Food Waste," which concluded that flexible packaging reduces food waste if a systems approach of looking at both product and packaging is developed.

The objective of this study was to document quantifiable scientific evidence of flexible food packaging systems reducing consumer food waste. It also includes a discussion of the environmental significance of food waste and consumer attitudes and behavior around food waste.

There is published literature in peer reviewed journals of flexible packaging systems extending the shelf life of various food commodities. Findings also reveal that consumers are interested in reducing waste and extending the shelf life of their food, but are not aware of the benefits packaging offers for doing this.

Consumers do not understand packaging technologies and the value packaging brings in extending the shelf life of products in order to reduce food waste. A 2013 WRAP[1] study showed that 61% of consumers polled thought that fruits and vegetables 'go off' quicker in their packaging and just 13% knew that storing food in its original packaging will keep it fresher for longer. A recent Harris poll study conducted by Sealed Air Corporation found that 89% of American grocery shoppers think packaging materials are more harmful to the environment than discarded food.[2] Yet forty percent of the food in the US today goes uneaten which means each year we waste $165 billion[3], 20% of our land, and 30% of our available fresh water and send 34.7 million tons of food to our landfills[4] which decays anaerobically turning into methane and represents 25%[5] of all the methane emissions[6] from U.S. landfills.

In food waste studies, consumers rarely mention environmental consequences as a motivator to minimize food waste (unless prompted).[7] They feel guilty wasting money and wasting good food that someone else could have eaten, but when they place the food in the trash bin they do not believe it is bad environmentally. When asked about this they state: food is natural, it is biodegradable it's OK. However, people do view plastic flexible food packaging as bad; it is not biodegradable and it cannot be recycled. And it is at this point, the end of life, that packaging transitions from something of use, of value and of worth to something that is no longer any of these.[8]

Cover image by Circle Learning
1 Consumer attitude to food waste and food packaging, March 2013.
2 http://www.multivu.com/players/English/7270651-sealed-air-2014-food-waste-survey/gallery//image/ccab40e5-661d-4143-871b-561f51c75b06.HR.jpg
3 Gunders, Dana. "Wasted: how America is losing up to 40% of its food from farm to fork to landfill." Natural Resources Defense Council (2012).
4 http://epa.gov/epawaste/nonhaz/municipal/pubs/2012_msw_fs.pdf. Also see Appendix 3.
5 Every kg of food sent to landfill emits approximately .78kg CO_2 eq. of methane. EPA, Waste Reduction Model (WARM), http://epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf
6 Landfill methane emissions equal 107.4MMT CO_2eq. http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Chapter-Executive-Summary.pdf
7 EGraham-Rowe, Ella, Donna C. Jessop, and Paul Sparks. "Identifying motivations and barriers to minimising household food waste." Resources, Conservation and Recycling 84 (2014): 15-23.
8 Langley, Joe, Natalie Turner, and Alaster Yoxall. "Attributes of packaging and influences on waste." Packaging technology and science 24.3 (2011): 161-175.

A recent FPA study titled "The Role of Flexible Packaging in Reducing Food Waste" reported on the history of the rise in global concern for food waste and documented food waste initiatives around the globe. The study revealed the repeated emphasis by food waste programs on the need for education to begin changing consumer behaviors and concluded that flexible packaging reduces food waste. The objective of this current study is to document any scientific evidence of flexible food packaging system reducing consumer food waste.

While packaging has been identified as part of the solution to household food waste, to date there is no scientific literature that quantifies the amount of food saved through the use of packaging. There are consumer studies that quantify who is most likely to throw food away, what food is most likely to be thrown away, and why it is thrown away; but, there is no study that compares whether these factors change (who, what, why) if different types of packages are purchased. So while popular opinion is that portion control, re-closability and shelf life extension reduce food waste, we have no quantitative evidence that with a better designed package, consumer behavior will change.

Consumer studies show that people's top three concerns regarding food waste are: it's a waste of money, it's a waste of good food, and it makes them feel guilty. Studies reveal that while wanting to waste less (saving money and food) consumers struggle with this intention as it is in direct conflict with wanting to be a good provider (putting healthy meals on the table) and not being inconvenienced (shopping more frequently).

It is here; between these conflicts that FPA has the opportunity to tell the flexible packaging story of how flexible packaging keeps food fresh longer, helping you waste less. [9] Both are positive messages of how flexible packaging can help you do the right thing. With this message, consumers will be emotionally interested to engage and learn more.

9 "Packaging allows food to stay fresher for longer – not just on shelves but in your home as well" was identified as an effective statement to shift consumer attitudes. Consumer attitudes to food waste and food packaging, WRAP (2013).

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3 INTRODUCTION

The objective of this study is to document any scientific evidence of flexible food packaging systems reducing consumer food waste. This work follows up on the recent FPA study titled "The Role of Flexible Packaging in Reducing Food Waste" which concluded that flexible packaging has an opportunity to be the 'hero' that reduces food waste if a systems approach of looking at both product and packaging is developed. The study revealed the repeated emphasis by food waste programs around the world on the need for education to begin changing consumer behaviors.

In the final report several case studies were developed to illustrate how flexible packaging as part of a food/packaging system helps prevent food waste. However the data behind the stories was noted as being anecdotal, lacking scientific evidence. Thus, the initial phase of this current research was an extensive scientific literature review of food science, packaging and environmental peer reviewed journals to document any existing evidence that quantified the value of flexible packaging in preventing food waste. Attributes such as portion control, re-closability and film toughness were investigated as well as modified atmosphere (both active and passive), vacuum and active packaging systems.

4 LITERATURE REVIEW

The initial phase of this study was an extensive scientific literature review of food science, packaging and environmental journals to document any existing evidence that quantified the amount of food saved through the use of flexible packaging, and the value of this saved food in terms of environmental impacts. Effort was made to only include articles from peer reviewed journals published after 2000. Some books were included as well as older articles when necessary to fill knowledge gaps. The peer reviewed research of United Kingdom's non-profit recycling advocate, Waste & Resources Action Programme (WRAP), was also included. WRAP works with businesses, individuals and communities to help them reduce waste, develop sustainable products and use resources in an efficient way. WRAP developed the "Recycling Now" and "Love Food Hate Waste" initiatives. They have completed the most extensive consumer research on food waste to date.

Over 200 articles were located for review and about 100 of these were identified (see Appendix 1) as relevant to FPA's questions. These articles were then analyzed to develop a foundation for what is currently known, and uncover areas where there are knowledge gaps and research is needed. All literature was then synthesized to develop key messages around the documented data that FPA can use for education and communication now, and to recommend research FPA can support whose results may support future education and communication.

Flexible packaging attributes such as portion control, re-closability and film toughness were investigated as well as modified atmosphere (MAP, active and passive), vacuum and active packaging systems. While throughout the supply chain, from farm to fork, flexible packaging has an important role to play in reducing food waste (see Appendix 2), our literature search specifically looked at the retail and consumer phases. Flexible packaging solutions for production, harvest & storage, processing and distribution were not targeted in the literature search.

The results of this literature review are divided into three topics: Environmental Significance, Consumer Behavior, and Shelf Life.

4.1 Environmental Significance

Forty percent of the food in the US today goes uneaten[10] and each year the 34.7 million tons[11] of food sent to US landfills results in greenhouse gas emissions of approximately 27 million tons[12] of CO_2 eq. In addition to the direct greenhouse gas emissions created at end of life, there are two other less discussed indirect environmental consequences resulting from food waste: the avoidable consumption of natural resources (specifically land and water), and pollution occurring during food production.

Food that is produced, regardless of whether it is consumed or wasted, uses fresh water and other natural resources, including land. In fact, eighty percent of all freshwater consumed in the United States, and fifty percent of the land is used for producing food.[13]

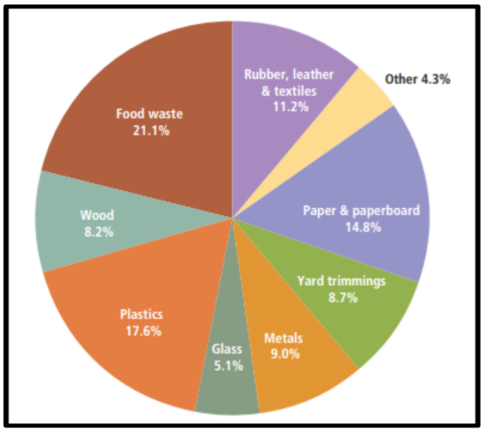


FIGURE 1: CATEGORIES OF MUNICIPAL SOLID WASTE. FOOD WASTE REPRESENTS 21.1% OF THE TOTAL MUNICIPAL SOLID WASTE GENERATED AFTER RECYCLING (164 MILLION TONS).
Source: EPA, Facts and Figures for 2012.

Producing food also results in:

- ✓ greenhouse gas emissions from cattle production;
- ✓ air pollution caused by farm machinery and trucks that transport food;
- ✓ water pollution and damage to marine and freshwater fisheries from agricultural chemical and nutrient runoff during crop and livestock production; and
- ✓ soil erosion, salinization, and nutrient depletion that arise from unsustainable production and irrigation practices.[14]

For a global view of the sustainability significance of food waste see Food and Agriculture Organization of the United Nations 2013 video: http://www.youtube.com/watch?v=IoCVrkcaH6Q.

Numerous life cycle assessment (LCA) studies have documented these food production impacts[15] and also how packaging impacts are relatively small compared to the impacts of producing, harvesting and distributing food.

10 Gunders, Dana. “Wasted: how America is losing up to 40% of its food from farm to fork to landfill.” Natural Resources Defense Council (2012).
11 http://www.epa.gov/epawaste/nonhaz/municipal/pubs/2012_msw_fs.pdf
12 Every kg of food sent to landfill emits approximately .78kg CO2 eq. of methane. EPA, Waste Reduction Model (WARM), http://epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf
13 Gunders, Dana. “Wasted: how America is losing up to 40% of its food from farm to fork to landfill.” Natural Resources Defense Council (2012).
14 Buzby, Jean C., Hodan F. Wells, and Jeffrey Hyman. "The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States." Economic Information Bulletin, United States Department of Agriculture, ii-33 (2014).
15 Roy, Poritosh, et al. "A review of life cycle assessment (LCA) on some food products." Journal of Food Engineering 90.1 (2009): 1-10.

Within the last couple of years LCA studies have claimed that the impacts of packaging should be allowed to increase, if new packaging reduces food losses.[16] These studies are recommending a change in the functional unit typically used in food packaging LCA's from "the delivery of a quantity of food" to "the delivery of a quantity of eaten food". If a package prevents food waste, this environmental savings is accounted for with this new functional unit as less food needing to be produced, packaged and shipped to deliver the same quantity of eaten food.

This has significant relevance for Design for Environment thinking and calculations. Currently the better package is the one that has the lowest impacts per unit of food delivered. In the future the better package will be the one that delivers the most eaten food for the least impacts. Mathematical models to make this calculation have been proposed[17].

Of the food packaging LCA's published since 2000 that have incorporated food waste into their models all have used hypothetical consumer food waste numbers and scenario analysis to document the importance of understanding food waste. No study has been able to use package specific consumer food waste numbers as this information is not available. Understanding the relationship between packaging attributes and food waste for different food items and packaging formats was identify as an important area for future work in Wikström and Williams, latest study.[18]

4.2 Consumer Behavior

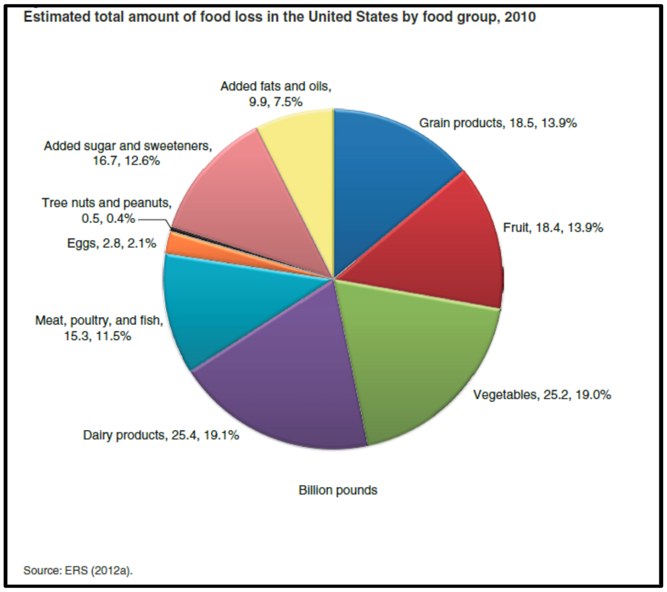
Consumer studies that have looked at household food waste have primarily focused on identifying what food is most likely to be thrown away, who is most likely to throw it away, why it is thrown away, and how people feel about wasted food. Studies are based on surveys, interviews, waste compositional analysis, and kitchen diaries. Most of this research comes out of Europe, and primarily the UK. The following sections summarize these studies.

Section 4.2.1 provides US statistics for what is thrown away, section 4.2.2 discusses who and why food is wasted, and section 4.2.3 discusses how consumers feel about wasting food. A 2012 study by WRAP explores consumer attitudes towards food packaging and is discussed in detail in section 4.2.4.

4.2.1 What food is wasted

The average amount of food loss per American was 429 pounds, of which 139 pounds at the retail level and 290 pounds at the consumer level went uneaten.[19] At the consumer level, 59 pounds of vegetables, 52 pounds of dairy products, and 41 pounds of meat, poultry, and fish per capita from the food supply went uneaten. See Appendix 4 for a detailed breakdown of consumer versus retail level food losses. Figure 2 summarizes the latest U.S. estimates of food waste at the retail and consumer levels by weight and dollar.

16 Silvenius, Frans, et al. "The role of household food waste in comparing environmental impacts of packaging alternatives." Packaging Technology and Science 27.4 (2014): 277-292.
17 Williams, Helén, and Fredrik Wikström. "Environmental impact of packaging and food losses in a life cycle perspective: a comparative analysis of five food items." Journal of Cleaner Production 19.1 (2011): 43-48.
18 Wikström, Fredrik, et al. "The influence of packaging attributes on consumer behaviour in food-packaging life cycle assessment studies-a neglected topic." Journal of Cleaner Production 73 (2014): 100-108.
19 Buzby, Jean C., Hodan F. Wells, and Jeffrey Hyman. "The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States." Economic Information Bulletin, United States Department of Agriculture, ii-33 (2014).



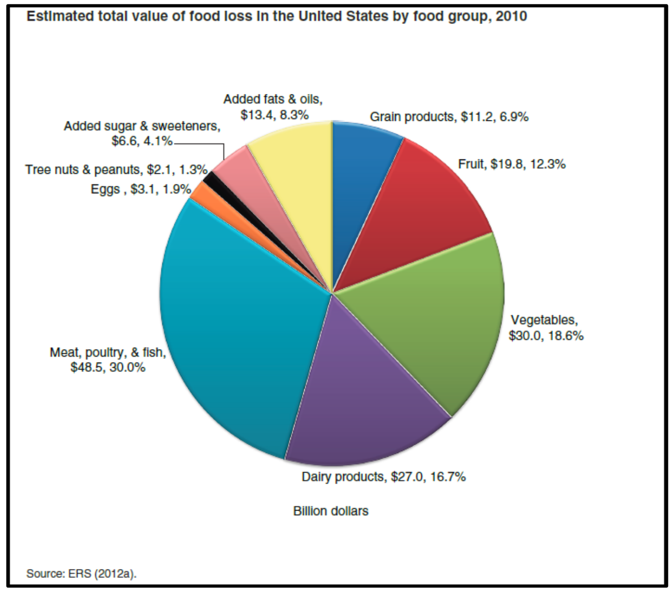


FIGURE 2: LATEST U.S. ESTIMATES OF FOOD WASTE AT THE RETAIL AND CONSUMER LEVELS. BY WEIGHT (LEFT), AND DOLLAR (RIGHT), USDA, FEBRUARY 2014. IN THE UNITED STATES, 31 PERCENT, 133 BILLION POUNDS, OF THE 430 BILLION POUNDS OF AVAILABLE FOOD SUPPLY AT THE RETAIL AND CONSUMER LEVELS IN 2010 WENT UNEATEN. THE ESTIMATED VALUE OF THIS FOOD LOSS WAS $161.6 BILLION, OR $522 PER CAPITA, BASED ON THE US POPULATION IN 2010.

4.2.2 WHO WASTES AND WHY THEY WASTE

In all the studies reviewed, the three main reasons food was wasted were:

1. food had spoiled,
2. too much was prepared or
3. personal preference ("fussy eaters").

A UK study (Figure 3) on household food and drink waste details that the reasons for disposal vary considerably by food group.

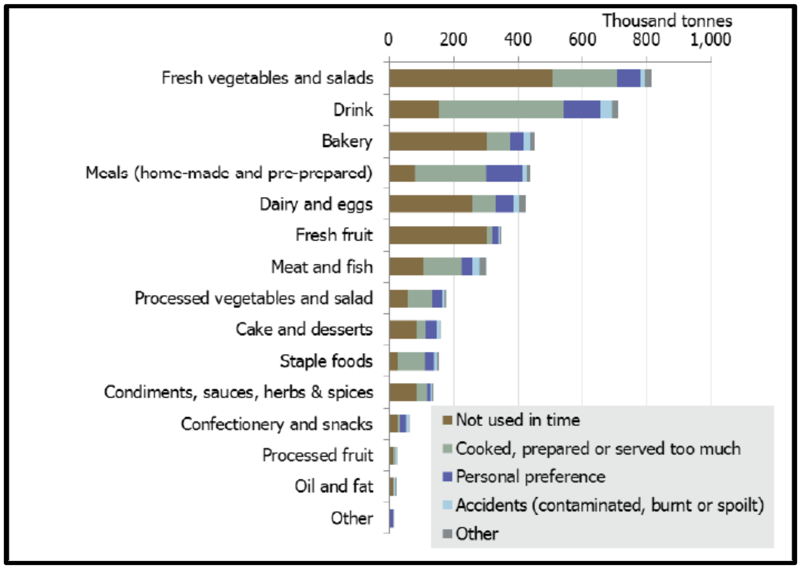


FIGURE 3: WEIGHT OF AVOIDABLE FOOD AND DRINK WASTE BY FOOD GROUP, SPLIT BY REASON FOR DISPOSAL.

Source: WRAP 2012 report which combines information from a number of studies including detailed waste compositional analysis from 1,800 households and kitchen diary records from 948 households.

✓ Spoilage is the primary reason for wasting fresh fruits, vegetables, salads, bakery dairy and eggs.

✓ Cooking or serving too much is the primary reason for wasting drinks, home-made meals, meat and fish.

Designing flexible packaging that extends shelf life is most important for this first group, while designing portion control packaging is most important for the second group.

Other recent consumer studies include:

- A study of 244 Romanian consumers[20] which included a web-based questionnaire investigating the role of food choices and food-related activities in producing food waste. Results show the consumers' planning and shopping routines predict their food waste, while their intentions not to waste food do not transfer into behavior. Final recommendations for policy makers and social marketers suggests that when trying to change people's food waste behavior one could either directly aim at changing consumers' routines or aim at changing their attitudes towards food waste. The latter route would make consumers feel more morally obliged and thus

20 Stefan, Violeta, et al. "Avoiding food waste by Romanian consumers: The importance of planning and shopping routines." Food Quality and Preference28.1 (2013): 375-381.

influence them to make changes in their planning and shopping routines (e.g., control their buying) that would result in lower food waste.

- A study of 380 Finnish households[21] which included both a questionnaire and food waste diary looked at socio-demographical, behavioral and attitudinal factors affecting food waste. The most common reasons leading to wastage was buying too much and/or managing food storage carelessly. Quite surprisingly very few factors investigated showed any statistically significant differences in the generation of food waste, and an interesting unexpected finding was that the amount of avoidable food waste was considerably higher in households where a woman was mainly responsible for grocery shopping. The authors speculate that women could be more likely to feel a need to provide their family with healthy food and buy more fresh products.

- A study of 61 Swedish households[22] which included both a questionnaire and food waste diary. Results quantified that 20-25% of food waste could be related to packaging, about 42-44% was related to spoilage and about 25% was related to the household preparing too much food. The study gave participants eight options in their diary to record the reason for wasting un-prepared food in storage:

  a. Bought too much
  b. Too large package
  c. Difficult to empty completely
  d. Bought the wrong thing
  e. Accident
  f. Passed best before date
  g. Bad/broken package
  h. Food has gone bad (rotten, sour, moldy, etc.)

  The study recommends that in future studies it may be useful to pose many more packaging related questions from the start in the diary to make it easier for the respondents to perceive more of the packaging related issues.

4.2.3 How people feel about food waste

One of WRAP's original pieces of research[23] looked at what the motivations and triggers are that could encourage a reduction in food waste.

Among those who <u>are not</u> bothered by food waste, their four main reasons were: not throwing enough food away to be bothered by it, not considering food waste to be a problem, thinking it is unavoidable, or being risk averse to food poisoning. Young families are far more likely to cite the latter.

21 Koivupuro, Heta-Kaisa, et al. "Influence of socio-demographical, behavioural and attitudinal factors on the amount of avoidable food waste generated in Finnish households." International Journal of Consumer Studies 36.2 (2012): 183-191.
22 Williams, Helén, et al. "Reasons for household food waste with special attention to packaging." Journal of Cleaner Production 24 (2012): 141-148.
23 Food Behaviour Consumer Research: Quantiative Phase, WRAP (2007).

Among those who <u>are</u> bothered by food waste, their three main reasons for concern where: a waste of money, a sense of wasting "good food" and a general sense of guilt.

These factors, and their importance relative to each other, are remarkably stable across the population as a whole.

This research also found that the environmental impact of food waste was likely not (results inconclusive) a trigger for behavior change. The environment is a much weaker, and secondary, concern. Consumers have so far failed to make any connection between food waste and environmental impact.

As this study is now seven years old, consumers may be starting to connect food waste to environmental impacts, particularly the natural resources (land and water) needlessly consumed at the beginning of life, the cradle. The EPA's Food Recovery Challenge[24] is now promoting the environmental benefits of reducing food waste and the Natural Resources Defense Council released an issue paper in 2012 titled "Wasted: how America is losing up to 40 percent of its food from farm to fork to landfill".

- A more recent study[25] conducted by psychology professors in the U.K., identified conflicting personal goals which may be hindering existing food waste reduction attempts. This paper reports on a qualitative study of the thoughts, feelings and experiences of 15 UK household food purchasers, based on semi-structured interviews. Most consumer research to date has involved people being given closed-ended questions followed by a series of possible responses (such as those used by the Swedish study detail in section 4.2.2). Participants of this study were given an opportunity to voice their own views. This study involved 45 minute interviews with pre-prepared questions that were used only as a guide to elicit further discussion.

  Two core categories of motives to minimize household food waste were identified:

  a. waste concerns and
  b. doing the 'right' thing.

  A third core category illustrated the importance of food management skills in empowering people to keep household food waste to a minimum. Four core categories of barriers to minimizing food waste were also identified:

  a. a 'good' provider identity;
  b. minimizing inconvenience;
  c. lack of priority; and
  d. exemption from responsibility.

  The wish to avoid experiencing negative emotions (such as guilt, frustration, annoyance, embarrassment or regret) underpinned both the motivations and the barriers to minimizing food waste. The study recommends

24 http://www.epa.gov/foodrecoverychallenge
25 EGraham-Rowe, Ella, Donna C. Jessop, and Paul Sparks. "Identifying motivations and barriers to minimising household food waste." Resources, Conservation and Recycling 84 (2014): 15-23.

that if household food waste reduction initiatives are to be successful they will need to be informed by people's motivations and barriers to minimizing household food waste.

- A study by the Fabian Society[26] with 40 participants using focus groups in a range of locations in the UK evaluated the extent to which the issues of food waste could be seen in terms of fairness, citizenship and stewardship over scarce resources. Results show that since most people do not consider themselves high food wasters, appeals to reduce food waste to save money will be limited in their efficacy.

4.2.4 FOOD WASTE VERSUS FOOD PACKAGING

A study published by WRAP in 2012[27] looked specifically at food waste and food packaging to investigate if, as other studies have suggested, attitudes towards packaging might be a barrier to further reducing the amount of food thrown away. This research confirmed that a priority for consumers is how long food stays fresh. Key insights from this new research, combined with previous research, show that currently consumers are not making best use of the information on pack, or the packaging itself, nor are they aware of the benefits packaging can offer to maximize in-home shelf-life.

There is a clear interest in packaging that can maintain food freshness, both before and after opening, and clearer on-pack messages about how to store food. All key findings and recommendations from this report are listed in Appendix 2.

Several relevant points for FPA from this report are:

- ✓ Many consumers do not recognize that packaging protects food in the home which in turn leads many consumers to adopt unpacking strategies that potentially decrease the longevity of products (i.e. taking products out of their packaging or piercing the packaging to 'let it breathe'). This finding is also important because, among the minority of consumers who do recognize that packaging can keep products fresher for longer, attitudes about packaging are significantly less negative.
- ✓ Concern about packaging reduces in response to more information. There is evidence of 'shifting' in consumer attitudes when they are shown a series of positive and factually correct, statements about packaging. Two messages were particularly effective: 'Packaging allows food to stay fresher for longer – not just on shelves but in your home as well' and 'The vast majority of packaging can be recycled (85%) so the impact is less than you think'.
- ✓ Concern about food waste increases in response to more information. And in comparison to the similar question around packaging, a clear difference emerged: on average, concern for both the issue of food waste and packaging started around the 72 out of 100 mark, after seeing a series of factually correct statements, concern for food waste had risen to around 80 whilst concern over packaging had fallen to around 58 out of 100.
- ✓ Two sub-groups, in particular, show highly significant variation throughout:

  Age: older consumers are more likely to think that packaging is a serious environmental problem and prioritize its perceived problems and disadvantages over any positives (in particular, they are most likely

26 Doron, N. "Waste not, want not: How fairness concerns can shift attitudes to food waste." Fabian Society (2012).
27 Consumer attitudes to food waste and food packaging, WRAP (2013).

to think that storing food in the original packaging causes it to sweat and spoil quicker). Younger consumers, by contrast, are more ambivalent and more likely to recognize the benefits of packaging - in particular, its role in keeping products fresher for longer.

Environmental disposition: consumers who define themselves as 'very' environmentally friendly are more likely to consider packaging to be a major environmental problem. However, they are also receptive to positive messages about packaging and more likely to acknowledge the progress that retailers and brands have made. They are also more likely to recognize food waste as a concern.

- ✓ One of the final recommendations suggests that food and packaging organizations (retailers, food and packaging manufacturers and trade associations) should consider whether they can do more to inform consumers about the innovations they are making around food labelling and packaging, to raise awareness of the benefits and encourage consumers to make use of these, and encourage/undertake further innovation.

4.3 Shelf Life Extension

In nearly every major report identified in the previous FPS study, "The Role of Flexible Packaging in Reducing Food Waste", portion control and re-sealable packaging is cited as a solution for food waste. However our literature search found no scientific data documenting the food saved by either of these two attributes. Rather, there is a great deal of scientific literature documenting the extension of shelf life achieved with packaging systems such as modified atmosphere packaging (MAP), vacuum and active packaging.

In the next sections MAP, vacuum and active packaging are explained and then details of how they are used to extend the shelf life of fruits and vegetables and meats are given. Sections 4.4.3 and 4.5.7 provided a list of documented shelf life extension studies. Abstracts on each of these studies are provided in Appendix 6. Appendix 6 also contains several cheese studies not discussed in the sections below.

4.3.1 Modified Atmosphere Packaging (MAP)

The principle of MAP is the replacement of air in the package with different fixed gas mixtures and the use of flexible films to control the dispersion of gas into and out of the package. Oxygen (O_2), nitrogen (N_2) and carbon dioxide (CO_2) are the three main gases used. These gases are applied individually or in combination to alter the atmosphere surrounding the food. Modified atmospheric packaged foods have become increasingly more available, as food manufacturers have attempted to meet consumer demands for fresh, refrigerated foods with extended shelf life and no preservatives.

The successful commercialization of MAP in the late 1970s was preceded by over 150 years of scientific research on the inhibitory effects of CO_2 on microbial growth, as well as the effect of gaseous atmospheres on respiring produce.[28] Flexible plastic packaging materials comprise nearly 90% of the materials used in MAP.[29] These materials provide a range of permeability to gases and water vapor and the strength needed for MAP. Every type of food has an ideal atmospheric condition for preserving its freshness and the goal of MAP is to alter the normal gas

28 Robertson, Gordon L. (2012). Food Packaging: Principles and Practice, Third Edition (Page 431).
29 Mangaraj, S., T. K. Goswami, and P. V. Mahajan. "Applications of plastic films for modified atmosphere packaging of fruits and vegetables: a review." Food Engineering Reviews 1.2 (2009): 133-158.

concentration of air from about 20% oxygen and 80% nitrogen to an ideal atmosphere that delays the decay of the food product.

4.3.1.1 Passive MAP

In this approach an atmosphere high in CO_2 and low in O_2 passively evolves within a sealed package over time as a result of the respiration of the product and the gas permeability of the packaging film. Ideally sufficient O_2 can enter the package to avoid anoxic conditions and the occurrence of anaerobic respiration, while at the same time excess CO_2 can diffuse from the package to avoid injuriously high levels. Passive MAP is commonly used for fresh respiring fruits and vegetables.

4.3.1.2 Active MAP

In this approach, the atmosphere within a sealed package is actively altered to contain a desired gas mixture. Active MAP is commonly used to extend the shelf life of fresh meats. Several methods can be used to modify the gas atmosphere inside a packaged product. These include:

- ✓ removing the air inside the package using a vacuum followed by flushing with the desired gas mixture,
- ✓ injecting a gas mixture into the package and flushing the air out immediately prior to sealing.

Regardless of whether vacuum or gas flush packaging is used to create an MAP, the package itself must provide a barrier to permeation over the expected shelf life; otherwise the beneficial effects of reducing O_2 will be lost.

4.3.2 Vacuum Packaging

With vacuum packaging a tough high barrier film is used to create a package from which air is completely removed. Vacuum packing prevents growth of aerobic spoilage organisms, shrinkage, and oxidation. Vacuum packaging is often considered to be a form of MAP since the removal of air from the environment itself is a modification of the atmosphere. It is commonly used to store dry foods over a long period of time, such as cereals, nuts, cured meats, cheese, smoked fish and coffee. On a more short term basis, vacuum packing is used to store chilled fresh foods, such as vegetables, meats, and liquids.

4.3.3 Active Packaging

Active packaging is a very dynamic field with continuous advancement and market growth. Between 2007 and 2012 the market grew 5.7% and is projected to expand 8% annually.[30] The technology is based on the concept of incorporating components into the packaging systems that release or absorb substances so as to prolong shelf life, sustain quality, safety and sensory characteristics of food. Moisture absorbers, oxygen scavengers, carbon dioxide generators/absorbers, ethylene absorbers, antimicrobial agents, and ethanol emitters, are all examples of active packaging components.

Traditionally these active ingredients have been incorporated into packaging in the form of a sachet or pad but the trend is to incorporate these components into the packaging material. This avoids negative perceptions of consumers caused by the presence of a non-edible artefact packaged with their food, and eliminates the risk of

30 Smart packaging on the rise, April 2014. www.adhesivemag.com

ingestion by accidental rupture of the sachets.[31] Furthermore, in close-fitting packages such as vacuum packs for cheese and meats where O_2 permeation is a prime cause of quality loss, sachets cannot be used. A more attractive alternative is the incorporation of oxygen absorbing materials into the plastics components of packages. Advances in nanotechnology will enable the development of better and new active packaging.[32]

4.4 Fruits and Vegetables

Consumption of fresh fruits and vegetables is growing as consumers seek foods high in nutritional value and free of preservatives or chemicals. Keeping produce "fresh" after harvest is challenging since fruits and vegetables contain large amounts of water and are alive and therefore breathing oxygen, and respiring carbon dioxide. Water loss leads to skin wrinkling, loss of crunchiness and crispiness, wilting and undesirable color changes. Most fruits and vegetables lose their freshness when the water loss is 3%–10% of their initial weight. The shelf life of fruits and vegetables can be extended by slowing down respiration and minimizing water loss.

The respiration rate of a vegetable (Table 1) is a good guide to its storage life: the higher the rate, the shorter the life. Fruits are a bit more complicated as some fruits, called climacteric, increase respiration when they are ripening and produce ethylene (C_2H_4, a natural plant hormone).

TABLE 1: RELATIVE RESPIRATION RATES OF SELECTED COMMODITIES

Respiration Rate	Commodity
Very low	Dates, dried fruits, nuts
Low	Apples, citrus fruit, garlic, grapes, kiwifruit, onions, potatoes (mature), sweet potatoes
Moderate	Apricots, bananas, cabbage, carrots, cherries, fogs, lettuce, mangoes, nectarines, peaches, pears, peppers, plums, potatoes (immature), tomatoes
High	Avocados, blackberries, cauliflower, lima beans, raspberries, strawberries
Very high	Artichokes, Brussels sprouts, cut flower, green onions, snap beans
Extremely high	Asparagus, broccoli, mushroom, peas, spinach, sweet corn

31 Realini, Carolina E., and Begonya Marcos. "Active and Intelligent Packaging Systems for a Modern Society." Meat science (2014).
32 Pereira de Abreu, D. A., J. M. Cruz, and P. Paseiro Losada. "Active and intelligent packaging for the food industry." Food Reviews International 28.2 (2012): 146-187.

TABLE 2: EXAMPLES OF CLIMACTERIC AND NON-CLIMACTERIC FRUITS

Climacteric fruit	Non-climacteric fruit
Apple	Blackberry
Apricot	Blueberry
Avocado	Cherry
Banana	Grape
Cantaloupe	Grapefruit
Fig	Lemon
Guava	Lime
Honeydew melon	Mandarin
Kiwifruit	Orange
Nectarine	Pineapple
Papaya	Pomegranate
Peach	Strawberry
Pear	
Tomato	
Watermelon	

Non-climacteric fruits (Table 2) ripen without a marked increase in respiration and ethylene production. Apples, bananas, melons, apricots, tomatoes (among others) are climacteric fruit. Citrus, grapes, strawberries are non-climacteric (they ripen without ethylene and respiration bursts). Generally, vegetables do not show a sudden increase in metabolic activity that parallels the onset of ripening, unless sprouting and regrowth is initiated.

Thirty four percent of fresh vegetables and thirty seven percent of fresh fruits are lost at the retail and consumer level (see Appendix 4).

4.4.1 Modified Atmosphere Packaging (MAP) of fresh fruits and vegetables

Modified atmosphere packaging of fresh produce relies on the passive modification of atmosphere inside the package and is achieved by the natural interplay between two processes: the respiration rates of the commodity and the permeability of the packaging films. Equilibrium between the respiring rate of the produce and the permeability rate of the film must be created. Proper MAP will restrict the rate of water loss to control the relative humidity around the produce, and decrease the respiration rate of the produce, slowing ripening rates in fruit and the activity of decay-causing organism's to further extending shelf life.

The flexible packaging industry has become increasingly responsive to the specific gas requirements of fresh produce and is now providing films specifically designed for given produce items. Films for low, medium and high respiration rate commodities are now available. This has allowed fresh-cut processors to begin providing a much greater diversity of products, which now includes artichoke hearts, baby salad greens, sliced strawberries and many others.[33]

33 Mangaraj, S., T. K. Goswami, and P. V. Mahajan. "Applications of plastic films for modified atmosphere packaging of fruits and vegetables: a review." Food Engineering Reviews 1.2 (2009): 133-158.

4.4.2 Active Packaging of fresh fruits and vegetables

Ethylene absorbing films are starting to be incorporated into packaging films. Ethylene (C_2H_4) is a natural plant hormone and plays a central role in the initiation of ripening and can have both positive and negative effects on fresh produce. Ethylene production is reduced by about half at O_2 levels of around 2.5%. [34] This low O_2 retards produce ripening by inhibiting both the production and action of C_2H_4.

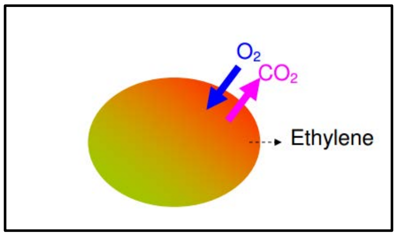


FIGURE 4: RESPIRATION AND RIPENING OF FRUITS AND VEGETABLES.
Source: Guide Packaging Fresh fruit and vegetables, Danish Technology Institute (2008).

- ✓ Positive effects include catalyzing the ripening process.
- ✓ Negative effects include increasing the respiration rate (which leads to softening of fruit tissue and accelerated senescence). [35]

4.4.3 Shelf-life extension examples from scientific literature review

The following studies all have documented shelf life extension numbers for various fresh fruit and vegetable flexible packaging systems. Interesting to note, many studies discuss water loss or microbial decay, but including sensory information is fairly rare. Typically sensory evaluation involves a panel of trained evaluators and the use of a Sensory Acceptability Limit score (SAL). Additional details of these studies are provided in Appendix 6.

- Bell pepper shelf life extended from 4 days to 20 days with modified atmosphere packaging (MAP) using perforated polypropylene films.
- Mango shelf life extended to 40 days from 20 days with non-perforated ethylene-absorbing highly gas-permeable film.
- Broccoli florets shelf life increased to 20 days with micro-perforated OPP bags from 6 days for broccoli wrapped in PVC.
- Zucchini slices packed in OPP bag extended shelf life to 4-5 days from 1-2 days when unpackaged.
- Green beans shelf life increased from 7 to 19 days if packaged in non-perforated 25 micron PE film.
- Banana shelf life extended to 36 days with perforated HDPE and LDPE. Unpackaged last 15 days.
- Table grape shelf life is extended with passive MAP bags made with 20, 40 and 80 micron OPP film, and can reach 70 days with the thick 80 micron OPP film.
- Cherries shelf life extended packaged from 14 days to 28 days and weight loss reduced from 24% to less than 1% with passive MAP compared to unpackaged.
- Pear shelf life extended to 15 days with non-perforated .025mm PP bags from 7-10 days at room temperature without packaging.

34 Sandhya. "Modified atmosphere packaging of fresh produce: current status and future needs." LWT-Food Science and Technology 43.3 (2010): 381-392.
35 Robertson, Gordon L. (2012). Food Packaging: Principles and Practice, Third Edition (Page 408).

4.5 MEAT & POULTRY[36]

Extending the shelf life of meats is very different than fruits and vegetables. Rather than water and respiration playing the primary role in spoilage, lipid oxidation and bacterial growth plays the critical role. In terms of nutrition the lipids are providing essential fatty acids, fat soluble vitamins, omega-3 fatty acids, and linoleic acid. While nutritionally beneficial, the oxidation of lipids gives rise to rancid odors and flavors, texture changes and nutritional losses.[37] Oxygen is also the essential gas used metabolically by aerobic spoilage bacteria and pathogens, a key food safety concern. So with meats, chilling and limiting oxygen are the key components to extending shelf life.

Twenty seven percent of beef, twenty two percent of poultry and thirty nine percent of fish are lost at the retail and consumer level (see Appendix 4).

4.5.1 RED MEAT

In the packaging of red meat appearance greatly influences consumer decision on whether or not to purchase. Bright red colors are preferred. Unfortunately oxygen creates the red color that consumers associate with good eating quality; the same gas that oxidizes lipids and feeds aerobic spoilage organisms.

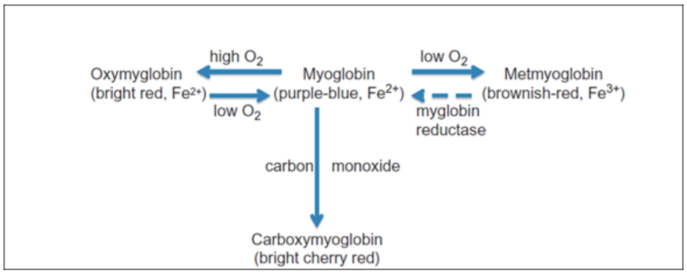


FIGURE 5: EFFECTS OF OXYGEN ON THE COLOR OF RED MEAT.

- ✓ There is little correlation between bright red meat and good eating quality, but the color of red meat is the dominant factor underlying retail meat marketing.
- ✓ Consumer will usually relate color loss to bacterial growth* although a loss of this bright red color, known as "bloom" in the industry, is affected by many factors.

Myoglobin is the protein that is responsible for meat color. In its normal state it is purple blue, but in the presence of high oxygen, it is bright red, in low oxygen it is brownish-red. The color of fresh meat (Figure 5) depends chiefly on the relative amounts of the three color derivatives of myoglobin present at the surface of the meat: myoglobin, oxymyglobin and metmyoglobin. Red meat color can move back and forth between these three states. However, if myoglobin is exposed to carbon monoxide it turns bright cherry red and this not reversible.

*Bacteria also cause meat to turn brown. This is attributed to the high oxygen demand of aerobic bacteria, which reduces the O2 tension at the meat surface and causes the formation of brown metmyoglobin.

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36 Much of this discussion on meat spoilage comes from: Robertson, Gordon L.. Food Packaging: Principles and Practice, Third Edition (2012).
37 Tian, Fang, Eric A. Decker, and Julie M. Goddard. "Controlling lipid oxidation of food by active packaging technologies." Food & function 4.5 (2013): 669-680.

4.5.2 Poultry

In the last decade, chicken-based meat products have become increasingly popular worldwide due to their high nutritional quality and low cost. The major factor limiting the shelf life of poultry is microbial spoilage. Raw poultry meat has a relatively high pH which readily supports the growth of microorganisms when stored under chill or ambient conditions. Depending on the degree of processing following slaughter, their spoilage varies between 4 and 10 days under refrigeration. [38] Poultry muscle generally has low concentrations of myoglobin and high rates of oxygen consumption, which means that very little oxymyglobin is formed when poultry muscle is exposed to air. Consumers do not associate a red color with freshness.

4.5.3 Fish

Fish and shellfish are highly perishable due to four issues:

1. A high pH which readily supports the growth of microorganisms. The chemical composition and microbial flora of seafood vary considerably between species, different fishing grounds and seasons, but the pH of most fish is greater than 6.0.
2. The presence of autolytic enzymes[39] which cause the rapid development of undesirable odors and flavors.
3. The presence of large amounts of non-protein nitrogen, including the compound trimethylamine oxide (TMAO). TMAO enables some spoilage bacteria to grow even when oxygen levels are depleted.
4. The large percent of unsaturated oils which gives fish oils their nutritional significance but also makes them very vulnerable to oxidation. The ready oxidation of fish oils adds rancid off-odors to the fishy odors, and the nutritional benefits of the omega-3 fatty acids are lost over time.

Fish vary greatly in their lipid content. Non-fatty fish, such as cod and haddock, have lipid contents of 1%–2% in contrast to fatty fish such as herring and mackerel which can have lipid contents of more than 30%.

4.5.4 Modified Atmosphere Packaging (MAP) of meats

In meat packaging the three principal gases used for active MAP are carbon dioxide (to inhibit bacteria and molds), nitrogen (to avoid oxidation of fats and pack collapse), and oxygen (to prevent anaerobic growth). As the red color of meat is an important criterion for its acceptability and marketability, oxygen is used in fresh beef packaging to maintain the red color. The majority of products are packed in a high oxygen environment (approximately 80% oxygen) in order to maintain bloom (the red color), with at least 20% carbon dioxide to prevent microbial growth.

However this high O_2 environment increases lipid oxidation (leading to flavor deterioration and off-odors) and a decrease in beef tenderness. An alternative to high oxygen is to include carbon monoxide (CO) in concentrations of 0.3 to 0.5% and high concentrations of carbon dioxide. CO binds strongly to myoglobin to form carboxymyoglobin (see figure 5) and results in a stable bright red muscle color that better satisfies consumers' color demands. Modified atmosphere packaging with low concentrations of CO (CO-MAP) and high concentrations of CO_2 meets the color demands of consumers and can improve the shelf-life of beef and pork.

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38 Patsias, A., et al. "Shelf-life of a chilled precooked chicken product stored in air and under modified atmospheres: microbiological, chemical, sensory attributes." Food microbiology 23.5 (2006): 423-429.

39 In biology, autolysis, more commonly known as self-digestion, refers to the destruction of a cell through the action of its own enzymes.

In 2004, the U.S. Food and Drug Administration approved the use of CO in consumer-ready fresh meat packaging. The use of low (0.4%) concentrations of CO in a packaging system is classified as a generally recognized as safe (GRAS) technology and currently is in commercial use in the United States.[40]

4.5.5 VACUUM PACKAGING OF MEATS

Vacuum packaging of meat was introduced into the United States in 1967 with the "boxed beef" concept. Prior to 1967, beef carcass shipments were shipped to retail outlets where carcasses were fabricated into retail items by individual stores. Now carcasses are broken down into primal and subprimal cuts, separated into boneless and bone-in cuts and then vacuum packaged in a bag for distribution and fabrication.

Vacuum packages for retail meat cuts are usually vacuum skin packaging (VSP) systems.[41] Meat is placed on a bottom web material (flexible or ridged) and a top web flexible material is heat shrunk to conform to the shape of the product. VSP packaging equipment removes atmospheric air or flushes the air from the package with gaseous mixtures of N_2 and CO_2 before sealing the film layers.

Retailers of consumer beef packaging have to balance the extended shelf life benefits of vacuum packaging with the detraction of the purple myoglobin color. Since the bright red oxymyglobin color is regained when meat is removed from VP packets and exposed to air a variation of VSP is for the lidding film to have outer barrier and inner air permeable layers. Before retail display, the outer barrier film layer is peeled away so that air can then contact the meat product and "bloom" into the preferred red color of oxymyglobin.

4.5.6 ACTIVE PACKAGING OF MEATS

Significant research is currently being conducted on antibacterial and antioxidant films. A great variety of antimicrobial agents including organic acids and their salts, sulfites, nitrites, antibiotics, alcohols, enzymes and natural components such as bacteriocins, especially nisin, have been incorporated into active films.[42] Active antioxidant films are being made with natural extracts of oregano and rosemary and research is focused on incorporating these natural antioxidants into biodegradable films.[43] These new technologies are still making their way into the market but show great promise for delivering safe minimally processed meats.[44]

4.5.7 SHELF-LIFE EXTENSION EXAMPLES FROM SCIENTIFIC LITERATURE REVIEW

The following studies all have documented shelf life extension numbers for various meats in flexible packaging systems. In the meat and poultry and dairy category the literature is a bit older for MAP and vacuum packaging as would be expected since meats have been packaged this way for a while with the move to centrally prepared distribution. Current research is primarily around active packaging which is still being brought to market.

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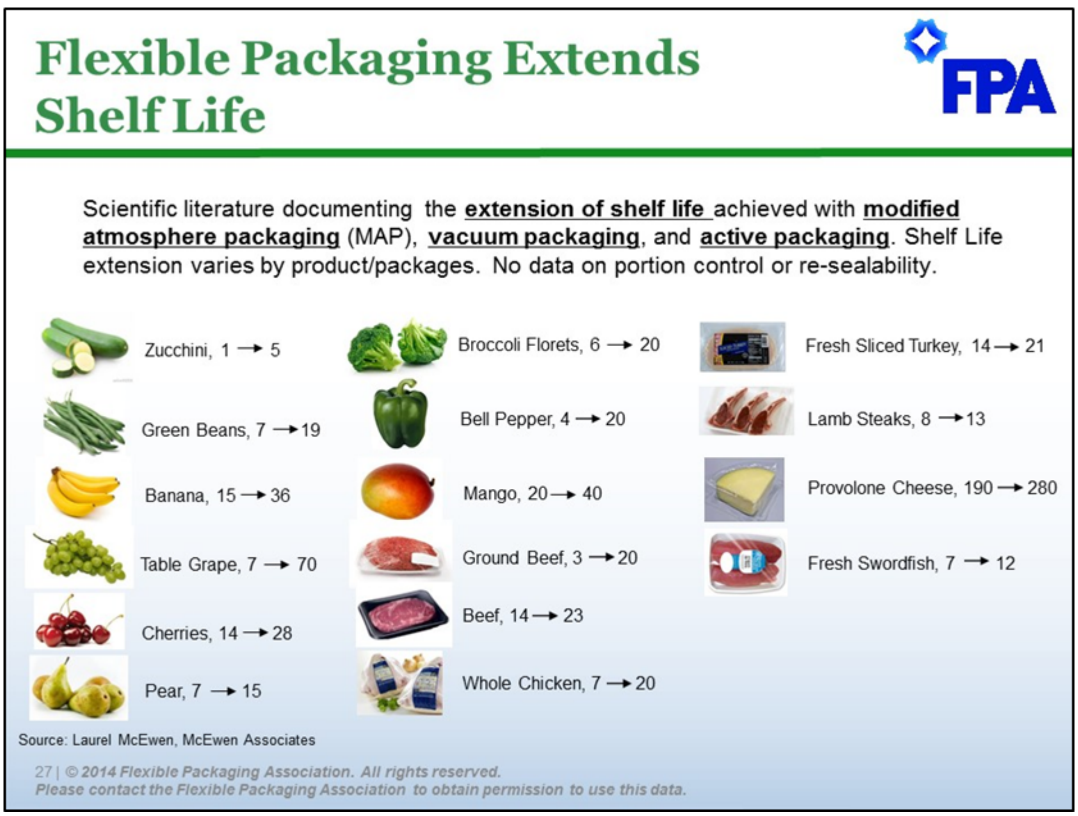
40 Grebitus, Carola, et al. "Fresh meat packaging: Consumer acceptance of modified atmosphere packaging including carbon monoxide." Journal of Food Protection 76.1 (2013): 99-107.
41 Zhou, G. H., X. L. Xu, and Yuan Liu. "Preservation technologies for fresh meat–A review." Meat science 86.1 (2010): 119-128.
42 Jofré, Anna, Teresa Aymerich, and Margarita Garriga. "Assessment of the effectiveness of antimicrobial packaging combined with high pressure to control Salmonella sp. in cooked ham." Food Control 19.6 (2008): 634-638.
43 Realini, Carolina E., and Begonya Marcos. "Active and Intelligent Packaging Systems for a Modern Society." Meat science (2014).
44 Arvanitoyannis, Ioannis S., and Alexandros Ch Stratakos. "Application of modified atmosphere packaging and active/smart technologies to red meat and poultry: a review." Food and Bioprocess Technology 5.5 (2012): 1423-1446.

- Ground Beef shelf life increased from 2-3 days in traditional overwrap Styrofoam trays to 11-12 with use of high oxygen MAP, to 29 days with use of carbon monoxide, and to 20 days with vacuum packaging.
- Beef shelf life extended from 14 to 23 days with use of MAP and antioxidant active film containing 1% oregano.
- Whole chicken shelf life increased from 7 to 20 days when packed in active MAP.
- Fresh chicken breast fillets packaged in active MAP extended shelf life 9-10 days.
- Fresh sliced turkey meat stored under modified atmosphere kept safely up to 14 days and kept 21 days under vacuum.
- Fresh sliced turkey packaged in carbon monoxide MAP lasts 25 days.
- Smoked turkey meat packaged in active MAP increases shelf life 5 days.
- Lamb steaks packaged packed in MAP with antioxidant oregano active film extends shelf life from 8 to 13 days.
- Ham slices protected for 12 days if accidently contaminated during slicing with antimicrobial LDPE film.
- Retort packaging made with oxygen scavenger PP film extends shelf life of meatballs to 9 months.
- Fresh swordfish shelf life increased to 12 days with modified atmosphere packaging from 7 days with no packaging. Bluefin Tuna fillet shelf life extended to 18 days from 2 days with use of modified atmosphere and active LDPE films embedded with a-tocopherol (vitamin E, antioxidant).



1. **Bell pepper shelf life extended from 4 days to 20 days with modified atmosphere packaging (MAP) using polypropylene films.**

The effect of packaging materials [low density polyethylene (LDPE), polypropylene (PP)] and storage environment [modified atmospheric packaging (MAP)] on shelf life enhancement of bell pepper in terms of quality attributes such as physiological weight loss, ascorbic acid, texture, surface color and subjective quality analysis have been studied at ambient and refrigerated condition. Different packaging techniques used for the experiment were MAP with LDPE, MAP with PP, MAP in perforated LDPE films, MAP in perforated PP films, shrink packaging with bi-axially oriented PP (BOPP) film and vacuum packaging with PP film.

Among different packaging techniques and storage conditions, MAP with perforated PP film in refrigerated condition was found to be the best followed by vacuum pack with PP film in refrigerated condition and could be used to store for 20 days for bell pepper with maintenance of texture, color, ascorbic acid and marketability.

Fig. 11 Samples in control after 8 days

Fig. 9 Samples in PP film with hole after 20 days

Sahoo, Nihar R., et al. "A comparative study on the effect of packaging material and storage environment on shelf life of fresh bell-pepper." Journal of Food Measurement and Characterization (2013): 1-7.

2. **Broccoli florets shelf life increased to 20 days with micro-perforated OPP bags from 6 days for broccoli wrapped in PVC.**

The following films were tested: three oriented-polypropylene based films at three different thickness 20, 40 and 80 µm (OPP20, OPP40, OPP80, respectively), and five anti-fog polypropylene based films (PP, thickness 30 µm) with different micro-perforations: 50, 20, 12, 9 and 7 micro-holes (diameter 70 µm) by package. For the sake of clarity, the different micro-perforated films were referred to as MP-PP-50 (PP micro-perforated, 50 micro-holes), MP-PP-20 (PP micro-perforated, 20 micro-holes), MP-PP-12 (PP micro-perforated, 12 micro-holes), MP-PP-9 (PP micro-perforated, 9 micro-holes) and MP-PP-7 (PP micro-perforated, 7 micro-holes). The MP-PP-20 and MP-PP-7 films were the most effective films in controlling mass loss, wilting and sensory quality for a longer period. Shelf-life of fresh-cut broccoli packaged in the two micro-perforated films was higher (13.9 and 19.8 days, respectively) than control samples or samples packaged in the OPP20 film. Both controls became rapidly unacceptable (after about 6 and 9 days, respectively), because of yellowing and wilting.

Lucera, A., et al. "Fresh-cut broccoli florets shelf-life as affected by packaging film mass transport properties." Journal of food engineering 102.2 (2011): 122-129.

Note: these images from older study, similar results: Serrano, M., et al. "Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging."*Postharvest Biology and Technology* 39.1 (2006): 61-68.

3. **Zucchini slices packed in OPP bag extended shelf life to 4-5 days from 1-2 days when unpackaged.**

Zucchini squash is a highly perishable vegetable that deteriorates rapidly after slicing, due to firmness loss, browning and decay, its shelf life is limited to 1–2 days. Sliced zucchini were packaged in oriented polypropylene-based (OPP) bag (thickness 90 µm) and into a bio-polymeric film (COEX thickness 35 µm) under passive and active modified atmospheres (90% N2, 5% CO2, and 5% O2). Shelf life was extended to 4-5 days with the OPP bag under both passive and active modified atmospheres.

Lucera, A., et al. "Influence of different packaging systems on fresh-cut zucchini (Cucurbita pepo)." Innovative Food Science & Emerging Technologies 11.2 (2010): 361-368.

4. **Green beans shelf life increased from 7 to 19 days if packaged in non-perforated 25 micron PE film.**

Shelf life of fresh-cut green beans packaged in the no-perforated film (polyethylene, 25 lm) and in two micro-perforated films (polypropylene films with 7 and 4 micro-holes per package) was higher (19.2, 18.13 and 17.7 days, respectively) than that of the control (7.5 days) or samples packaged in the micro-perforated film with 12 micro-holes per package (16.5 days).

Lucera, Annalisa, Amalia Conte, and Matteo Alessandro Del Nobile. "Shelf life of fresh-cut green beans as affected by packaging systems." International Journal of Food Science & Technology 46.11 (2011): 2351-2357.

5. **Banana shelf life extended to 36 days with perforated HDPE and LDPE. Unpackaged last 15 days.***

Perforated high density polyethylene (HDPE) bags (0.0375 mm thick), perforated low density polyethylene (LDPE) bags (0.0375 mm thick), plastic crates lined with dried banana leaf, plastic crates lined with straw and plastic crates without lining (as a control) were used as packaging materials with three varieties of bananas. Banana remained marketable for 36 days in the high density polyethylene and low density polyethylene bags, and for 18 days in banana leaf and straw packaging treatments. Unpackaged fruits remained marketable for 15 days only. Fruits that were not packaged lost their weight by 24.0% whereas fruits packaged in banana leaf and straw became unmarketable with final weight loss of 19.8% and 20.9%, respectively. Packaged fruits remained well until 36th days of storage with final weight loss of only 8.2% and 9.20%, respectively.

*Note: This study is applicable to distribution phase, not consumer phase.

Hailu, M., T. Seyoum Workneh, and D. Belew. "Effect of packaging materials on shelf life and quality of banana cultivars (Musa spp.)." Journal of Food Science and Technology (2012): 1-17.

6. **Table grape shelf life is extended with passive MAP bags made with 20, 40 and 80 micron OPP film, and can reach 70 days with the thick 80 micron OPP film.***

The effects of passive and active modified atmosphere packaging conditions (MAP) on quality of packaged table grape were investigated. Three films made up of oriented polypropylene and characterized by a different thickness (20, 40 and 80 lm, respectively) were used to package the grape in air (passive MAP) and under three different initial headspace gas compositions (active MAP). As controls, grape samples were also stored without packaging. Results obtained highlight that all selected packaging films significantly prevent product decay, thus promoting a substantial shelf life prolongation, if compared to the unpackaged product. In particular, the best results were recorded with the thickest polymeric matrix sealed in air, which assured a shelf life more than 70 days. The active MAPs were not found significant for a shelf life prolongation.

*Note: We were unable to find a study that documented shelf life extension for grapes packaged in micro-perforated passive MAP.

Costa, C., et al. "Effects of passive and active modified atmosphere packaging conditions on ready-to-eat table grape." Journal of Food Engineering 102.2 (2011): 115-121.

7. **Cherries packaged in passive MAP reduced mass losses from 24% to less than 1% and extended shelf life from 14 days unpackaged to 28 days.***

"Napoleon" cherries (Prunus avium L. "Napoleon"), were packed in Polypropylene (PP) and polyvinyl chloride-polyethylene (PVC-PE) trays and then sealed with biaxially oriented polypropylene film (BOPP, 20 μm), cast polypropylene film (CPP, 35 μm), and polyethylene terephthalate polyethylene films (PET-PE 62.5 μm). Fruits were packed in air (~21% O2, 79% N2) and gas mixtures (5% O2, 5% CO2, 90% N2 [MAP2], and 5% O2; 10% CO2; and 85% N2 [MAP3]). Samples packaged with PP tray and BOPP film under 21% O2 79% N2 preserved their physical, chemical, and sensory quality better than other treatments.

*Note: We were unable to find a study that documented shelf life extension for cherries packaged in micro-perforated passive MAP.

Esturk, Okan, Zehra Ayhan, and Mehmet Ali Ustunel. "Modified atmosphere packaging of "Napoleon" cherry: effect of packaging material and storage time on physical, chemical, and sensory quality." Food and Bioprocess Technology 5.4 (2012): 1295-1304.

8. **Pear fruits have a very short shelf life of 7-10 days at room temperature without packaging. This can be extended to 15 days with non-perforated .025mm PP bags.**

Fruits were packed in low density polyethylene (LDPE, 0.025 mm), polypropylene (PP, 0.025 mm), linear low density polyethylene (LLDPE, 0.0125 mm) and high density polyethylene (HDPE, 0.025 mm) with or without perforation and stored at ambient condition (25±2 °C and 65.0±5% RH). Reduced rate of weight and decay losses was recorded in pear fruits packed in PP non-perforated (8.04%) as compared to other treatments. The maximum firmness (5.18 kgf) and minimum ascorbic acid loss (49.97%) were also recorded in PP non-perforated. Use of plastic packaging materials to extend shelf life of pear fruits may be considered as an economic and alternative method of fresh pear fruits storage at ambient condition. Plastic packaging materials have shown that besides reducing weight loss and decay in pear fruits, they also effectively retained firmness, color change and nutrient loss of fruits during storage. Out of four types of packaging films used, non-perforated PP (0.025 mm) packaging materials had more beneficial effect on shelf-life parameters of pear fruits, by maintaining the quality parameters close to those of fresh fruits.

Nath, A., et al. "Extension of shelf life of pear fruits using different packaging materials." Journal of food science and technology 49.5 (2012): 556-563.

9. **Mango shelf life extended to 40 days from 20 days with non-perforated ethylene-absorbing highly gas-permeable film.**

The films used in this study were the following: (1) non-perforated highly gas-permeable film (HNP); (2) non-perforated highly gas-permeable film with ethylene-absorbing characteristics (HNPE); (3) micro-perforated highly gas-permeable film (HMP); and (4) common low-density polyethylene film (LNP). Mangoes without packaging films were used as the control (C). The highly gas-permeable films were designed to have the oxygen and carbon dioxide permeability coefficients in the same range by controlling microstructures or morphologies and compositions of the films. The shelf life of mangoes was extended to 40 days with HNPE, 35 days with HNP, and 30 days with HMP, as compared with 20 days with control and 5 days with LNP. Extended shelf life of mangoes of 35–40 days would allow exporters to ship the fruits under a controlled temperature via sea freight with substantially reduced cost as compared with air freight. This study suggests that packaging and distribution technologies could help increase opportunities to achieve high-quality fresh fruits and vegetables in the international markets from worldwide producers.

Figure 4. Different causes of mango quality loss (from left to right: shrinkage, anthracnose and stem-end rot) in various packaging systems stored at 12°C.

Boonruang, Kanchana, et al. "Comparison of various packaging films for mango export." Packaging Technology and Science 25.2 (2012): 107-118.

10. Beef shelf life extended from 14 to 23 days with use of MAP and antioxidant active film containing 1% oregano.

Fresh beef steaks were placed into a polystyrene tray and covered with an active polypropylene film containing various concentrations (0.5, 1, 2 and 4%) of an oregano extract. Control samples were packaged without the active film. Packages were filled with a 80% O_2/20%CO_2 atmosphere and displayed under illumination (14 h) at 1±1 °C for 28 days. The display life of beef samples demonstrated that at least 1% oregano was needed for obtaining a significant increase of display life from 14 to 23 days.

Camo, Javier, et al. "Display life of beef packaged with an antioxidant active film as a function of the concentration of oregano extract." Meat science 88.1 (2011): 174-178.

11. Lamb steaks packaged packed in MAP with antioxidant oregano active film extends shelf life from 8 to 13 days.

Lamb steaks were placed on a polystyrene tray and packaged with active film containing a 4% oregano or rosemary extract. Trays were filled with a gas mixture of 70% O_2 + 20% CO_2 + 10% N_2 and sealed with a polyethylene and polyamide laminate film of water vapor permeability 5–7 g/m2/24 h at 23 °C and oxygen permeability 40–50 mL/m2/24 h at 23 °C. The samples were stored under illumination (24 h) at 1 ± 1 °C. The use of a rosemary extract, a rosemary active film or an oregano active film resulted in enhanced oxidative stability of lamb steaks. Active films with oregano were significantly more efficient than those with rosemary, exerting an effect similar to that of direct addition of the rosemary extract; in fact, they extended fresh odor and color from 8 to 13 days compared to the control.

Camo, Javier, José Antonio Beltrán, and Pedro Roncalés. "Extension of the display life of lamb with an antioxidant active packaging." Meat Science 80.4 (2008): 1086-1091.

12. Fresh sliced turkey meat stored under modified atmosphere kept safely up to 14 days and kept 21 days under vacuum.

Fresh turkey meat was packaged in PET/PE pouches (62µm with oxygen transmission rate of 140-150 cc/sq m/24 h/1t) under aerobic vacuum and MAP (80% O_2 and 20% CO_2) and then stored at 4°C . Microbiological qualities of total viable count (TVC) and anaerobic counts along with physical qualities of pH, drip loss and sensory analysis were performed. The results indicated that the turkey meat packaged in MAP displayed desirable TVC, anaerobic count and drip loss, but low sensory scores after 14 days. Vacuum packaged turkey could be safely kept up to 21 days.

Rajkumar, R., et al. "Effect of modified atmosphere packaging on microbial and physical qualities of turkey meat." Am. J. Food Technol 2 (2007): 183-189.

13. Fresh sliced turkey packaged in carbon monoxide MAP lasts 25 days

Sliced meat samples were individually packaged using polypropylene and polyvinyl chloride film, and in 4 different modified atmospheres containing the following different gas mixtures: MAP 1, 50% N2 and 50% CO2; MAP 2, 0.5% CO, 50% CO2, and 49.5% N2; MAP 3, 0.5% CO, 80% CO2, and 19.5% N2; and MAP 4, 100% N2. All the samples were stored at 0 ± 1°C in the dark for 12 to 25 days (d). Meat samples packaged in aerobic packaging were analyzed for their microbial and physicochemical characteristics on d 0, 5, and 12 of storage, which was extended to 19 and 25 d when samples were under MAP. For meat packaged with MAP 3, the total mesophilic and psychrotrophic counts were significantly lower (P < 0.001) than those observed in condition MAP 1. The introduction of CO, added to a higher concentration of CO2, inhibited microbial flora in general, with particular action on Brochothrix thermosphacta. In terms of microbial quality, the shelf life of turkey meat under the MAP study conditions was longer than that of meat in aerobic packaging (5 d): 12 d for mixture MAP 4, 19 d for MAP 1 and MAP 2, and 25 d for MAP 3. Only MAP 4 without CO2 or CO prevented lipid oxidation of the meat. The presence of CO in anoxic gas mixtures with CO2 for turkey meat under MAP was useful, giving the bright pink color preferred by consumers without leading to the appearance of undercooked meat.

Fraqueza, M. J., and A. S. Barreto. "Gas mixtures approach to improve turkey meat shelf life under modified atmosphere packaging: The effect of carbon monoxide." Poultry science 90.9 (2011): 2076-2084.

14. Smoked turkey meat packaged in active MAP increases shelf life 5 days.

Sliced and smoked turkey fillets were packed in PET//LDPE/EVOH/LDPE (PET: polyethylene terephthalate, LDPE: low-density polyethylene and EVOH: ethylene vinyl alcohol) barrier pouches (200 g per pouch) having an oxygen permeability of 2.32 ml/m2 *day*atm at 23 1C. The samples were packaged in air (control), vacuum, skin and in two modified atmospheres (MA): MA1 (30% CO2/70% N2) and MA2 (50% CO2/50% N2). Shelf life for both MA's was approximately 27-30 days in comparison to 22-23 days for control.

Ntzimani, Athina G., et al. "Formation of biogenic amines and relation to microbial flora and sensory changes in smoked turkey breast fillets stored under various packaging conditions at 4 C." Food microbiology 25.3 (2008): 509-517.

15. Whole chicken shelf life increased from 7 to 20 days when packed in active MAP.

The effect of modified atmosphere packaging (MAP) (70% C02/30% N2; 30% C02/70% N2 on the shelf-life of fresh chicken carcasses stored at 2, 4, 7 and 9C was investigated. The best conditions for the prolongation of shelf-life were found to be the MAP of chicken carcasses under 70% C02/30% N2, with the best being stored at 2C, followed by those stored at 4, 7 and 9C. Under these MAP conditions, the shelf-life of chicken carcasses stored at 2 and 4C were 25 and 21 days, respectively, compared with 7 days at 4C for the air-packaged carcasses.

Sawaya, W. N., et al. "Influence of modified atmosphere packaging on shelf-life of chicken carcasses under refrigerated storage conditions." Journal of food safety 15.1 (1995): 35-51.

16. Fresh chicken breast fillets packaged in active MAP extended shelf life 9-10 days

Fresh chicken breasts fillets were placed in polyethylene/polyamide/low density polyethylene (LDPE/PA/LDPE) barrier pouches (one fillet per pouch), 75 µm in thickness, having an oxygen permeability of 52.2 cm3 m^{-2} day^{-1} atm^{-1} at 75% relative humidity (RH), 23 ^{o}C, a carbon dioxide permeability of 191 cm3 m^{-2} day^{-1} atm^{-1} at 0% RH, 23 ^{o}C

and a water vapor permeability of 2.4 g^{-} 2 day^{-} 1 at 100% RH, 23 ^{o}C. The following gas mixtures were used: M1, 30%/65%/5% (CO2/N2/O2) and M2, 65%/30%/5% (CO2/N2/O2). On the basis of microbiological data (TVC), shelf-life extensions of 2, 4 and 9–10 days were achieved by VP and M1 and M2 gas mixtures from .

Balamatsia, Christiana C., et al. "Possible role of volatile amines as quality-indicating metabolites in modified atmosphere-packaged chicken fillets: Correlation with microbiological and sensory attributes." Food chemistry 104.4 (2007): 1622-1628.

17. Cooked breaded chicken breasts shelf life extended 6 days with active MAP.

Precooked breaded chicken samples were placed in low-density polyethylene/polyamide/low-density polyethylene (LDPE/PA/LDPE) barrier pouches (1 fillet/pouch), 75 µm in thickness having an oxygen permeability of 52.2 ml/m2 day atm at 60% RH/25^{o}C and water vapour permeability of 2.4 g/m^{2} day at 100% RH/25^{o}C. The following gas mixtures were used: M1: 30%/70% (CO2/N2), M2: 60%/40% (CO2/N2) and M3: 90%/10% (CO2/N2). Samples were stored at 4 ^{o}C. The use of MAP as shown in the present study, resulted in an extension of shelf-life of precooked chicken by ca. 4 days (M1 gas mixture), and by more than 6 days (M2 and M3 gas mixtures), respectively. Precooked chicken meat was better preserved under M2 and M3 mixtures maintaining desirable odor/taste attributes even on final day of storage tested.

Patsias, A., et al. "Shelf-life of a chilled precooked chicken product stored in air and under modified atmospheres: microbiological, chemical, sensory attributes." Food microbiology 23.5 (2006): 423-429.

18. Ham slices protected for 12 days if accidently contaminated during slicing with antimicrobial LDPE film.

Antimicrobial LDPE film placed between ham slices inoculated with Staphylococcus aureus and Escherichia Coli reduced growth of these pathogens for 12 days demonstrating that antimicrobial films can be an important barrier against microbial contamination, contributing to food safety. Cured cooked meat products such as cooked ham are generally regarded as safe. However, recontamination with pathogenic microorganisms during post-processing may be the cause of outbreaks of foodborne diseases. Cooked ham is generally exposed to thermal treatment long enough to eliminate pathogens; however, to meet consumer demand for a convenient product, the ham undergoes a slicing process, during which the product can be contaminated if the hygienic conditions of the equipment are not adequate, therefore resulting in risk to the consumer.

Camilloto, Geany Peruch, et al. "Preservation of sliced ham through triclosan active film." Packaging Technology and Science 22.8 (2009): 471-477.

19. Ground Beef shelf life increased from 2-3 days in traditional overwrap Styrofoam trays to 11-12 with use of modified atmosphere and 20 days with vacuum packaging.

Shelf life of ground beef extended from 2-3 days with air permeable overwrap, to 11-12 in high O2 modified atmosphere packaging (MAP), 20 days with low O2, CO2 & N2, 28 days with low O2 and CO, and 45 with vacuum skin packaging.

McMillin, Kenneth W. "Where is MAP going? A review and future potential of modified atmosphere packaging for meat." Meat Science 80.1 (2008): 43-65.

20. **Retort packaging made with oxygen scavenger PP film extends shelf life of meatballs to 9 months**

Processed meatballs were packaged in a passive package without oxygen scavenger (control) and three different active packages having PP-based oxygen scavenger master batch materials (OSMB) of 40, 80 and 100% in the middle layer and stored at 23 and 30 ^{o}C for 9 months. The semi-ridged tray was designed as a multilayer structure, PP/adhesive/EVOH/adhesive/OSMB (oxygen scavenger)/PP. All lids were made of traditional cast films for retort process; PET/Nylon/EVOH/PP. The oxygen scavenger was iron based compounds ($Fe(OH)_2$). Quality changes of packaged products were evaluated by measuring the oxygen concentration of the headspace in the containers, thiobarbituric acid, color, and flavor. Flavor changes in all active packages was almost 50% lower than the control.

Shin, Yangjai, Joongmin Shin, and YounSuk Lee. "Effects of oxygen scavenging package on the quality changes of processed meatball product." Food Science and Biotechnology 18.1 (2009): 73-78

21. **Fresh swordfish shelf life increased to 12 days with modified atmosphere packaging from 7 days with no packaging.**

Swordfish steaks were packaged in three different atmospheres, including treatments: air (A), vacuum (VP) and MAP (M; 40% CO2, 30% N2, 30% O2). Steaks in lots A, VP and M were packaged in low-density polyethylene/polyamide/low-density polyethylene (LDPE/PA/LDPE) barrier pouches (one steak weighing approximately 150710 g/pouch) 75 mm in thickness having an oxygen permeability of 52.2 cm3/m2/d/atm at 75% relative humidity (RH), 25 1C and a water vapor permeability of 2.4 g/m2/d at 100% RH, 25 1C. The gas mixture of lot M was (40%/30%/30%; CO2/N2/O2). All samples were stored under refrigeration (4+/-.5 ^{o}C). Sensory analyses indicated a shelf-life of ca. 7 days for air, 9 days for VP and 11–12 days for the MA-packaged swordfish samples.

Pantazi, D., et al. "Shelf-life of chilled fresh Mediterranean swordfish (Xiphias gladius) stored under various packaging conditions: Microbiological, biochemical and sensory attributes." Food Microbiology 25.1 (2008): 136-143.

22. **Bluefin Tuna fillet shelf life extended to 18 days from 2 days with use of modified atmosphere and active LDPE films embedded with a-tocopherol (vitamin E, antioxidant).**

Packaging in a 100% N2 modified atmosphere is possible to extend product shelf-life from 2 days for control samples (air without film) up to 18 days at 3^{o} C. Moreover, the combined use of MAP and the active film resulted in a less oxidized product after 18 days of storage at 3 ^{o} C. Active packaging films were produced by embedding a-tocopherol into an unstabilized low density polyethylene (LDPE) matrix at a concentration of 0.5%. Results showed that (i) 100% N2 atmosphere has a protective effect on hemoglobin and lipid oxidation processes monitored, (ii) active film is able to reduce fat oxidation, (iii) the combined effect of MAP and active packaging can be considered a valuable tool to increase the shelf-life of raw fish products.

Torrieri, Elena, et al. "Effect of modified atmosphere and active packaging on the shelf-life of fresh bluefin tuna fillets." Journal of Food Engineering 105.3 (2011): 429-435.

23. **Provolone cheese packaged in an atmosphere of 30% CO2 and 70% N2 extends shelf life to 280 days, from 190 days when vacuum packaged.**

The aim of this work was to evaluate the shelf-life of portioned Provolone cheese packaged in protective atmosphere using four different CO2/N2 gas mixtures (10/90, 20/80, 30/70 and 100/0 vol/vol) and at 4 and 8 1C, in order to simulate, respectively, the most common domestic and retail storage conditions. Control samples were vacuum-packaged. Furthermore, the acquired data were utilized to predict the commercial shelf-life of the cheese. The gas mixture made up of 30% CO2 and 70% N2 guaranteed portioned Provolone cheese the best preservability, since it was able to slow the proteolytic and lipolytic phenomena typical of cheese ripening more than all other gas mixtures. Furthermore, this mixture lengthened Provolone cheese shelf-life by 50% in comparison with vacuum-packaging, bringing it to 280 days.

Favati, Fabio, Fernanda Galgano, and Anna Maria Pace. "Shelf-life evaluation of portioned Provolone cheese packaged in protective atmosphere." LWT-Food Science and Technology 40.3 (2007): 480-488.

24. Mozzarella cheese shelf life improved by 6 days with antibacterial cellulose films.

Antimicrobial films were formed by the incorporation of nisin (NI), natamycin (NA) and a combination of both (NI + NA) into cellulose polymer. Film efficacies were evaluated in vitro against Staphylococcus aureus ATCC 6538, Listeria monocytogenes ATCC 15313, Penicillium sp. and Geotrichum sp. The films were also evaluated on sliced mozzarella cheese against molds and yeasts, Staphylococcus sp. and psychrotrophic bacteria. Over 9 days of storage, the films containing NA and NI + NA showed inhibition of yeast and mold growth on sliced mozzarella cheese. These films improved the shelf life of the cheese by 6 days compared with the control. The film containing NA showed potential for application as active food packaging for sliced mozzarella cheese.

dos Santos Pires, Ana Clarissa, et al. "Development and evaluation of active packaging for sliced mozzarella preservation." Packaging Technology and Science 21.7 (2008): 375-383.

25. Oxygen absorbing laminate extends shelf life of cheese spread to 6 months at 100°F for military rations and delayed the decay of vitamin C.

Oxygen within the sealed package can reduce the quality of liquid-based food products with high oil content such as hot-filled meal-ready-to-eat (MRE) cheese spread, a component of military operational rations. The aim of this study was to test a novel oxygen absorber-containing laminate material and its ability to maintain and/or extend shelf life of a cheese-spread MRE item. An iron-based oxygen absorber (ABSO2RB) activated by moisture was incorporated into the laminate and used to pack hot-filled cheese spread MREs. ABSO2RB-laminates met the accelerated shelf-life requirement of 1 mo at 51.7 ◦C (125 ◦F), and 6mo at 37.8 ◦C (100 ◦F). This study clearly shows the benefits of using active packaging technology on retaining nutrition and prolonging shelf life of high-fat, liquid content MRE items.

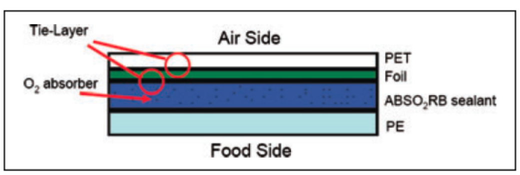


Figure 1 – Schematic of the laminate structure of the oxygen-absorbing packaging material.

The packaging structure consisted of 48 gauge PET/10 lbs per ream PE/0.35 mil-inch aluminum foil per 3 mil ABSO2RB sealant. The ABSO2RB sealant is a blend of low-density polyethylene (LDPE) and linear LLDPE (polyolefins) with an iron-based oxygen absorber that is water activated.

Gomes, Carmen, et al. "Effect of Oxygen-Absorbing Packaging on the Shelf Life of a Liquid-Based Component of Military Operational Rations." Journal of food science 74.4 (2009): E167-E176.

5 CONCLUSION

Modified atmosphere packaging of fresh fruits and vegetables and meats represents the best opportunity for FPA to communicate the benefits of flexible packaging. These food commodities represent a large portion of consumer food waste, have documented shelf life extension studies in scientific journals, and are part of a heathy diet: plus flexible packaging makes up 90% of the materials used. An emotional appealing video that hits on parents' desires to be good providers and do the right thing by not wasting could be developed. In this video the waste message should reference social and environmental stewardship not the wasted money as most people do not think they waste much in the first place. Infographics can be produced to explain the anatomy of an MAP; one a fruit & vegetable re-closeable perforated bag with a handle, and the other a ground beef package. These infographics should target consumer food companies, NGO's and consumers looking to learn more about the features of modified atmosphere packaging. Features that extend shelf life would be explained in these infographics. Sustainability metrics (natural resources conserved, money saved, and emissions avoided) could be added if this information becomes available. This information cannot currently be calculated, only hypothesized (see Appendix 7). FPA should look to support a consumer study that evaluates if less food is actually wasted when a consumer uses alternative packages. While popular opinion is that portion control, re-closability and shelf life extension reduce food wastes; we have no quantitative evidence that with a better designed package, consumer behavior will actually change. For all we know, consumers waste the same amount of food regardless of the package.

Preventing the environmental impacts of food waste should be a secondary message. Yes, we know that the food in the landfill is way worse than the plastic and the life cycle impacts of creating the packaging is way less than creating the food. Developing a positive educational message around flexible packaging will help people waste less.

6 APPENDIX 1: LITERATURE REVIEW REFERENCES

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7 Appendix 2: Supply Chain Food Loss

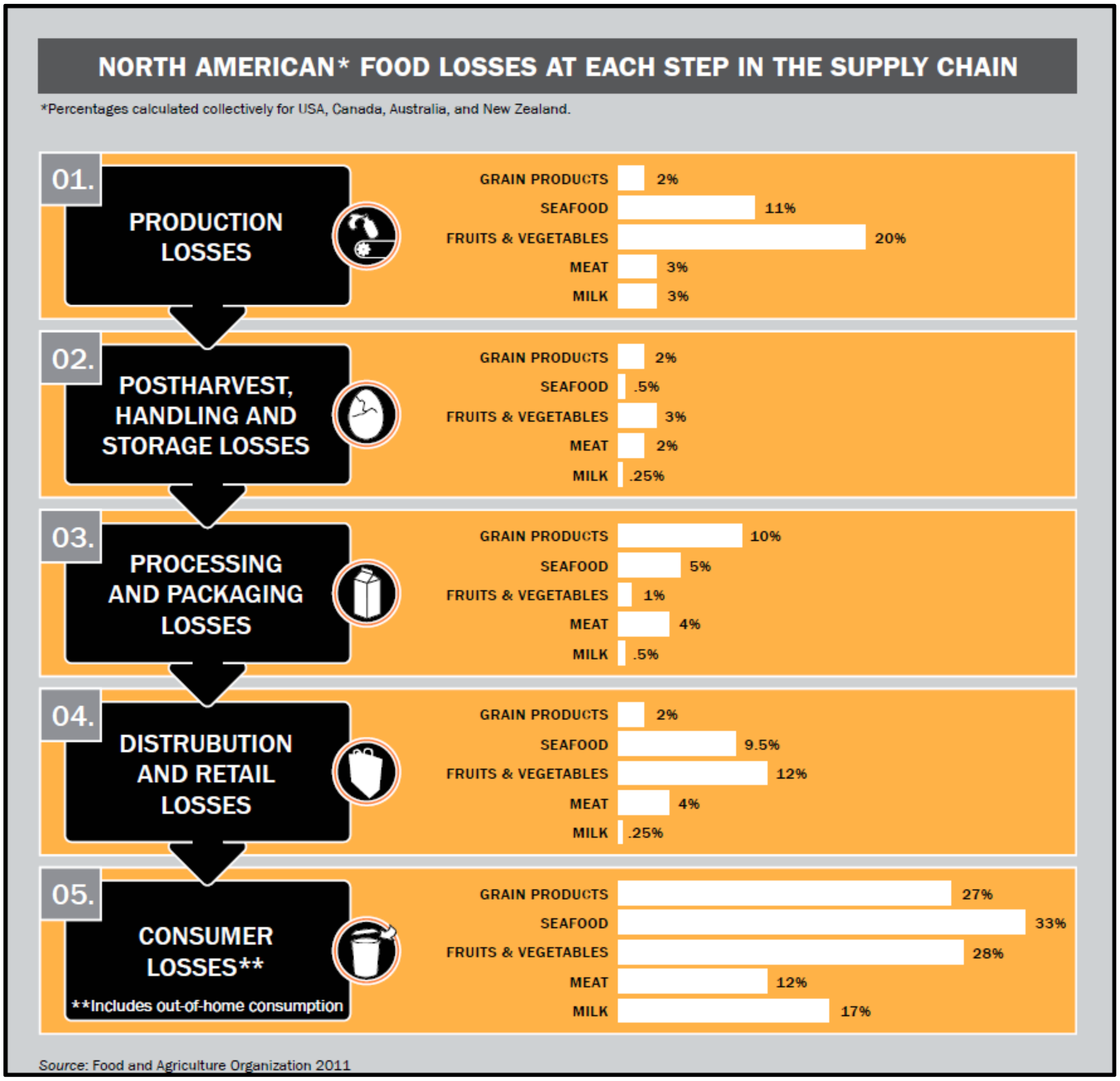

FIGURE 6: FOOD LOSSES AT EACH STEP IN THE SUPPLY CHAIN.

8 APPENDIX 3: MSW FIGURES, EPA

TABLE 3: MUNICIPLE SOLID WASTE (MSW) BY PRODUCT TYPE, 2012.

Table 2. Generation, Recovery, and Discards of Products in MSW, 2012*
(in millions of tons and percent of generation of each product)

Products	Weight Generated	Weight Recovered	Recovery as Percent of Generation	Weight Discarded
Durable goods				
Steel	14.57	3.94	27.0%	10.63
Aluminum	1.52	Not Available	Not Available	1.52
Other non-ferrous metals†	2.00	1.36	68.0%	0.64
Glass	2.19	Negligible	Negligible	2.19
Plastics	11.46	0.77	6.7%	10.69
Rubber and leather	6.52	1.35	20.7%	5.17
Wood	6.16	Negligible	Negligible	6.16
Textiles	3.88	0.55	14.2%	3.33
Other materials	1.73	1.30	75.6%	0.42
Total durable goods	**50.03**	**9.27**	**18.5%**	**40.76**
Nondurable goods				
Paper and paperboard	30.60	15.44	50.5%	15.16
Plastics	6.51	0.13	2.0%	6.38
Rubber and leather	1.01	Negligible	Negligible	1.01
Textiles	10.15	1.70	16.7%	8.45
Other materials	3.07	Negligible	Negligible	3.07
Total nondurable goods	**51.34**	**17.27**	**33.6%**	**34.07**
Containers and packaging				
Steel	2.23	1.61	72.2%	0.62
Aluminum	1.87	0.71	38.0%	1.16
Glass	9.38	3.20	34.1%	6.18
Paper and paperboard	38.01	28.92	76.1%	9.09
Plastics	13.78	1.90	13.8%	11.88
Wood	9.66	2.41	24.9%	7.25
Other materials	0.30	Negligible	Negligible	0.30
Total containers and packaging	**75.23**	**38.75**	**51.5%**	**36.48**
Other wastes				
Food, other‡	36.43	1.74	4.8%	34.69
Yard trimmings	33.96	19.59	57.7%	14.37
Miscellaneous inorganic wastes	3.90	Negligible	Negligible	3.90
Total other wastes	74.29	21.33	28.7%	52.96
Total municipal solid waste	**250.89**	**86.62**	**34.5%**	**164.27**

* Includes waste from residential, commercial, and institutional sources.
† Includes lead from lead-acid batteries.
‡ Includes recovery of other MSW organics for composting.
Details might not add to totals due to rounding.
Negligible = less than 5,000 tons or 0.05 percent.

9 Appendix 4: Estimated total retail and consumer level food losses by commodity, USDA

TABLE 4: ESTIMATED TOTAL FOOD LOSS IN THE UNITED STATES, RETAIL AND CONSUMER LEVEL.

Commodity	Food Supply[a]	Losses from food supply[b]					
		Retail level		Consumer level		Total retail and consumer level	
	Billion pounds	Billion pounds	Percent	Billion pounds	Percent	Billion pounds	Percent
Grain products	60.4	7.2	12	11.3	19	18.5	31
Fruit	64.3	6.0	9	12.5	19	18.4	29
Fresh	37.6	4.4	12	9.5	25	13.9	37
Processed	26.7	1.6	6	2.9	11	4.5	17
Vegetables	83.9	7.0	8	18.2	22	25.2	30
Fresh	53.5	5.2	10	12.8	24	18.0	34
Processed	30.4	1.8	6	5.3	18	7.1	24
Dairy products	83.0	9.3	11	16.2	20	25.4	31
Fluid milk	53.8	6.5	12	10.5	20	17.0	32
Other dairy products	29.1	2.8	10	5.7	19	8.5	29
Meat, poultry, and fish	58.4	2.7	5	12.7	22	15.3	26
Meat	31.6	1.4	4	7.2	23	8.6	27
Poultry	22.0	0.9	4	3.9	18	4.8	22
Fish and seafood	4.8	0.4	8	1.5	31	1.9	39
Eggs	9.8	0.7	7	2.1	21	2.8	28
Tree nuts and peanuts	3.5	0.2	6	0.3	9	0.5	15
Added sugar and sweeteners	40.8	4.5	11	12.3	30	16.7	41
Added fats and oils	26.0	5.4	21	4.5	17	9.9	38
Total	430.0	43.0	10	89.9	21	132.9	31

[a]Food supply at the retail level, which is the foundation for the retail- and consumer-level loss stages in the loss-adjusted data series.
[b]Totals may not add due to rounding.
Per capita losses at the retail and consumer levels for each commodity (not shown) were estimated by multiplying the quantity of that commodity available for consumption by the appropriate loss assumption. Individual loss estimates were then multiplied by the U.S. population and summed up into their respective food groups and retail or consumer levels.
Source: ERS (2012a) and the U.S. population on July 1, 2010 (309.75 million).

10 Appendix 5: Key Findings from 'Consumer Attitudes to Food Waste and Food Packaging,' WRAP

Many consumers do not recognize that packaging protects food in the home. While there is recognition that packaging is important to keep the product safe on its way to and in the store, there is less recognition that it plays a role at home. In fact, the prevailing view is the opposite, i.e. that keeping products in the packaging leads them to spoil more quickly. This in turn leads many consumers to adopt unpacking strategies that potentially decrease the longevity of products (i.e. taking products out of their packaging or piercing the packaging to 'let it breathe').

- These findings are consistent with previous WRAP research, both in terms of in-home behavior and the potential reduction in product life resulting from this. This finding is also important because, among the minority of consumers who do recognize that packaging can keep products fresher for longer, attitudes to packaging are significantly less negative.

Consumer confidence around storing food is high, but can be misplaced; the information on labels, and how they are used could both be more effective. The majority of consumers are confident in their way of storing food items with habits developed through trial and error or passed down from parents. However, a large proportion are actually storing items under less than ideal conditions, in terms of ensuring they last as long as possible.

There is a noticeable gap between the amount of consumers who've seen particular packaging innovations and the number who say it would be a good idea. Re-closable packs, packaging that makes the product last longer and split packs are three of the innovations that consumers rated as being most useful to them. Re-closable packs are highlighted as being relatively prevalent in shops currently, but there seems to be far fewer people who've noticed 'a lot' of packaging that keeps food fresher or split packs.

- 34% have noticed 'a lot' of re-closable packs in-store, but only 13% have seen packs that 'keep food fresh for longer' or 'split packs' (12%).

There is recognition that food retailers and manufacturers have made progress in recent years to reduce the amount of packaging. Even those who consider packaging to be a major environmental problem acknowledge progress.

Attitudes to packaging shift according to the context and the mind-set that consumers are in. In store, in a shopping context, packaging is a low order priority and plays a supporting and practical role in product choice (aspects of packaging, such as re-closability can be factors influencing choice). When framed in the wider context of food issues, only a small minority identify packaging as one of their top concerns.

- In store, quality, freshness and the look/smell of the product are the most important factors with around two in three (65%) mentioning them unprompted. This compares to 53% who cite price, value for money or special offers, and just 6% who cite pack size or how the food is packaged.
- When asked to choose between two cheese products – one with re-closable packaging and the other without - one in five (20%) of the consumers who chose the re-closable pack specifically cited the re-closable function as the main reason for their choice.
- In the wider context of concerns about food, 'how it is packaged' is a low order issue – cited by only 16% of consumers. In contrast, 'the price of food' (64%) is the most frequent response, followed by

‘how long fresh food lasts for’ (48%). Furthermore, twice as many consumers identify ‘food waste’ as a concern (33%) compared with packaging.

However, when prompted consumers’ attitudes to packaging are negative in the context of the environment. There is little doubt that once packaging is set within a framework of environmental concern, and this particular mind-set is triggered, then attitudes are negative.

- Close to four in five (81%) believe that it is a major environmental problem and 57% think it is wasteful and unnecessary.

Concern about packaging reduces in response to more information. There is evidence of ‘shifting’ in consumer attitudes when they are shown a series of positive, and factually correct, statements about packaging. However, when mixed in amongst an equal number of negative statements, attitudes to packaging changed little overall (shifting according to individual statements but with no overall net change).

- Consumers were shown five positive statements about packaging and asked to rate, on a scale of 0-100, how much of a problem they thought it was (with 0 = not a problem and 100 = a serious problem). From an average starting score of 73/100 (i.e. prior to seeing the messages) concern about packaging fell by 21% to a score of 58/100. Two messages were particularly effective: ‘Packaging allows food to stay fresher for longer – not just on shelves but in your home as well’ and ‘The vast majority of packaging can be recycled (85%) so the impact is less than you think’. A third message, ‘Without packaging many of the food products that we enjoy would only be available for a few months of the year – rather than all year round as they are now’, was particularly effective when it was the first message seen.

- However, when mixed in amongst an equal number of negative statements attitudes to packaging changed little overall. There were shifts in response to individual statements but the positive and negative statements largely cancelled each other out.

Concern about food waste increases in response to more information. The above style of question was also used with positive statements on food waste:

- Consumers were shown five positive (and factually correct) statements about food waste and asked to rate, on a scale of 0-100, how much of a problem they thought it was (with 0 = not a problem and 100 = a serious problem). From an average starting score of 71/100 (i.e. prior to seeing the messages) concern about food waste increased by 9% to a score of 80/100. Three messages were particularly effective: ‘In the UK we throw away enough food, from our homes, to fill Wembley Stadium to the brim nine times over – every year’; ‘Wasting food costs the average family £480 a year. For families with children the cost can be up to £690 a year’ and ‘Food waste gives off harmful gases like methane when it rots in landfill. Methane is 20x worse for the atmosphere than carbon dioxide’.

- In comparison to the similar question around packaging, a clear difference emerged: On average, concern for both the issue of food waste and packaging started around the 72 out of 100 mark After seeing a series of factually correct statements, concern for food waste had risen to around 80 whilst concern over packaging had fallen to around 58 out of 100.

Concern about packaging does not appear to be compromising action on food waste reduction. Unlike previous surveys that suggested packaging may be a far more pressing issue for consumers than food waste, this research finds that, when prompted, they consider both issues to be ‘equally problematic’ and do not have a fixed opinion as to which is 'worse'. However, consumers appear comfortable holding both views at the same time, and those most concerned about packaging are indeed also those most concerned about food waste.

- 70% of consumers think that food waste is bad for the environment (rising to 76% of consumers when the phrase 'wasting food' is used instead of 'food waste').

- When asked whether food waste or packaging is worse for the environment, consumers tend to agree with whichever of the two is presented first. For instance, 44% agree that 'food waste is a bigger environmental problem than packaging'. When the statement is reversed, 50% agree that packaging is worse than food waste. However, a significant proportion of consumers are uncertain and opt for 'I think they're both about the same'.

- Only a small, but significant, minority (14%) say they will 'do no more to reduce their food waste until more is done by manufacturers / supermarkets to reduce packaging'.

Attitudes to packaging are linked to the ability to recycle. There is a strong correlation between concerns about packaging materials and how easy it is to recycle them at home. The more difficult it is to recycle an item the more concern is expressed about it.

- Levels of consumer concern about different packaging materials are linked to how easily they can recycle them. For example, plastic pots, trays and tubs are a concern for almost half (49%) of consumers who say they cannot easily recycle these, compared to 26% of consumers who say they can recycle them easily.

- When asked what changes in packaging consumers would find most useful, 'recyclable – i.e. can be recycled' was quoted as the second (equal with packaging that helps the product last longer) highest.

Two sub-groups, in particular, show highly significant variation throughout:

- **Age**: older consumers are more likely to think that packaging is a serious environmental problem and prioritise its perceived problems and disadvantages over any positives (in particular, they are most likely to think that storing food in the original packaging causes it to sweat and spoil quicker). Younger consumers, by contrast, are more ambivalent and more likely to recognise the benefits of packaging - in particular, its role in keeping products fresher for longer.

- **Environmental disposition:** consumers who define themselves as 'very' environmentally friendly are more likely to consider packaging to be a major environmental problem. However, they are also receptive to positive messages about packaging and more likely to acknowledge the progress that retailers and brands have made. They are also more likely to recognise food waste as a concern.

Having been presented with the research, the steering group has identified several opportunities to help reduce food waste and also address concerns around packaging, for example:

- As consumers we can all make more use of the information provided on packaging, particularly as much of this is being updated, and the packaging itself, to ensure that the way we store food at home keeps it fresher for longer.

- Food and packaging organizations (retailers, food and packaging manufacturers and trade associations) should consider whether they can do more to inform consumers about the innovations they are making around food labelling and packaging, to raise awareness of the benefits and encourage consumers to make use of these, and encourage / undertake further innovation.

- Consumer campaigns, such as Love Food Hate Waste (www.lovefoodhatewaste.com), and other communications activities around food and food waste can do more to raise awareness of the benefits of reducing food waste, and the role that packaging can play in that. They can inform consumers about the innovations businesses are making around food labelling and food packaging, and give advice about, for example, buying the right pack size and looking more closely at labels. They could also offer updated guidance around the best way to buy food with the appropriate packaging to keep it fresher for longer, for example if it will be eaten straight away buying loose, if you want to keep it for longer buying packaged.

- Continued innovation in packaging recyclability along with increased provision of recycling services, and clear communication on how to use them, has the potential to reduce concerns around packaging, helping consumers deal with packaging at the end of its life.

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