Packaging for Plant-based diets- Exploring the requirements of future packaging materials

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2021

MASTER THESIS

Packaging for Plant-based protein diets - Exploring the requirements from the consumer and industry perspective

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UNIVERSITY

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Published by
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Subject: Food Packaging Design (MTTM01)
Division: Packaging Logistics
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Abstract

The sustainable production and consumption of foods is gaining traction and globally, it is believed that there is nutritional transitional taking place from animal-based protein to plant-based protein. Product requirements, supply chain conditions, and consumption patterns for animal-based proteins and plant-based proteins will vary. This ensures that the packaging of plant-based foods must now meet new standards. This research study used mixed methods to understand the perception of consumer and industry towards plant-protein diets in comparison to animal protein diets and to study the differences between the requirements of the packaging of these diets. The findings revealed three key points: (i) consumers' opinions, preferences, and attitudes toward various diets; (ii) their dissatisfaction with plastic packaging and the need for sustainable packaging; and (iii) the requirements on packaging materials for plant-based versus animal-based diets from the perspective of consumers and the industry.

Keywords: nutritional transition, consumption patterns, packaging materials, barrier properties

Acknowledgements

This thesis would not have been possible without the guidance and support of my supervisor, Katrin Molina-Besch. Throughout the research period, she has been encouraging and has always made time for comments and discussion. She has contributed her unique ideas and helped to define the path of this thesis due to her vast expertise and knowledge in the field of packaging.

I would like to express my deepest gratitude to some of my friends who helped me in collecting survey responses during the study.

Finally, I would like to thank my parents who gave me the opportunity to do master's degree in Sweden at Lund University.

I would also like to thank some of my friends here in Sweden who kept me motivated and always been encouraging throughout the study programme.

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CO_2	Carbon-di-oxide
FAO	Food and Agricultural Organization
PET	Poly(ethylene)terephthalate
PLA	Poly (Lactic)acid or Polylactide
PHA	Polyhydroxy Alkenoates
PVC	Poly Vinyl Chloride
STEPS	Sustainable Plastics and Transition Pathways
SDG	Sustainable Development Goals
UN	United Nations

1.Introduction

This chapter provides the background and motivation of the study, aim and objective of the study. Finally, delimitations of the study are presented.

1.1 Background and Purpose of the study

Food plays an important role in the day-to-day life of every human being. It provides nutrients which act as an energy source for our existence and to carry out everyday activities. Both plants and animals are used as food sources. Plant-based foods are produced through agriculture whereas animal-based foods are produced from animals which consumes plants as their food source. Food is the single most powerful force enabling human health, and how we produce food has a significant environmental influence. As a result, food plays a critical role in ensuring global environmental sustainability. (Eatforum, 2019).

A healthy food should promote health, which is defined broadly as a state of complete physical, mental, and social well-being rather than simply the absence of illness. Scientific targets for healthy foods are based on a large number of studies on foods, dietary patterns, and health outcomes. Healthy diets have an adequate calorie intake and are composed mostly of a variety of plant-based meals, a modest number of animal source foods, unsaturated fats rather than saturated fats, and a limited number of refined grains, highly processed foods, and added sweets (Eatforum, 2019).

The growing population and recent technology improvements have an impact on increased agricultural output, i.e., more intensive methods of agriculture are used to increase harvest, which generates greater environmental challenges. Furthermore, the production of animal-based foods requires more resources than the production of plant-based foods. Taking everything into account, the problem of supplying a balanced food from sustainable sources to the world's growing population is becoming more difficult. (Eatforum, 2019)

Although, global food production rate has kept pace with growth of population, 820 million people still need adequate food, and many people consume either low

quality foods or too much food. Unhealthy diets also cause many health problems and therefore increase the chances of mortality (Eatforum, 2019).

Considering all the factors together, a global dietary transition is desperately needed for example, shift from animal-based protein diets to plant-based protein diets, doubling world consumption of healthy foods like fruits, vegetables, legumes, and nuts, while reducing less nutritious foods like added sugars and red meat by more than half. This diet shift results in reduced greenhouse emissions and larger agricultural cultivation without increased expansion of agricultural, promotes human health and environmental sustainability (Eatforum, 2019).

This would also feed a larger population and helps in reducing diseases related to overconsumption of calories or protein. Without these actions, the world would be in the risk of failing to meet UN's Sustainable Development goals and the Paris Agreement, therefore resulting in the environment with population suffering from malnutrition and avoidable diseases and severely degraded planet (Eatforum, 2019).

Up to few years ago, when considering sustainability, the environmental impact of finished products was a major concern, but this has been broadened into a more holistic approach to improve sustainability footprint throughout the entire life cycle of a product. It is important to produce sustainable packaging not only because packaging waste is an important source of environmental problems but also it is most noticeable from the buyer's perspective (STEPS, 2021).

Food packaging is used to protect the food from outside damages, maintain its texture, extend shelf life, waste reduction and many more factors. Traditionally, materials that have been used in food packaging are metals which include aluminum, foils, laminates; glass; paper and paperboard materials; and plastics-Plastics are a popular material of choice due to their durability, low cost, light weight and high performance. But the difficulty to recycle plastic is one of the major disadvantages when compared to glass, metal and paper (STEPS, 2021).

Developing more sustainable plastic packaging is the current challenge and many firms are working to ensure plastics are sustainably developed, produced, used, and recycled (STEPS, 2021).

The materials used in packaging should possess good barrier character to oxygen, water vapor, good mechanical performance and transparency. Therefore, these plastics have been widely used in packaging sectors (Sangroniz, et al., 2019).

The product requirements, supply chain conditions and consumptions patterns can be expected to differ between animal-based proteins and plant-based proteins. This in turn means that packaging for the increasing amount of new plant-based protein foods entering the market must fulfill new types of requirements.

This thesis will focus on understanding the consumer's expectations and requirements towards plant-based and animal-based protein diets. Additionally, it also identifies the differences between requirements of packaging of animal-based

and plant-based protein products which would help in further development or optimization of the sustainable packaging for future plant-based protein diets.

This research study is also started with the motivation from the research project STEPS (Sustainable Plastics and Transition Pathways) that aims to achieve the transition to a more sustainable plastic system.

1.2 Aim and Objective of the study

The aim of this master thesis is to explore the requirements of packaging materials due to a shift to plant-based protein diets from the consumer and industry perspective. The following are the research objectives of this master's thesis:

- ⇒ To investigate consumers opinion towards animal and plant-based diets and to explore their perception towards packaging requirements of these diets,
- ⇒ To explore the industry perception of requirements of packaging materials for plant-based contra animal-based diets which would help in developing sustainable packaging for future plant-based protein diets.

Given the goal and area of the study, this master thesis contributes with insights that relate to the achievement of selected goals of the UN 2030 Agenda for Sustainable Development. It is particularly relevant to SDGs 9 (Industry, Innovation and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Climate Action).

1.3 Delimitations of the Study

The study focuses on the existing consumer opinion, awareness, and preference for plant-based and animal-based diets, and the findings show the existing variation in consumption patterns. It also concentrated on collecting existing information about the need for plant-based diets in the future and its challenges.

The study also concentrated on analyzing the existing differences in the barrier requirements of packaging of plant-based and animal-based foods in order to gain knowledge about sustainable packaging for future plant-based diets.

It also concentrated on analyzing the existing gaps in the barrier requirements of packaging for plant-based and animal-based foods in order to gain information

about sustainable packaging for future plant-based diets. Furthermore, the study also addresses the prevailing difficulties and limitations in achieving sustainable packaging for current diets.

This research, however, was limited to a time period of 20 weeks and does not concentrate on a specific geographical region, nor does it focus on packaging for any specific plant protein which makes it difficult to have a deeper understanding in the differences of barrier requirements. Moreover, to address the study's objectives, only consumer surveys and interviews with industry representatives were used, resulting in data that solely gave the perceptions of consumers and industry representatives. Further experimentation, measurements, or observations were not carried out to confirm these findings.

Despite the fact that the study's objective was to include consumers from as many parts of the world as possible, the survey was designed in a single language to allow for a better interpretation of the findings. Because of the language barrier, the number of participants may also have been limited. Also, this study does not concentrate on providing solutions to the aforementioned issues.

2.Literature Study

This chapter provides an overview of the literature relevant to the study including the significance and importance of the study.

2.1 Sustainable Diets

Within the context of worldwide environmental change, the growing population and societies rely on secure food production and distribution systems which allows for food availability, abundance and accessibility. However, whereas seemingly sustaining life, such systems might also contribute to depleting the natural resources, causing undesirable effects on the environment, and forcing us to consume diets that are unhealthy and unsustainable (Graça, Godinho, & Truninger, 2019).

The demand for animal-based foods is high due to the rise in population and an increased standard of living. There is a lot of environmental data demonstrating the unsustainability of current overall food utilization practices which are high in animal-based foods (Sabate & Soret, 2014).

Considering the current food consumption patterns and environmental impacts caused by them, there is a conflict between food security and food sustainability. Solving this conflict requires an extreme shift of a huge population from animal-based protein foods. Other techniques such as advancement in agriculture, food waste reduction etc., have to be done simultaneously but these methods are not sufficient to make food production more sustainable (Sabate & Soret, 2014).

A dietary shift to plant-based protein foods globally is a good alternative for a sustainable future. This shift towards sustainable diets (or) plant-based foods would also help to achieve UN's Sustainable goals 2(Zero hunger), 3(Good Health and

Well-being), 11(Sustainable cities and communities), 12(Responsible Consumption and Production), and 13(Climate action) by the year 2030 (UN, 2021).

In 2010, the Food and Agricultural Organization defined a sustainable diet as a healthy diet that contributes to lower environmental impacts, provides an optimal health state and protects from malnutrition (Sabate & Soret, 2014). In the current scenario of the world and the food system, many individuals do not have access to sufficient, safe and affordable diets which is necessary for improving their health and well-being whereas others consume too much or low-quality foods. This results in malnutrition such as hunger, micronutrient deficiencies, overweight etc., and is the leading cause of diseases around the globe (FAO, 2019).

Worldwide evaluations suggest that malnutrition in all its forms costs the society USD 3.5 trillion per year in which overweight and obesity alone is costing USD 500 billion per year. In the year 2016, unhealthy diets were considered as the world's second-largest risk factor for deaths and disability-adjusted life years (DALYs) whereas in 2017, they contributed to approximately 11 million deaths and 255 million DALYs (FAO, 2019).

A healthy diet involves sustainable production and consumption (WHO, 2018). The current food production system is the major cause of the degradation of the environment and natural resources. It contributes to the usage of two-thirds of water, causing deforestation and biodiversity loss which leads to 20-30% of greenhouse gas emissions. With the expected population rise of 9.8 billion by the year 2050, the current food systems could not be claimed as sustainable with these environmental effects and impacts (Mekonnen & Hoekstra, 2012).

On the other hand, the type of food consumed and produced also matters because plant-based foods produce fewer greenhouse gases and the production requires less water than animal-based foods (Mekonnen & Hoekstra, 2012) and is shown in the **Figure 1**. According to the report, greenhouse gas emissions due to animal-based products is seemed to be doubled to 145% by the year 2050 (Global Nutrition Report, 2020)

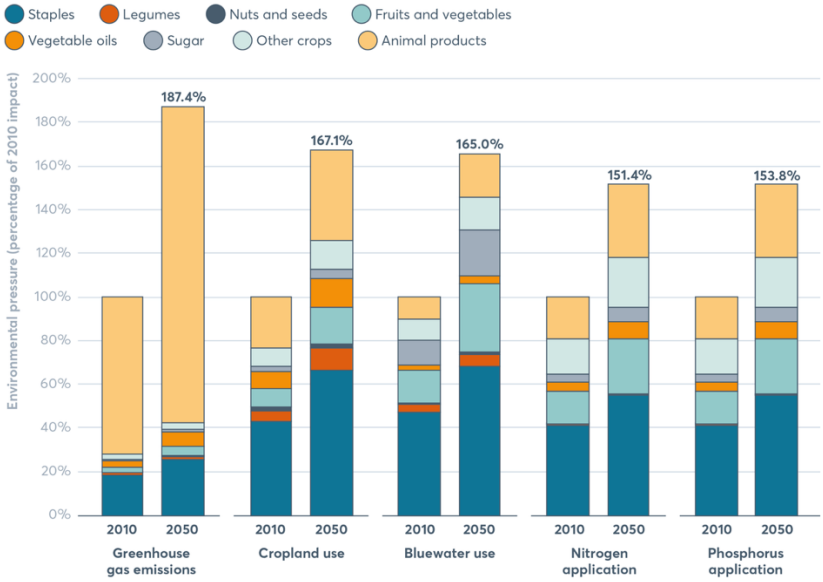


Figure 1.Global Nutrition Report, 2020 [10]

Food packaging and food distribution also have impacts on environmental sustainability. Globally, one-third of all food goes to waste and leads to large environmental impacts (WHO, 2018). Most of the food waste is related to the food's short shelf life and packaging is considered to be one of the main elements of food quality preservation, food preservation during storage, preventing food safety issues and extending shelf life. But the packaging also causes additional environmental impacts. Therefore, a sustainable packaging solution is an essential element that addresses food loss and waste thereby ensuring sustainable food consumption (Guillard, et al., 2018).

2.2 Animal-based vs Plant-based protein diets

2.2.1 Health effects of plant-based diets versus animal-based diets

A healthy diet and sustainable food production are achieved by increased consumption of plant-based foods and decreased consumption of animal products (Willett, et al., 2019). Plant-based diets through their nutritional benefits reduce the risk of various non-communicable diseases. Adequate intake of dietary protein is essential for the body. Plant diets with varieties of foods provide adequate intake of

all amino acids (WHO, 2018). Given that many whole food sources of plant-protein are lower in calorie density than animal protein sources, a higher total food intake is needed to meet energy requirements, which in turn helps meet essential amino acid requirements (Hertzler, Lieblein-Boff, Weiler, & Allgeier, 2020).

Furthermore, the availability of several plant-based protein isolates and concentrates (soy, pea, canola, potato, fava, etc.) in the food industry has made it much easier for consumers to increase their consumption of plant proteins. It was once difficult for people to consume relatively large quantities of protein from whole plant foods since they normally have a low protein level (Hertzler, Lieblein-Boff, Weiler, & Allgeier, 2020).

Animal sources of protein are considered to be complete protein as they supply all of the amino acids that the body cannot make on its own (Sabate & Soret, 2014). Nonetheless, an important positive correlation between animal protein consumption and an increased incidence of cardiovascular disease and certain cancers has been reported, which may be due to the high sulfur amino acid content of animal proteins (Naghshi, Sadeghi, Willett, & Esmaillzadeh, 2020).

2.2.3 Environmental impact of animal-based versus plant-based protein diets

There is excessive loss of energy in raising animals for human consumption and is considered an inefficient process. The efficiency ratio of animal foods compared with plant foods for human consumption has been evaluated by many authors (Sabate & Soret, 2014). In the current scenario, approximately 20% of total energy produced and 70% of total freshwater consumption are used to produce food crops. The majority of these crops and wastes are used for livestock growth in the form of feed and fodder, transforming plant protein to animal protein for human consumption (Kumar, et al., 2020). It is shown that on average the fossil energy required to produce animal protein is 11 times greater than the energy required to produce plant protein (Sabate & Soret, 2014).

However, this ratio varies depending on the type of animal product. When compared with soy protein, the land needed to raise the feed to produce animal protein is 6-17 times more prominent. Therefore, the conversion of plant foods to feed animals is considered an inefficient process. Livestock farming also causes greenhouse emissions. Therefore, intensive production of animal protein harms the environment more than nutritionally equivalent plant proteins (Sabate & Soret, 2014).

2.3 Sustainable Food Packaging

Food packaging is important because it ensures the safety and quality of food. It protects the food from contamination, physical and chemical damage, provides easy transportation and maintains its shelf life. Advancement in the packaging industry makes it more useful and convenient for consumers. Food packaging and food distribution also have impacts on environmental sustainability. Globally, one-third of all food goes to waste and leads to large environmental impacts (WHO, 2018).

A part of the food waste in food supply chains is related to the food's short shelf life and packaging is considered to be one of the main elements of food quality preservation, food preservation during storage, preventing food safety issues and extending shelf life. But the packaging also causes additional environmental impacts. Therefore, a sustainable packaging solution is an essential element that addresses food loss and waste thereby ensuring sustainable food consumption (Guillard, et al., 2018).

2.4 Packaging materials and their barrier properties

Containment, protection, convenience and communication are the four primary and interconnected functions of packaging (Robertson, 2009). There are three types of packaging- primary, secondary and tertiary. The primary packaging is in contact with the food product, and it is the major protective barrier. For example, paperboard cartons, metal cans, plastic pouches, glass bottles. The secondary packaging (for example, corrugated cardboard/case) consists of a number of primary packaging and an arrangement of a number of primary or secondary packages on a pallet or a roll container is called tertiary packaging (Robertson, 2009).

The packaging material of a particular food product is selected based on the barrier properties of the packaging material. Based on the protection requirements such as maximum moisture gain or O_2 uptake, foods are classified, and suitable packaging material is selected which provides the necessary barrier to attain the desired shelf life of the product. Different materials have different barrier properties. Metal cans and glass containers are considered impermeable materials for the passage of gases, odors and water vapor (Robertson, 2009).

Generally, aluminum cans and tin-coated steel are used when it comes to metal-based packaging and are used for packaging beverages and canned foods. Aluminum because of their advantages such as, lightweight and ability to be reused are progressively utilized for canning. It is likewise used as laminates, wraps and bottle closures. Metal cans are made of tin covered steel sheets to protect corrosion of steel, particularly for packaging products with low ph. Glass containers have

excellent oxygen barrier properties (Parveez & Rasheed, Coating on packaging products to enhance shelf life., 2021).

Paper-based materials are considered permeable. Therefore, paper-based materials are often coated with plastic polymers to provide adequate barrier properties for the packaging of food (Robertson, 2009).

Plastic packaging materials have varying degrees of protection depending on the type of polymer used for packaging food products (Robertson, 2009).

2.5 Disadvantages of plastic packaging and the use of biopolymers

Polyethylene, polypropylene, polystyrene, polyvinyl chloride (PVC), and polyethylene terephthalate (PET) are the five most popular plastic polymers used in packaging. Plastics are also being used more often in secondary and transportation packaging; reusable plastic boxes and trays are replacing single-use cardboard and wooden boxes (Pongrácz, 2007).

Plastic packaging is a low-cost packaging, consumes lower energy during production when compared with other alternate materials such as paper, glass, steel and aluminum, provides sufficient mechanical strength and prevents food contamination. Although there are more advantages, the difficulty to recycle is one of the major disadvantages (Parveez & Rasheed, Coating on packaging products to enhance shelf life., 2021).

Single use plastics are used once for a short period of time before being discarded. It is widely used in packaging of fruits and vegetables, food containers, cups for beverages and beverage containers (BPF, 2021). Although these single-use plastic packaging provide a hygienic method of purchasing food and minimize waste, the environmental and health consequences of this plastic waste are widespread and can be serious. Single-use plastics are more likely to end up in the oceans than recycled and reusable alternatives (EC, Single-use plastics, 2021).

Between now and 2050, emissions from plastics production and incineration accounted for 56 gigatons of CO_2. Almost all greenhouse gases are released at each point of the plastic lifecycle: 1) fossil fuel production and transportation, 2) plastic extraction and manufacturing, 3) plastic waste management, and 4) the continuing effects of plastic as it enters oceans, rivers, and landscape (CIEL, 2015). Developing more sustainable plastic packaging is the current challenge and many firms are working to ensure the sustainability of plastic packaging (STEPS, 2021). Because of their resistance to biodegradation, increased use of plastics has caused significant ecological problems in the environment.

The natural and synthetic biopolymers which can be degraded quickly in the environment and imitate the properties of traditional polymers, can be used to solve the problems caused by plastics. PLA (10.9 percent), biodegradable polyesters (10.8 percent), biodegradable starch blends (9.4 percent), and PHA make up the majority of biodegradable plastics (3.6 percent) on the market today. Asia accounts for 63.1 percent of bioplastics output, while North America accounts for 13.5 percent, Europe accounts for 13.0 percent, and South America accounts for 10.0 percent (Yadav, Mangaraj, Singh, Kumar, & and Simran, 2018).

Mostly these biopolymers are used for flexible packaging whereas non-degradable plastics are used for rigid packaging. Instead of traditional polymers, biodegradable polymers can be used for modified atmospheric storage (MAP) of fruits and vegetables (Yadav, Mangaraj, Singh, Kumar, & and Simran, 2018). However, some disadvantages of using biopolymers as food packaging materials over traditional non-biodegradable materials include poor mechanical (e.g., low tensile strength) and barrier properties (e.g., high water vapor permeability).

Biopolymers are brittle, have a low heat distortion temperature, and have a low tolerance to long-term processing. For example, the high molecular weight PLA has good water solubility resistance but has poor performance due to a low heat distortion temperature, poor tolerance to extreme heat and humidity, and poor flexibility (Yadav, Mangaraj, Singh, Kumar, & and Simran, 2018).

Certain other bioplastics possess brittleness, low melting point, high water vapor and oxygen permeability which limit their use as films in the applications of food packaging. Other starch- and cellulose-based packaging materials have a low water vapour barrier due to their hydrophilic nature, which causes poor processability, brittleness, susceptibility to deterioration, reduced long-term stability, and poor mechanical properties. PHA/PHB hardness, brittleness (due to high glass transfer and melting temperatures), thermal instability, and low impact resistance all limit their use in food packaging (Jabeen, Majid, & Nayik, 2015).

However, several different methods have been used to improve the properties of bioplastics, especially the gas and water barrier properties. Coating, mixing, the inclusion of nanoparticles, the addition of cellulose, chemical/physical alteration, and so on are some of the techniques (Jabeen, Majid, & Nayik, 2015) (Robertson, 2009) (Nilsen-Nygaard, et al., 2021).

2.6 Factors Influencing the shelf life of food

Understanding the needs of the food is crucial in determining the best package to optimize shelf life. The purpose of the package for perishable, chilled products is to

protect the product, in which microbial contamination is considered important because microbial or enzyme activity is the mode of spoilage for these products.

The barrier of the package will affect the shelf life of shelf stable items. Moisture absorption, for example, will affect the crispness of a cracker, necessitating the use of a moisture barrier. Light protection may also be required. Without light protection, milk is susceptible to vitamin degradation and off-taste. Techniques such as modified atmosphere packaging and use of active packaging (such as ethylene absorbers) extend shelf life of perishable products. (MOCON, Food Packaging and it's Influence on Shelf Life, 2017). Packaging is an important factor in the shelf life of food products. The intrinsic factors such as initial quality of the product, inherent nature of the product and the formulation of the product also affects the shelf life.

The external factors such as storage temperature, storage relative humidity, time interval before and after packaging, initial and final gas composition, gas purity, headspace to product purity, HACCP procedures also influence the shelf life of the product (Caleb, Mahajan, F.A.J., & Opara, 2013). As mentioned earlier in Chapter 1, the packaging requirements of animal-based protein diets may not be the same as the packaging requirements of plant-based protein diets as the product requirements, supply chain conditions and consumption patterns among consumers vary.

As mentioned above, plant protein foods have different nutritional content and product characteristics than animal protein foods. For example, when comparing boiled kidney beans, which is a plant protein source, it consists of calories 127 g, water 67%, protein 8.7 g, carbohydrates 22.8g, sugar 0.3 g, fiber 6.4 g, and fat 0.5 g per 100g (Kidney Beans 101: Nutrition Facts and Health Benefits, 2020). When comparing this with ground beef of 10% fat content, it has calories: 217, water: 61%, protein: 26.1g, sugar o g, fiber 0 g, fat 11.8 g (Beef 101: Nutrition Facts and Health Effects, 2020). They are richer in protein than milk products. A comparison of further product characteristics of normal kidney beans without processing versus minced meat states that kidney beans have a moisture content of 10.1 (% w.b), water activity of 0.475 whereas ground beef has a moisture content of 71.2 (% w.b) and water activity of 0.992 (Schmidt & & Fontana Jr, 2007).

Since kidney beans are a combination of high content of carbohydrates, protein and water, a study analyzed how these factors affect the stability of the beans during the storage period of six months. The samples collected were between 13.3% and 15% moisture content. It was found that there is significant reduction in the moisture content of all the samples during the storage period (Nyakuni, et al., 2008). Poor storage conditions can cause seed hydration problems, lowering digestibility and nutrient bioavailability. Storage defects such as "bin burn," "hard-shell," and "hard-to-cook" (HTC) phenomenon are discovered to develop under unfavorable storage conditions, resulting in a considerable loss of bean quality and economic value (Uebersax & & Siddiq, 2013) . In addition, seed coat and cotyledon rupture cause clumping and splitting when beans are preserved at low moisture levels, whereas

excessive initial moisture increases discoloration, off-flavor development, loss of water uptake capability, and mold growth (Uebersax & & Siddiq, 2013).

To ensure that the integrity of the package allows for minimal subsequent contamination of the product, dry edible kidney beans are packaged in food-grade impermeable materials such as plastic (polyethylene, polypropylene) whereas canned and thermally processed kidney beans are stored in metal cans in most of the countries because of their good barrier properties (Uebersax & & Siddiq, 2013).

As mentioned earlier, ground beef has higher moisture content and fat content, which when not stored and packaged properly leads to color change, microbial damage, lipid oxidation which leads to less shelf life. In order to address these problems, a study analyzed the effects of different packaging systems to increase the shelf life of ground beef under refrigerated conditions (Conte-Junior, et al., 2020). It was observed that VP (vacuum packaging) and MAP (Modified Atmospheric Packaging) with appropriate number of gases offers better shelf life than traditional over-wrapped tray. The main beneficial effects of VP include the suppression of off odors and spoiling by Pseudomonas, but the meat takes on a distinctive purple-red color, which is a significant disadvantage when compared to MAP (Conte-Junior, et al., 2020) (D'AGATA, et al., 2010).

Similarly, cow milk (calories 168 g, protein 8 g, fat 10 g, carbohydrate 11 g) is compared with oat milk (calories 80 g, protein 2.5 g, fat 4 g, carbohydrates 16 g) (Sethi, Tyagi, & Anurag, 2016). Cow milk is sterilized and packaged in an aseptic carton packaging to prevent microbial growth, lipid oxidation, and to ensure the good quality of the product (tuszynski, 1978). According to OATLY, dairy milk alternative, such as oat milk when ambient stored packaged in an aseptic carton to keep it in sterile environment and to ensure its longer shelf life whereas refrigerated oat milk is not aseptically packaged, and it is required to keep in a chilled environment (OATLY, 2021).

3.Methodology

This chapter provides an overview of the choice of the specific methodology followed by the description of the qualitative and quantitative methods used in the study. Finally, data analysis and limitations of the study is discussed.

3.1 Choice of Methodology

The study involved research using a mixed method approach by working with two different kinds of data which helped in better understanding of the area that hasn't been researched previously or considered under-researched. According to Creswell, quantitative research involves collecting *what types* of data whereas qualitative research involves collecting *why?* types of data. In this study, a survey was conducted which is a quantitative research and interviews were conducted which is a qualitative research (Creswell, 2014).

The survey was conducted to know what type of food (either plant-based or animal based) consumers buy, how they store and prepare these types of food and how often they buy them. It also included analyzing their preferences/opinion towards plant-based and animal-based protein diets. Additionally, it helped in understanding the consumer's opinion about current packaging and the need for sustainable packaging.

The interviews were conducted with industry experts in the field of Food Innovation and Development, and the industrialists in the field of Food and Packaging industry. It was conducted to know the urge and need for plant-based diets and the ongoing research/developments specifically regarding plant-based protein diets, to understand the protection requirements of packaging materials, and to collect information about the barrier requirements of future packaging materials for plant-based protein foods.

These methods were best suited for the objectives of this research because surveys were conducted to explore differences in the consumption patterns between animal-based and plant-based proteins whereas interviews with the experts were conducted to explore packaging requirements from the perspective of consumer and industry and in particular the differences in the requirements of packaging of plant-based versus animal-based protein products.

3.2 Description of Quantitative Data

The quantitative data was collected and analyzed by conducting a survey questionnaire. The main motive of doing this survey was to understand the consumer opinion towards different diets (animal-based and plant-based) and their perception of packaging of these diets in as many as different parts of the world as possible. More specifically, the survey was conducted to know the type (plant-based or animal) of food consumed by the individuals, to perceive how often consumers buy, store and prepare foods, to understand and evaluate the supply and demand of foods consumed, to map the need for the development of new packaging materials and to get a better understanding of the barrier requirements of future packaging materials of plant-based protein diets. It was also designed to collect data about the consumer's thoughts on sustainable diets and sustainable packaging.

The survey questions were prepared as a draft initially. Based on the discussion with two consumers from the region of Skåne (Sweden), the questions have been reframed and posted on social media such as Facebook and WhatsApp and remained available for 3 weeks. It was also sent individually to the current network. The survey consisted of 20 questions which is presented in **Table 1** and was expected to be completed in 10 minutes. The respondents of the survey were expected to be 18-75 year-old-adults.

The participants of the survey were from all parts of the world and not limited to one geographical area. It was expected that the young people would find the survey online and further pass it to their network including family, relatives, friends, colleagues etc., to achieve higher participation rates and results.

Table 1. Survey Questionnaire:

1.	What type of food do you eat daily?	(Animal-based, Plant-based or both)
2.	How likely are you to prefer to consume animal-based protein (E.g., Dairy and meat products) daily?	Scale (1-5)

3.	How likely are you to prefer to consume plant-based protein (E.g., cereals, lentils) daily?	Scale (1-5)
4.	How often do you buy animal-based protein foods?	(Daily, Weekly, Monthly, other)
5.	How often do you buy Plant-based protein foods?	(Daily, Weekly, Monthly, other)
6.	How do you store these foods usually?	(Dry storage, Refrigerated storage, Frozen, other)
7.	How do you prepare these foods usually?	(Steaming, Frying, Baking/Roasting, Raw)
8.	How important is packaging to you when purchasing these food products?	Scale (1-5)
9.	Do you prefer sustainable labelling when purchasing food products at the store?	(Yes, No, Maybe)
10.	Do you have any comments/thoughts or concerns regarding the packaging used for protein products (can be either animal or plant origin)?	
11.	Do you have any thoughts/comments on plant-based protein foods?	
12.	If you are a vegan/Vegetarian, do you find many plant-based protein products in the market?	(Yes, No, Maybe, Need more products)
13.	To what extent do you prefer to shift to a plant-based protein diet because it is safer for the environment?	Scale (1-5)
14.	What would be the reason you think of when you buy plant-based protein products?	(Health Benefits, Better for the environment, Like the taste)
15.	If you prefer plant-based diets, would you rather buy organic which is natural or highly processed plant-based foods?	
16.	To what extent do you think sustainable packaging is more important for foods with lower environmental impact (Eg., Organic Foods)?	Scale (1-5)
17.	Do you check expiration dates when purchasing plant-based protein food products?	(Yes, Maybe, Depends on the product)

18.	Do you check expiration dates when consuming plant-based protein food products?	(Yes, Maybe, Depends on the product)
19.	Do you buy plant-based protein food products which are close to expiration dates?	(Yes, Maybe, Depends on the product)
20.	Assuming, plant-based protein foods have a shelf life of up to 3 months (depends on the product and storage conditions). How likely are you to prefer to buy a plant-based protein food with more than 3 months of shelf life	

The aim of this survey was not to make statistical inferences in relation to the wider population but to generate the most important and useful insights that has been gained during this survey research. Therefore, this study follows non-probability sampling in which a sample of participants or cases may not have to be representative or random, but there must be a valid reason for including certain cases or individuals over others (Taherdoost, 2016). Due to limited time and financial limitations, this study follows both convenience and snowball sampling where the researcher first reached out to her current network to find the first participants who agreed to participate in the survey.

Additionally, these participants were also asked to nominate additional subjects that they are familiar with to increase the participation rate. This type of sampling is inexpensive and one of the popular choices among students. The total of 102 responses were collected with a slightly higher male participation rate (44% female and 56% male respectively). The results of the questions are summarized and presented in the form of pie charts and graphs. Further qualitative inferences and limitations are discussed in the results and discussion section of the research study.

3.3 Description of Qualitative Data

The qualitative research methodology includes structured interviews, semi-structured interviews, focus group interviews etc., Unstructured and semi-structured interviews primarily concentrate on the interviewee's perspective and experience, with the aim of obtaining rich and detailed information (Bryman, 2012). The type of research suitable for this thesis is structured interviews where each one of the interviewees gets the same questions. This study follows purposive or judgmental sampling because the interviewees were chosen who were considered most useful for the purpose of the research (Bryman, 2012).

The experts involved in this research study are from the food industry and packaging industry working in the area of food innovation and development. Due to the corona outbreak, it was not possible to conduct offline face-to-face interviews, but the interviews were conducted online using online platforms such as Zoom and Microsoft Teams. A total of seven interviews were conducted and they provided insights about the packaging materials for protein-based food products (animal-based and plant-based), the need for sustainable diet and packaging, consumer expectations and demands about food packaging and helped to explore the protection requirements of packaging materials with respect to the type of food product. Since the outcome of the first interview from IKEA was more related to sustainable diets and packaging, a further of two other experts from IKEA have been interviewed to obtain detailed knowledge on the protection of requirements of packaging materials. The list of interviewees includes,

1. Jessica Mauritsson, Innovation Manager, AR Packaging, Sweden.
2. Henrik Ringdahl, Global Range Selector, (Packaging), IKEA Foods, Sweden.
3. Helen Thompson, Founder & Owner, BloominGood Food, Sweden.
4. Selime Kadir, Packaging Solution Manager, Oatly, Sweden.
5. Sofia Erixson, Packaging Manager, ICA, Sweden.
6. Maaike Van Der Eerden, Packaging Engineering, IKEA Food Services, Sweden.
7. Anna Widell, Regulatory and Product Compliance Leader, IKEA Food Services, Sweden.

Table 2. Interview Questions

1.	How do you perceive that the requirements on the packaging have changed over the past 5-10 years?
2.	What types of packaging are used for your food products?
3.	What are the differences in the requirements of packaging for plant-based protein and animal-based protein foods? (Specifically, barrier requirements)
4.	Which packaging materials are suitable for plant-based products?
5.	Do you perceive that the currently available packaging materials and methods fulfil/meet the requirements of plant-based protein foods?

6.	Do the currently available packaging materials provide sufficient protection to extend the shelf life of your products? (plant-based)
7.	How happy and satisfied are you with the current packaging for plant-based protein foods?
8.	What do you think is the critical factor affecting the shelf life of a plant-based protein product?
9.	How is the consumer response to the current packaging for plant-based protein foods?
10.	What are the consumer expectations/needs related to food packaging? Are these expectations generally applicable or specific to a food product, for example, plant-based foods?
11.	Will you develop more packaging for plant-based protein products in the future?

3.4 Data Analysis and Methodological Limitations

The quantitative data collected from the survey are presented in graphs and pie charts rather than statistical data and discussed in the results and discussion section. Interviews were recorded, transcribed and analyzed as soon as possible after they were conducted. It is important to recognize that all studies have limitations.

The current argument against mixed methods study is one of the first limitations. In other words, some researchers regard mixed methods as unfeasible since they each belong to different frameworks of principles, assumptions, and methods that are incompatible (Bryman, 2012). Nonetheless, this limitation was resolved by outlining the reason for this approach and the study objective, as well as providing full description and information about the sampling, design, and data analysis for both components. Second, as non-probability sampling is used, there is a significant risk of a non-representative population, which must be acknowledged in the research and data analysis. This sampling method does not choose subjects at random from the target population (Bryman, 2012).

As a result, non-random samples typically yield samples that are not representative of the entire population (e.g., city or country), and therefore the potential to generalize results based on them is limited. Although the observations and conclusions are viewed from a broad perspective, the author is aware of and accepts this limitation. Furthermore, this research effort is only a starting point, and the findings will be used to further advance this field of study rather than to draw conclusions.

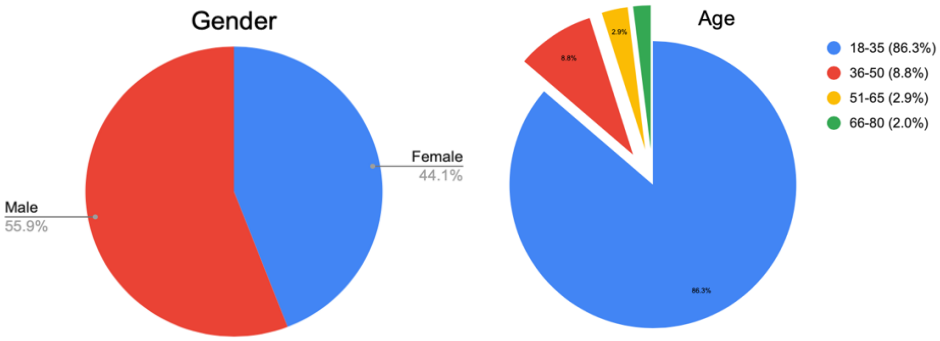
4.Results and Discussion

This chapter provides demographic information of the respondents of the survey, followed by qualitative and quantitative data findings and discussion.

4.1 Demographic Information

The respondent's socio-economic profile which is obtained from the survey is presented in this section and is shown in **Figure 2**. The total number of participants in this study is 102 individuals between the ages of 18-75. Males account for 57 (55.9%) of the 102 respondents, while females account for 45 (44.1%). About 86% of the respondents are aged between 18-35, 8.8% are between 36-50, 2.9% are between 51-65 and finally 2.0% are between 66-80.

The respondents are from various parts of the world including Europe, American and Asian countries. Approximately 56% of the respondents are from European countries out of which 41% are from Sweden. Similarly, about 40% of the respondents are from Asian countries out of which 33% are from India. The rest of the respondents are from American countries. Finally, over 96% of the respondents have or are pursuing a university education.



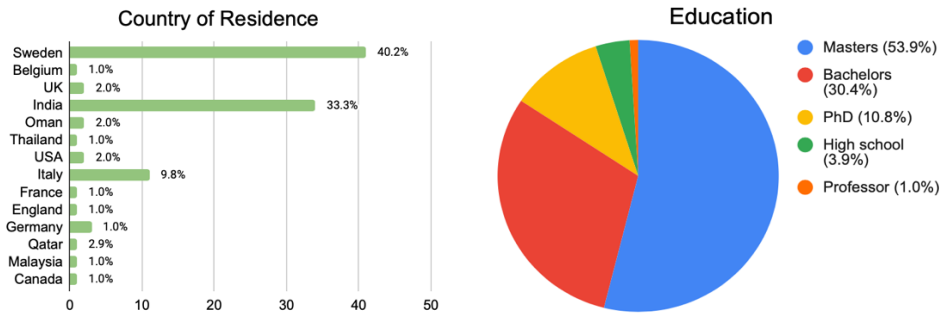


Figure 2. Demographic Information of survey participants

4.2 Quantitative Data Findings and Discussion

The following section presents and discusses the results from the survey conducted during the study.

4.2.1 Daily Consumption of Foods of Consumers

As shown in **Figure 3**, about 73% of respondents described themselves as omnivores when given the option of plant-based/animal-based or a mixture of both, as they eat a combination of both plant-based and animal-based foods on a daily basis. Just 3% of respondents choose animal-based diets on a regular basis, while 25% of respondents eat a plant-based diet.

Since the responses came from all over the world, a closer examination of each response was conducted to determine which group of respondents consume animal-based foods slightly more/less than others. It was discovered that participants from European and American countries consume slightly more animal-based diets and combinations of both diets, whereas Asians, especially Indians, consume slightly more plant-based diets.

Vegetarians are more common in India for a variety of reasons, including cultural beliefs and the availability of plant-based options for daily consumption, such as vegetable curries, lentils, pulses, and other protein-rich foods. It is also thought that certain Indian consumers consume meat products on occasion during festive seasons.

Despite the abundance of plant proteins available on the market, meat and meat products are still the primary source of dietary proteins in the majority of European countries (EC, Dietary Protein, 2021). This is a reality that is more relevant to western countries.

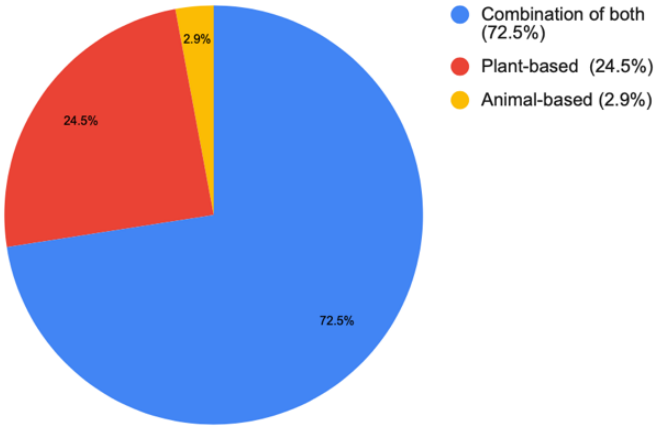


Figure 3. Pie chart depicting daily food consumption of respondents

4.2.2 Consumer Preferences, Liking and Attitude towards different protein diets - Plant-based and Animal-based

In the survey study, when asked about the participants if they prefer to eat animal-based or plant-based protein on a regular basis, nearly 34% said they are neutral on the subject of animal-based protein and about 46% said they are likely to prefer animal protein. While totally 81% said they are likely to prefer to eat plant-based protein which is shown in **Figure 4 and 5**.

As a result, it is clear that the trend towards integrating plant-based protein consumption into daily life is gaining traction, especially among younger, more educated consumers. Many factors contribute to this daily consumption of plant-based protein, including health benefits, animal welfare, and environmental concerns.

According to the available statistics, 70% of the world's population is consuming less meat, and the number of new vegan items available has risen by over 250% since 2010 (AXA, 2021).

Although this study showed that 70% of the population is consuming less meat, another recent study showed that the world now produces three times as much meat as it did fifty years ago. In 2018, production was estimated to be around 340 million tonnes and one of the reasons stated in the study for increased consumption of meat

could be the high-income population of the country. The increased income gives people the possibility to consume more meat (Ritchie & Roser, 2017).

Another noteworthy aspect to consider regarding the low consumption of meat is that the pandemic COVID-19 might have increased public knowledge of zoonoses and resulted in changes in meat consumption. It prompted individuals to choose and stock up upon shelf-stable plant-based protein sources rather than animal-based protein sources. Previous zoonotic outbreaks, such as SARS and swine flu, led to short-term reductions in meat consumption, a shift toward certain types of meat, and a more widespread shift in perceptions of the health hazards associated with meat consumption. The second way COVID-19 could reduce consumption of animal products is through supply chain disruption and panic buying (Attwood & Hajat, 2020).

In a 2020 United Soybean Board (USB) Plant-based Protein Study, 1,000 U.S. consumers aged 16 to 49 were polled, and 61% said they ate more plant-based foods and drinks than they did two years earlier (Fooddive, 2020). Despite all this, a recent Mintel survey showed that consumers have a bias that plant-based proteins do not provide enough protein (Fooddive, 2020).

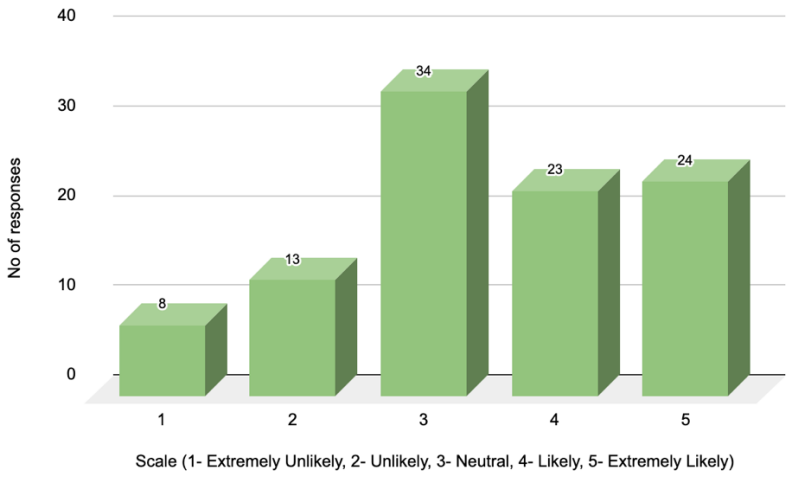


Figure 4. Bar graph showing the likelihood of respondents preferring to consume animal-based protein foods.

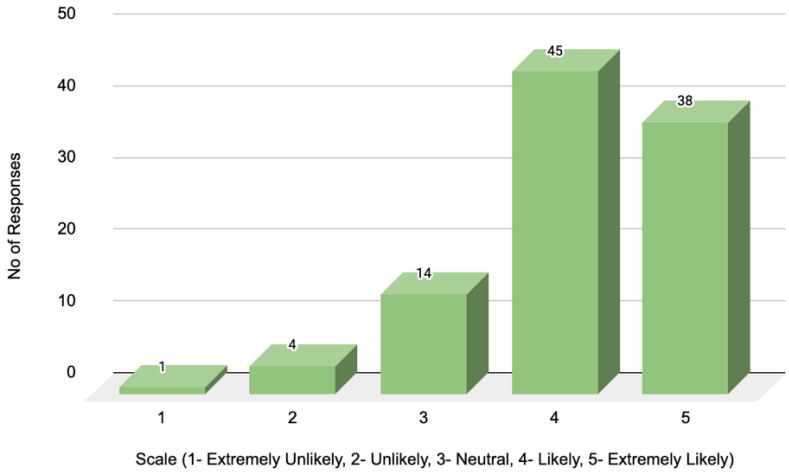


Figure 5. Bar graph showing the likelihood of respondents preferring to consume plant-based protein foods

According to the report, animal meat is the best protein source for 73% of meat eaters, 46%, and 49% of vegetarians, vegans, or pescatarians. When considering the survey results, 81% prefer to consume plant-based protein products, implying that they perceive plant-based proteins as the best source. However, this cannot be realistic, and the researcher believes that the respondents are biased towards plant-based protein diets because the majority of consumers are highly educated and are aware that plant-based proteins are healthier and better for the environment.

When asked if the participants prefer organic/highly processed/no plant-based foods, nearly 70% prefer organic foods over processed foods, 4% prefer processed foods, 19% prefer both processed and organic foods, and 7% replied "no," implying they prefer animal-based foods, as shown in **Figure 6.** and this explains that both developed and developing countries are becoming increasingly interested in organically grown food (Eyinade, Mushunje, & Yusuf, 2021).

Organic food is preferred by consumers because they believe organic foods have more attractive qualities than conventionally manufactured alternatives. Other product characteristics, such as taste, appearance, nutritive value, freshness, color, and other sensory characteristics, affect consumer preference in addition to food safety, health, and environmental issues (Eyinade, Mushunje, & Yusuf, 2021).

However, consumer preferences vary depending on the product and regions (Eyinade, Mushunje, & Yusuf, 2021). More precisely, the choice and attitude towards plant-based protein diets, or any diet for that matter, is maybe influenced by the availability of that particular food in a given region or sector. (Eyinade, Mushunje, & Yusuf, 2021)

When asked about the availability of more plant-based protein products in their specific market which is shown in **Figure 7**. 41% of respondents which includes participants from Western and Asian countries answered "Yes", 25% "answered need more products", 25% answered "maybe" and almost 10% answered "No" which implies that they couldn't find enough plant-based protein products in the market.

When looking closely at the results, many participants who answered "no" and "need more products" are from Asian countries especially India. Despite the availability of a wide range of plant-based protein products, many vegan and vegetarian Indian consumers expect more options similar to those offered in Western countries.

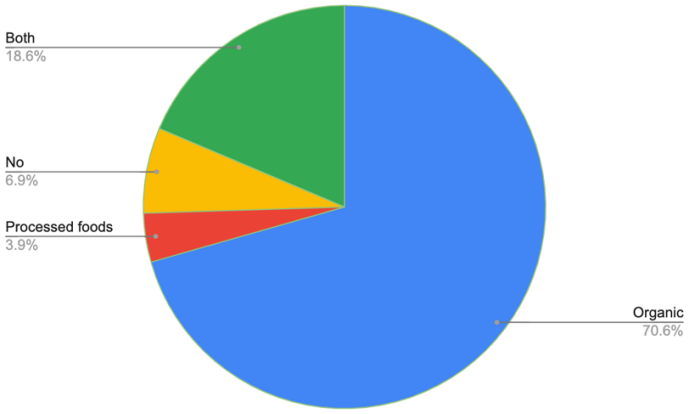


Figure 6. Pie chart showing respondents preferences of organic/highly processed/no plant-based products

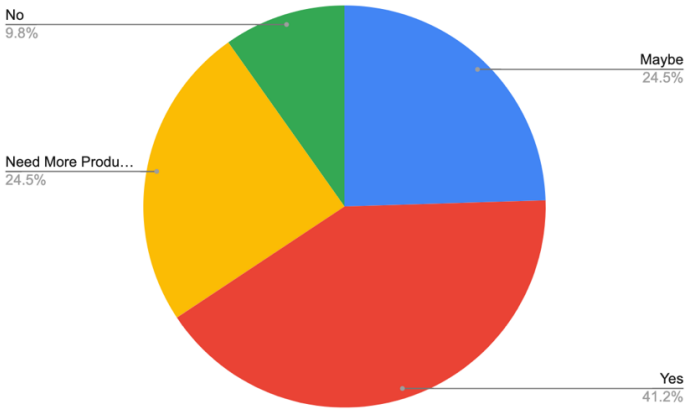


Figure 7. Pie chart showing the availability of plant-based protein products in the market from consumer's point of view

4.2.3 Consumer's opinion towards plant-based protein diet

The following are the findings from the survey conducted. According to 10% of the respondents, plant-based proteins yield slower results but are most effective and sustainable. Both animal and plant-based proteins have both pros and cons (Ismail, Senaratne-Lenagala, Stube, & Brackenridge, 2020).

Plant-based proteins, in particular, are considered incomplete proteins because they lack certain basic amino acids that the body cannot produce. However, by consuming a variety or combination of plant-based proteins, this can be avoided (Ismail, Senaratne-Lenagala, Stube, & Brackenridge, 2020).

Not all plant-based proteins are incomplete. Soybean, quinoa, and other grains are examples. Some respondents were more worried about the environmental consequences of consuming animal protein-based foods. They assume that plant-based proteins can help mitigate the negative effects that lead to the planet's deterioration.

Even 57% of respondents are likely to shift to a plant-based diet because it is safer for the environment as shown in **Figure 8.**

The majority of respondents believe that plant-based protein education is insufficient. People need to be more knowledgeable about their value and protein consumption, as most of them are more familiar with animal-based proteins.

According to them, plant-based proteins, in particular, should be promoted more. While some respondents believe that plant proteins are nutritious, they prefer meat to plant proteins due to taste and cost. According to the survey results, the cost of plant-based protein foods is exorbitant, and as a result, many consumers opt for animal-based protein products.

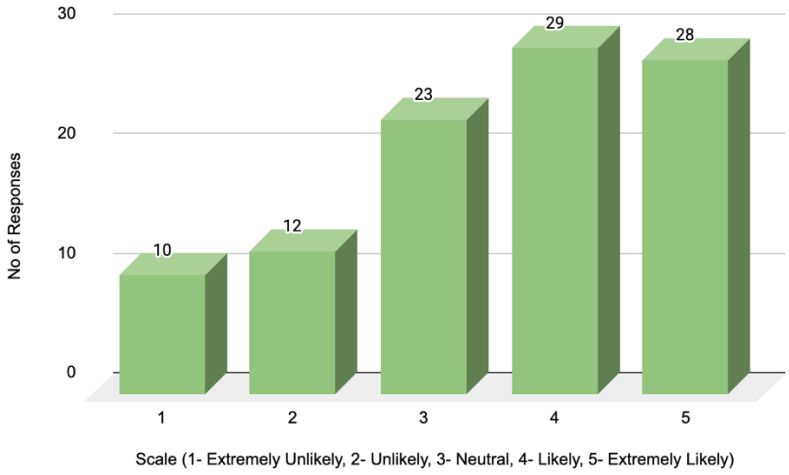


Figure 8. Graph showing the likelihood of respondents who prefer to shift to a plant-based protein diet because it is safer for the environment

A recent survey from the International Food Information Council found that in the previous year, almost seven out of ten people said they had tried at least one new plant-based protein. The majority of people (28%) sought a plant-based meat substitute. Many people tried new varieties of milk alternatives (24%) or other dairy alternatives (21%), as well as new varieties of packaged foods rich in plant proteins (21 percent) (IFIC, 2021).

According to a quarter of the participants, taste is the most important factor in deciding whether to eat plant-based or animal-based protein. Price (20%), protein form (19%), and healthfulness (17%) were all considered important factors (IFIC, 2021).

The results from this survey study when asked about the reason to buy plant-based proteins which is shown in **Figure 9.** state that 7% of respondents chose "health benefits" and 21% chose "health benefits" & "better for the environment". 11% of respondents chose "better for the environment" and Only 5% of respondents chose the "taste" factor.

It can be concluded that taste is the most important factor for consumers and that is the reason they prefer animal protein foods instead of plant-based protein foods. It can also be said that consumers buy plant-based proteins when they want to maintain a healthy and sustainable diet.

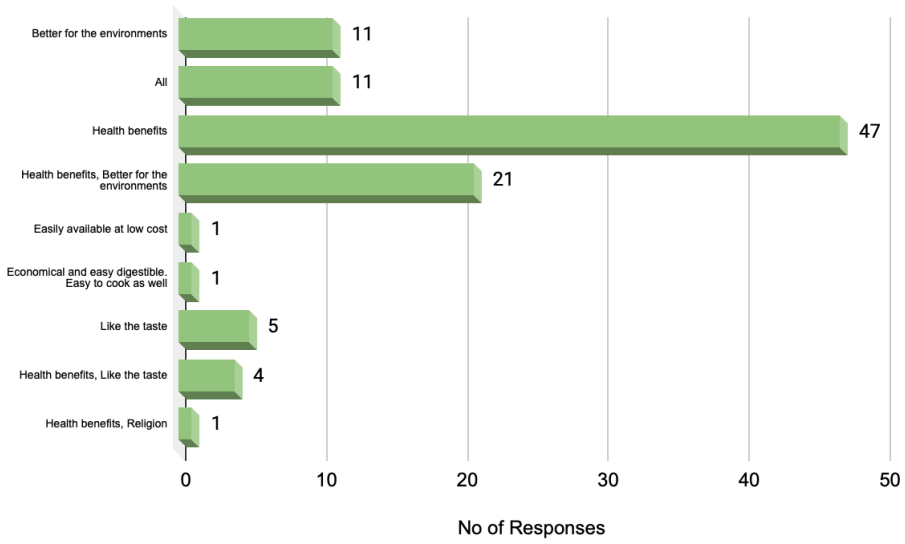


Figure 9. Graph showing why consumers buy plant-based proteins.

4.2.4 Handling of different diets (animal-based and protein-based) by consumers

As shown in the **Figure 10 and Figure 11**, almost more than half of the participants said they buy animal protein and plant protein foods weekly. Some of the participants also commented that due to the pandemic COVID-19 and with complete lockdown in some parts of the world, they couldn't buy fresh foods.

Despite this situation, 27% of respondents said they buy plant-based protein daily and 13% said they buy animal-protein foods daily. 16% prefer to buy plant-based protein monthly and 21% prefer to buy animal-based protein monthly.

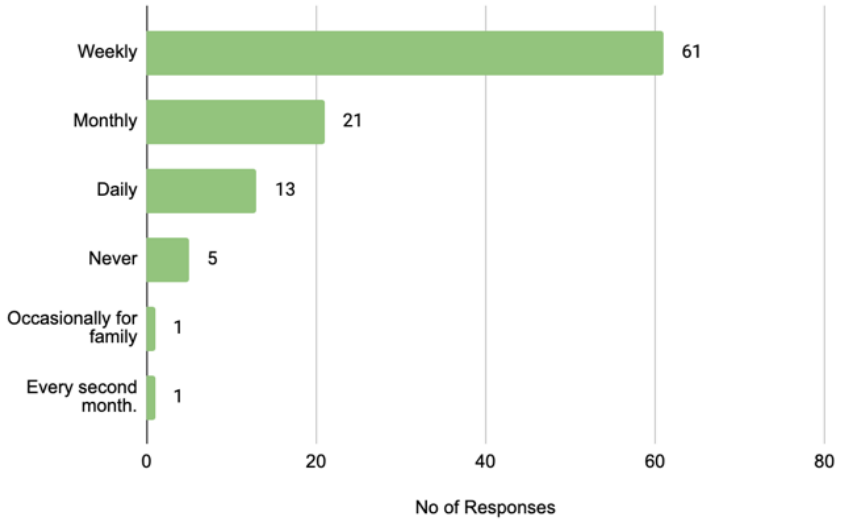


Figure 10. Graph showing how often consumers buy animal-based protein foods

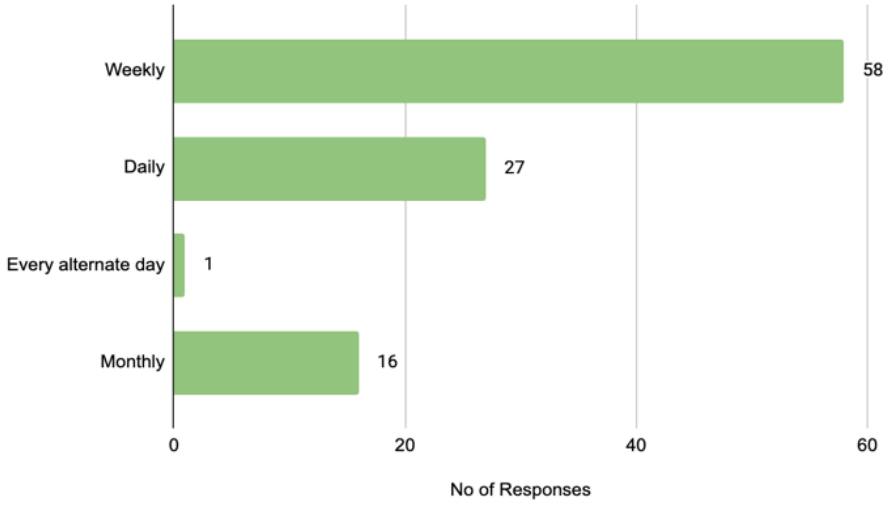


Figure 11. Graph showing how often consumers buy plant-based protein foods

Although most of the consumers buy these protein foods weekly, more than half of the participants check expiration dates when purchasing and consuming plant-based protein foods which is shown in **Figure 12 and Figure 13**. Almost half of the

participants don't want to buy plant-based protein foods when it is close to expiration dates and 45% answered that it depends on the product, and it shown in **Figure 14**.

However, the survey did not ask about consumer's thoughts about expiration dates when purchasing or consuming animal-based protein products. The results showed the importance of shelf life extension of products.

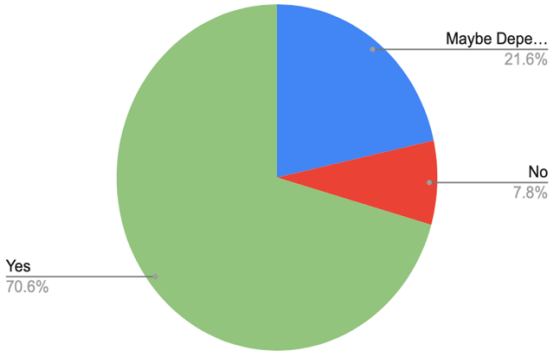


Figure 12. Pie chart showing Consumer's preference of expiration dates when purchasing plant-based protein foods

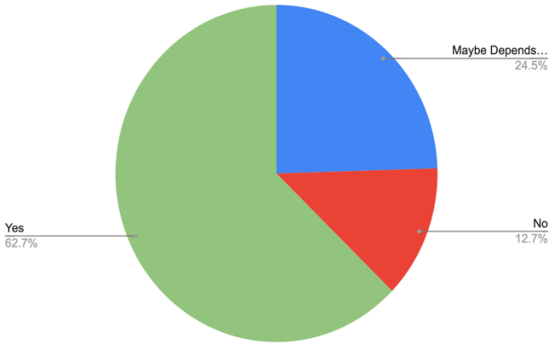


Figure 13. Pie Chart showing Consumer's preference of expiration dates when consuming plant-based protein foods

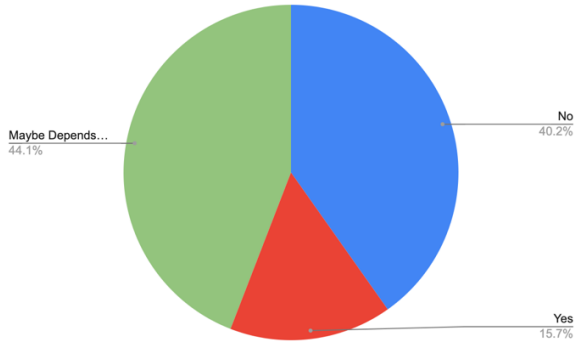


Figure 14. Pie chart showing Consumer's preference of buying plant-based protein foods close to expiration date.

Also when asked about storing these plant-based and animal-based protein products, almost two-third or 64% of the respondents preferred to store in a refrigerated environment which is shown in **Figure 15**. 19% chose dry storage whereas only 11% frozen. This shows that the consumer buy either fresh or chilled products more often than frozen product and majority of the consumers prepare these foods by steaming or frying which is shown in **Figure 16**.

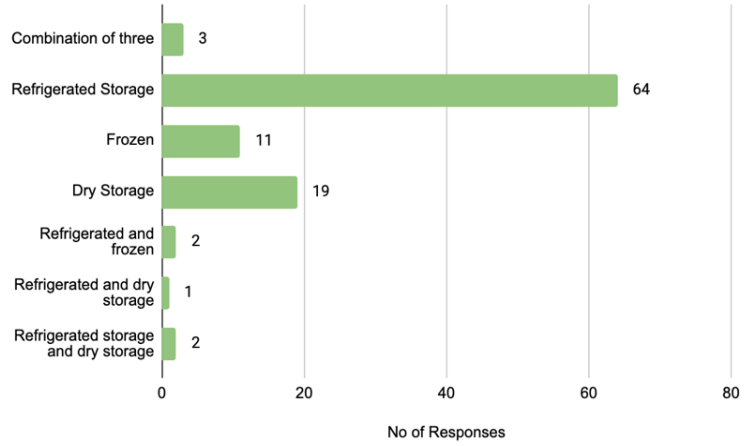


Figure 15. Graph showing Consumer's preference of storing animal-based and plant-based foods

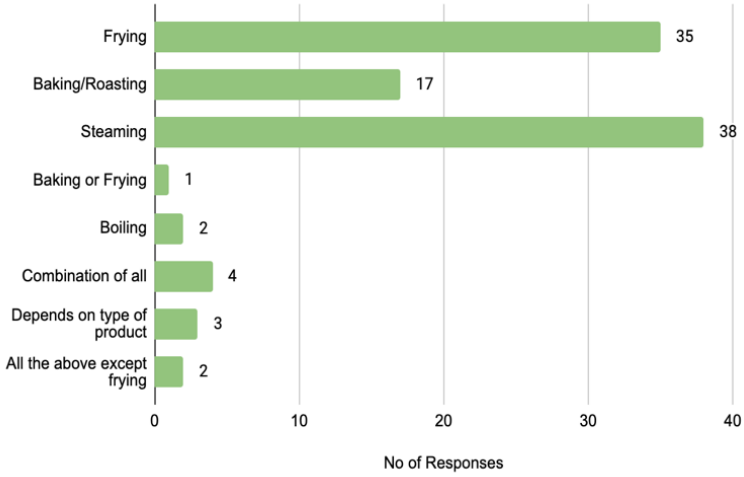


Figure 16. Graph showing Consumer's preference of preparing animal-based and plant-based foods

4.2.5 Consumer's viewpoint on currently available packaging materials for protein products

The responses from the participants when asked about the current available packaging for proteins products are presented in this section. The motive of asking this question to the consumers is to understand their opinion and preference towards current packaging for protein products. Additionally, it also aimed to know the specific consumer demand for packaging.

The majority of the respondents said that plastic packaging should be avoided and should be replaced with alternatives that are less harmful and more sustainable whereas some said that the currently available packaging materials are sufficient. Some respondents were more concerned about the product's shelf life. They discover that the shelf life of some products is insufficient, and they expect packaging to extend the shelf life of those products. However, the producer's perspective on packaging and shelf-life extension is explored in *Section 4.3.4 Currently available packaging and it's shelf-life extension*, which provides a more complete explanation.

Some of the respondents prefer air sealed packaging or vacuum packaging over other types of packaging for protein products. However, the handling and storage of products is difficult once the vacuum package has opened. Additionally, all kinds of protein product cannot be packed in vacuum packaging since different products have different characteristics. Other insights and viewpoints of the consumers about current packaging is listed in **Table 3.**

Table 3 Findings from the survey

1.	Barcode sensor that can be scanned by buyers to check the history of packaging and transportation of the food material. This way we can be sure that the vendor didn't tamper the package.
2.	Should be of proper labelling. Popular brands provide perfect labelling
3.	Preferring an air sealed package over loose products especially in tropical countries where the chance of contamination is high if not packed properly. Be it veggies or meat, the container used for packaging should be utmost clean and plastic products could be avoided.
4.	The packaging needs to be appealing as well as informative enough that it motivates to choose that very product over others. It also needs to be sustainable. Obviously, the packaging needs to serve the purpose of protecting the contents and keep them edible for a longer duration.

In addition to that, when asked about the importance of packaging while buying products at the store almost 83% of the respondents said packaging is really important to them when purchasing a food product which is shown in **Figure 17**. and almost 83% were likely to prefer to have sustainable packaging for plant-based products which is shown in **Figure 18**.

Additionally, when asked about sustainable labelling, 61% of the respondents said they prefer sustainable labelling as shown in **Figure 19.** A study explains that when environmental and ethical factors such as sustainable production and sustainable packaging are taken into account during the development of a product, it is provided a sustainable label (Grunert, Hieke, & Wills, 2014). However, the researcher claims that this information isn't always accurate because many of the respondents are educated and may have been biased when completing the survey questions.

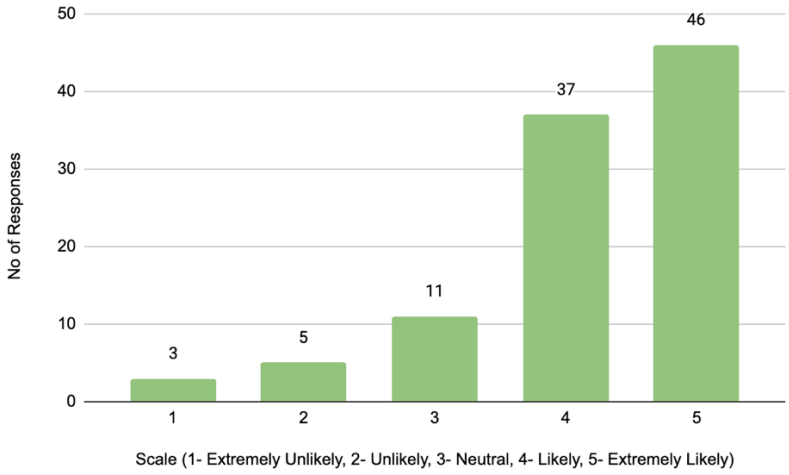


Figure 17. Graph showing Consumer's Importance of Packaging when purchasing a product

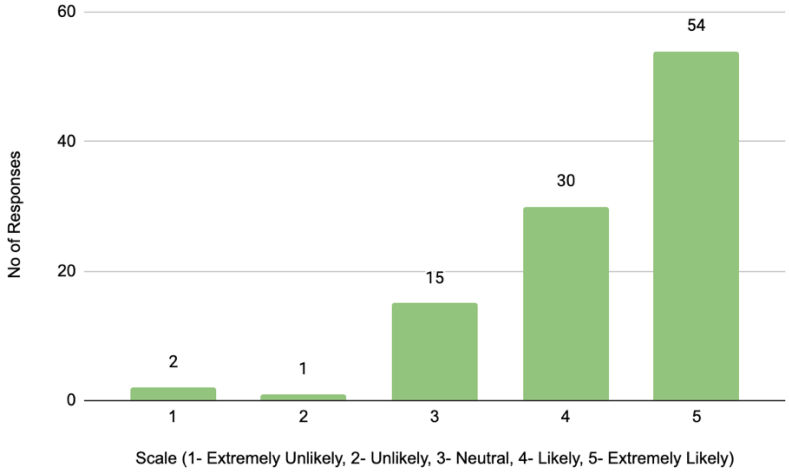


Figure 18. Graph showing Consumer's preference of Sustainable Packaging for Plant-based products

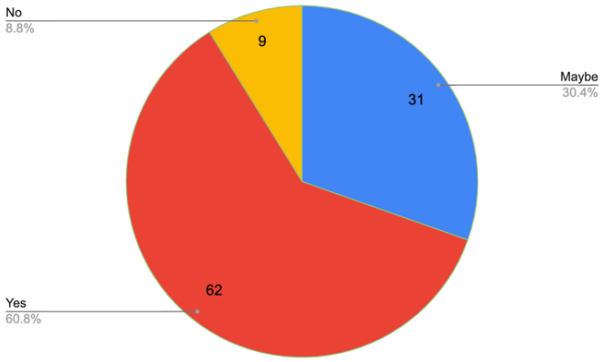


Figure 19. Graph showing Consumer's preference of sustainable labelling when purchasing the product

4.3 Qualitative Data Findings and Discussion

This section presents and addresses the findings from the study's interviews with industry experts. The main findings obtained during the qualitative study are presented in **Figure 20**.

1. Regulatory requirements for packaging materials have remained quite stable over the years.

2. Sustainability requirements have changed a lot over the years and industries are moving from plastic packaging to more circular materials.

3. Different types of materials are used for packaging such as plastic, paper, aluminium, glass etc., and same types of packaging is used for animal-based and plant-based protein products.

4. The packaging requirements change depending on the individual product and not solely on the protein source. In other words, it's not possible to generalize the differences in packaging barrier requirements for plant-based and animal-based protein products.

5. The current packaging materials are sufficient to extend the shelf life of frozen products but there is a need for new materials to extend the shelf life for ambient and chilled environment products.

6. The current packaging are not sustainable and has larger environmental impact. So, there is need for new materials that provides good barrier properties as well as low environmetal impact.

Figure 20. Main findings obtained during the interview

4.3.1 Packaging requirements over the past 5-10 years:

In order to design a package for a food product, it is necessary that the packaging material should meet certain requirements such as product requirements, supply chain conditions, regulatory standards and should promote sustainability. These requirements could have been changed as the world is driving through sustainability.

Since the study does not focus on packaging of a specific product, the interviewees were asked about the change in the regulatory and sustainability requirements over the past 5-10 years which could help in better understanding and development of sustainable packaging for sustainable diets.

The results which are shown in **Figure 21** state that the regulatory requirements of packaging haven't changed much during the past 5-10 years and the newly developed regulations also focused on plastic packaging than other materials such as paperboard, metal etc., Furthermore, as a drive toward sustainability, producers are trying to minimize packaging materials, particularly plastic packaging, and replacing it with more sustainable packaging that has a lower environmental effect and good protection properties. A detailed discussion regarding the transition of

regulatory and sustainability requirements over the years is carried out in the subsequent paragraphs.

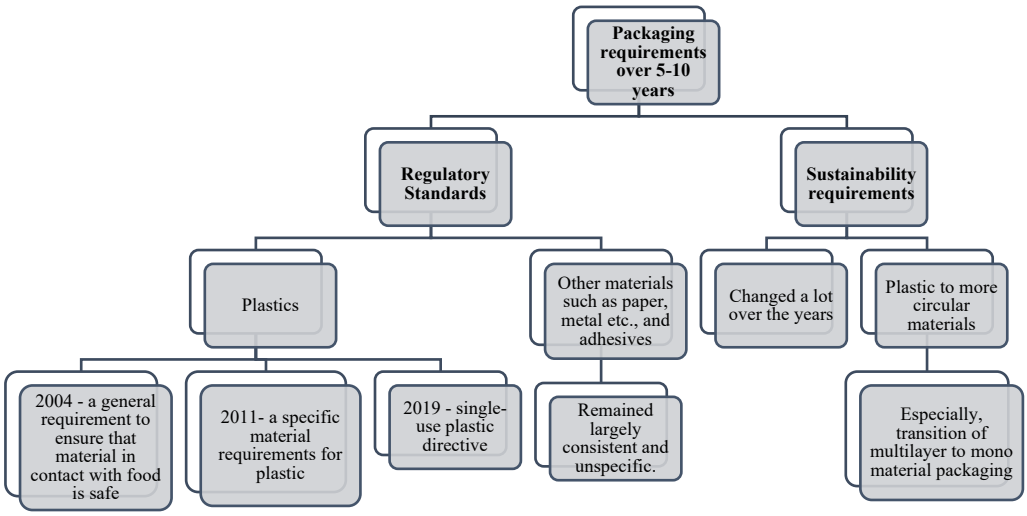


Figure 21. Flowchart showing the transition in regulatory and sustainability requirements over the past 5-10 years.

According to one interviewee, the regulatory standards have played an important role in packaging requirements, which haven't changed much and are quite stable for the last 10-15 years at least specifically in the EU (Widell, 2021).

For example, a general requirement was introduced in 2004 to ensure that the material in contact with food is safe and does not pass any contaminants into the food that could damage humans consuming the food, and a specific material requirement for plastic was developed in 2011 (Widell, 2021).

The intention of the EU was to develop specific requirements for paperboards, adhesives and many other materials but that never happened. Currently, the EU is doing a big review of all the food contact regulations. However, the regulatory standards for products other than plastics have remained largely consistent and unspecific (Widell, 2021).

The single-use plastic directive, which took effect in 2019, is not solely based on packaging, although it does affect certain packaging, with the aim of reducing plastic littering, so it has some effects on some packages. It's not a package-specific regulation, but it does have an effect from a sustainability standpoint (Widell, 2021).

It can be noted that the substance Poly((R)-3-hydroxybutyrate-co-(R)-3-hydroxyhexanoate), a biodegradable polymer obtained from microbial fermentation was approved by the European Commission in 2019 for use alone or in combination

with other polymers in the production of plastics intended to come into contact with dry or solid foods (EC, Food Contact Materials-Legislation, 2021).

This type of new advancements and legislation demonstrates the exciting future use of biopolymers in packaging. Existing and new EU legislation will change how plastic packaging is manufactured, used, and recycled in the EU. These EU regulations are currently being translated into national legislation across the EU. They would necessitate market changes from both manufacturers and consumers of plastic packaging (EY, 2021).

When discussing sustainability requirements, according to one interviewee, the requirements regarding sustainability have changed a lot over the last five to ten years. The term “sustainability” and “sustainable packaging” was aware but not super important 15 years ago (Eerden, 2021).

Efforts to define "sustainable packaging" by organizations such as the Sustainable Packaging Coalition (SPC) in the United States and the Sustainable Packaging Alliance (SPA) in Australia seek to express shared understanding within the industry, provide direction in decision-making, and shape vision for a more sustainable packaging framework (Nordin & Selke, 2010).

Moreover, the opinion and demand of consumers about sustainable packaging is changing a lot in the good direction that is from using more paper packaging to further circular materials (Eerden, 2021).

As the world becomes more industrialized and globalized, there is a greater need for light, low-cost packaging. From the perspective of the producer, there has recently been a change toward minimizing packaging, especially plastic packaging, in order to demonstrate that they are moving towards sustainability and economically safe/profitable practices (Thompson, 2021).

Not only from the perspective of producer, but there is also a global understanding of the problems associated with plastic waste, and local communities and governments are already enacting legislation to limit or prohibit the use of plastic such as (i) the Hong Kong government passed legislation requiring all retailers to charge consumers HKG 5 for each bag that is considered a plastic bag – and any bag that contains any plastic is considered a plastic bag, (ii) in certain parts of the United States, stores are no longer allowed to sell plastic bags, (iii) laws are also in effect requiring the use of paper with a minimum of 40% recycled content in packaging products and (iv) the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA), as well as many other European governments, are pushing for a substantial reduction in the usage of plastic bags (PROCOS, 2017).

Additionally, five to ten years ago, convenience and on-the-go packaging was important but now due to the sustainability drive, the importance of convenience packaging are not highlighted but new materials and new techniques are growing fast (Eerden, 2021).

New legislation such as the Paris Agreement on Climate Change, and the UN Sustainable goals, the concept of circular economy etc., is contributing to the development of these new sustainable materials and techniques (Erixson, 2021).

These developments also include transitioning multilayer packaging to mono material packaging for easy recycling and recovery (Mauritsson, 2021).

According to the interviewee, the key priority for IKEA seven years ago was to refine pallets, a tertiary packaging, in order to avoid transporting too much air, which was the base of flat packaging (Ringdahl, 2021).

Gradually, optimization of materials which were in use started to use more sustainable resources and the first move was to go over the drinks and try to understand what kind of drink packaging is best in various parts of the world using life cycle analysis (Ringdahl, 2021).

4.3.2 Types of packaging materials for plant-based and animal-based

To understand the protective requirements of different diet packaging, it is vital to understand the type of packaging used for these diets. Since the study involved exploring the barrier requirements of packaging for plant-based protein products, the interviewees were asked about the types of packaging used for plant-based protein products and the results are discussed below.

Overall, the results indicate that liquid products, such as beverages, are packaged in paper cartons with a layer of plastic and aluminum, whereas frozen products are usually packaged in plastic packaging. Frozen food is sometimes packaged in paper cartons, whereas specifically PLA is used to pack both fresh and frozen vegetables and meat products. It further states that EVOH combined with LDPE film provides enough protection for food goods in general, and that it is widely utilized in most industries.

As mentioned earlier in the chapter *Literature Study*, the primary food packaging is commonly made of paperboard cartons, metal cans, plastic pouches, glass bottles and so on. According to the interviewees, the largest food exporter of Sweden, IKEA, uses all kinds of packaging materials such as plastic, metal, glass paperboard, paper and different combinations of all this. There are different ranges of foods-chilled food, ambient environment food and frozen food and the packaging materials are based on this criteria (Widell, 2021) (Eerden, 2021).

The same material (plastic bags) is used for both plant-based and animal-based protein foods (Ringdahl, 2021). Some of the examples discussed during the study are shown in **Table 4**.

Table 4. Table showing different animal-based and plant-based products discussed during the study

	Food Product	Types of Packaging Material used
1.	IKEA's Veggie Hot dog	Standard Packaging, a plastic packaging
2.	Hot dog	
3.	IKEA's Plant ball (HUVUDROLL)	Plastic Packaging
4.	IKEA's Meat ball	
5.	Cow milk	Tetra Brik Aseptic
6.	Oat milk	
7.	FRÖMAGE	Brown paper with thin layer of polyethylene.

Since IKEA is not a local supplier, the products are shipped all over the world. So, it is necessary for most of the products to have a long shelf life. This aspect also influences the choice of packaging (Eerden, 2021).

For example, IKEA's Veggie hot dog, which is a plant-based hot dog containing lentils, kale, quinoa, onions and wheat protein, is packed in a standard packaging, a plastic packaging. The products meat balls, plant balls (HUVUDROLL), and fresh salmon are exported globally and require a long shelf life (Ringdahl, 2021).

Since the meat balls and plant balls are kept in a plastic packaging and frozen environment, it helps in longer shelf life. It is seen that the packaging of fresh salmon should be more optimized, and it is explored right now how other packaging alternatives can help extend shelf life (Ringdahl, 2021).

Supporting the above information, another interviewee from ICA discussed that, for packing fresh products some type of material is needed with good barrier properties. But for packaging frozen products, there is no need for high barrier materials. It can be LDPE film like a pouch, PLA packaging etc., (Erixson, 2021).

A study also suggests that PLA can be used to make lightweight films, extruded bags, yoghurt cans, bottled water and juices, cups, lunch boxes, and can also be used to pack fresh vegetables and fruits (Süfer & Celebi Sezer, 2017).

PLA may also be used to package frozen foods like peas, meat products and other vegetables, but not sharp items like shrimp with shells. Other materials are needed for these items. There are also carton solutions in the freezer. In the freezer, mostly virgin paper materials are used instead of recycled paper. If recycled paper materials

are used, a plastic barrier is needed to ensure that the substance does not come into contact with the food (Erixson, 2021).

This, though, is dependent on the product/raw material. A pie made by Orkla Foods, for example, is placed in aluminum trays and packed in a virgin carton box (Erixson, 2021).

For packaging liquid products such as oat milk, the Swedish oat drink company Oatly, which is the largest producer of oat milk uses Tetra Brik Aseptic for packaging. This packaging is made of paperboard, polyethylene and aluminum. Oatly uses carton packaging as primary packaging with as much as possible renewable content. Tetra Brik with gable top packaging is used for chilled segments whereas smaller Tetra Brik packaging is used for cream, vanilla sauce etc., Additionally paper-based/ paper cups are used to pack fresh yogurts and for smaller portions, a plastic cup is also used (Kadir, 2021).

FRÖMAGE, a home-made plant-based product, which is a vegan soft cheese alternative made of cauliflower, sunflower and hemp seeds. It was created by *Helen Thompson*, MSc in Agricultural Science and founder of Bloomingood food. This vegan soft cheese is packed in a brown paper lined with a thin layer of polyethylene and sticker to hold the packaging (Thompson, 2021).

In general, cheese is packaged in a variety of ways, depending on the region, its level of development, and how the food is consumed. For example, flexible flow wrap packages, vacuum wrapping, M.A.P packaging system, and various forms of re-closable packages (PFM, 2021). However, according to Thompson, brown paper with PE lining is now more convenient, but they are working on using glass jars instead so that they can be reused. This package, according to her, has an adequate shelf life of four weeks.

Bloomingood food is a small-scale company with a smaller chain and local food network, with little time between manufacturing and sales. But if it is to be produced on a large scale, then four weeks of shelf life might not be sufficient. With the motive of increasing the shelf life to 6/8 weeks, wax paper, plant-based PLA, PE packaging materials has been tested up to 12 weeks (Thompson, 2021).

According to her, there was sign of rancidity and the product didn't dry out after 12 weeks. There was no presence of high-risk bacteria but after 6 weeks there was mold growth in some of the products. It is possible that this is due to the lack of use of properly sterilized devices. It was freshly prepared in the kitchen and the wrapping of the product is also done by hand. It would be possible to produce goods with a longer shelf life if the environment was more technologically advanced and the packaging technology was more complex (Thompson, 2021).

Another important finding is that EVOH, Ethylene-Vinyl alcohol (5%) together with LDPE is a good barrier and is used in industries worldwide. Specifically, 2% (3-5 μ) EVOH is used in most of the industries in Sweden. (Mauritsson, 2021).

According to a study EVOH has one of the lowest oxygen permeability rates for polymers and excellent barrier properties against other gases including nitrogen and carbon dioxide (Maes, et al., 2018). Another study states that LDPE film is useful because of its moisture barrier properties, handling efficiency, heat sealing properties, and relatively high tensile strength. The combination of LDPE and EVOH into a single structure results in a perfect film for food packaging (Ge, Fortuna, & Lei, 2016).

4.3.3 Differences in the requirements of packaging for plant-based protein and animal-based protein foods (Specifically barrier requirements)

The packaging requirements for plant-based protein products are expected to different from animal-based protein products. The interviewees were asked about the differences in the requirements of packaging for plant-based protein and animal-based protein foods (Specifically barrier requirements) in order to understand the differences and explore the barrier requirements of different diets. Understanding these differences would further assist in developing sustainable packaging with good protection properties.

The study reveals that the requirements of the packaging changes depend upon the individual product and not solely on the protein source. In other words, it is not possible to define in general the differences in the barrier requirements of packaging of plant-based and animal-based protein products. (Eerden, 2021) (Erixson, 2021) (Kadir, 2021) (Mauritsson, 2021) (Ringdahl, 2021) (Thompson, 2021) (Widell, 2021)

According to one interviewee, the protection methods and how the food is packaged is important for packaging. Is the product frozen, is it packed hot, is it stored in ambient temperature all these factors influence the choice of the packaging material (Eerden, 2021).

A study show that the final taste, consistency, and shelf life of the final product is influenced by the packaging materials and storage technologies used (Zheng, Regenstein, & Teng, 2020).

Another interviewee stated that the packaging choice is also affected by the product characteristics such as fat content, water content, water activity, acidic content, dryness, etc., (Widell, 2021). But the same interviewee stated that dairy milk and milk alternatives such as oat milk and soy milk have the same packaging (paper cartons) which is contrasting to the previous results (Widell, 2021).

According to her, the most important barrier for liquid products like milk is to take care of the moisture content, light sensitivity and oxygen. The package should be designed in such a way that it protects the product from light oxidation, contamination from microorganisms and extends the shelf life (Widell, 2021). Diary

milk and its analogs have almost similar product characteristics; however, more research is needed to elaborate this discussion.

Another example is the recently developed IKEA's plant-based product, HUVUDROLL is frozen. The barrier and shelf-life conditions are the same, and the packaging is similar to that of meatballs (Ringdahl, 2021).

The production line is different for both the products. When a product is claimed to be vegan/vegetarian, it needs to have a separate production line than meat products (Erixson, 2021).

Another example could be plant-based fresh Tofu and Dairy cheese. A study show that the high moisture and protein content creates an ideal environment for the development of microorganisms, and hence the shelf life is affected even though refrigerated (Zheng, Regenstein, & Teng, 2020).

In both the cases modified atmospheric packaging (MAP) with the required amount of carbon dioxide and nitrogen is used. Hard cheese such as Tofu and Cheddar needs high atmospheric carbon dioxide which helps in the shelf-life extension of 2-3 weeks in air to ten weeks in MAP. In terms of microbiological and sensorial aspects, the MAP technique has been shown to be effective in extending the shelf life of cheese samples, with suggested gas mixtures varying depending on cheese form, manufacturing conditions, initial microbial load of cheese, packaging materials, and storage conditions, as well as post-processing activities (Zheng, Regenstein, & Teng, 2020) (Khoshgozaran, Azizi, & Bagheripoor-Fallah, 2012) (MOCON, Modified Atmosphere Packaging of Cheese, 2012).

Similarly, according to Thompson, when comparing FRÖMAGE with fresh cheese, the requirements of packaging are very similar. Both products need a strong moisture barrier to prevent microbial growth and mould, as well as to maintain the product in good shape to avoid dehydration (Thompson, 2021).

4.3.4 Currently available packaging and it's shelf-life extension

As previously mentioned, packaging is critical in extending the shelf life of a food product. The relationship between current packaging materials and shelf-life extension was discussed with interviewees in order to determine whether the available packaging materials are sufficient for extending the shelf life of available plant-protein products and to know whether there is need for new materials.

The findings show that currently available packaging materials are suitable for frozen products, but better packaging solutions are needed for products that are stored in ambient and chilled environments to extend their shelf life. It also includes those plastics have been widely employed to enhance the shelf life of food

products due to their excellent barrier qualities. These materials, on the other hand, have a bigger environmental impact. As a result, substantial research is being performed to develop bio-based polymers with low environmental effect in order to extend product shelf life. The overall findings of current packaging materials from the industry perspective are shown in **Figure 22**. A detailed discussion with various examples is shown in the following paragraphs

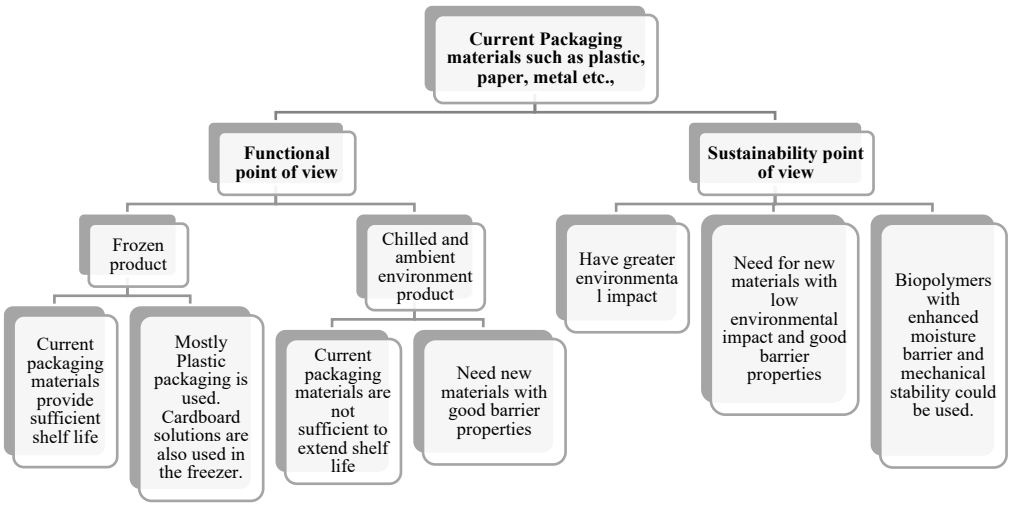


Figure 22. Flowchart showing the overall view of current packaging materials from the industry perspective

According to one interviewee, the current packaging (plastic, paperboard, etc.,) is sufficient and it provides a long shelf life at least for frozen products (Eerden, 2021) (Widell, 2021). Not only good packaging but also maintaining an appropriate low temperature is also necessary for shelf-life extension (Widell, 2021).

For ambient and chilled environment products, there is need for new packaging materials generally (Ringdahl, 2021). For example, as previously mentioned fresh salmon. IKEA is trying to extend the shelf life of fresh salmon using better packaging. Another example could be Seaweeds. The glass jar packaging protects the seaweeds from physical damage, acts as an oxygen, moisture barrier but it is heavy to transport. IKEA is expected to develop easy handling packaging for these seaweeds (Widell, 2021).

According to Henrik, at IKEA, single use plastic bags should be replaced with more sustainable packaging solutions because it is not sustainable to use plastic packaging for products that are used once. It is not recyclable and creates environmental impacts. It could be replaced with recyclable plastics or other alternate materials with less environmental impacts. (Ringdahl, 2021).

The current available packaging is adequate, but there is room for improvement when it comes to more sustainable packaging choices (Thompson, 2021). It is also impossible for manufacturers to produce without using plastic. That presents a challenge for plant-based protein foods, which are safer for the environment and are supposed to come in more sustainable packaging (Thompson, 2021).

According to the interviewee from ICA, plant-based products are needed and processed in smaller quantities than the meat industry. The product itself is pricey. It is also costly to use sustainable packaging. The target buyers are willing to spend more for products with less environmental impacts, but as they stand in front of the shelf in the shop, they are hesitant to pay the additional 5-6 SEK. But this situation is changing as demand for sustainable packaging is increasing from the consumer's side (Erixson, 2021).

For example, as mentioned earlier in the Section 4.2.4, almost 83% of the survey respondents said packaging is important and prefer to have sustainable packaging at least for plant-based products.

In IKEA, shelf life of 12 months is mostly aimed for frozen products. This could not be the same in all parts of the world. In some countries, it is not possible to have more than 15 months of shelf life. The shelf-life improvement is needed for ambient and chilled environment products, but this also depends on consumer perception. For example, consumers will think twice to buy a fresh product which is already two/three months old (Ringdahl, 2021).

For some of the aseptic packed products at OATLY, the shelf life is one year and for chilled products, it is a couple of weeks (Kadir, 2021).

For ambient storage, a better barrier is required to have a prolonged shelf life which can be achieved by UHT and Aseptic packaging. One issue with this type of carton packaging is it comes with multilayer packaging (aluminum, polyethylene and paperboard). The aluminum and plastic in these packaging makes it difficult to recycle. There is preference for mono materials for easy recycling but using paperboard as a mono material does not provide sufficient shelf-life extension (Kadir, 2021).

As a result, and as per the study suggested there is significant interest in replacing some or all of the conventional non-biodegradable polymers, especially in applications with short life cycles, such as packaging, or where recycling is difficult and/or inefficient (Volpe, Di Stasio, Paolucci, & Moccia, 2015) .

To achieve that one option may be to use less plastic or alternative forms of plastic in carton packaging, or to use another material instead of aluminum, or to use bio-based polymers (Ringdahl, 2021).

Additionally, a study showed that natural polymers (polyhydroxy butyrate (PHB) and its copolymers) and aliphatic polyesters (polycaprolactone, polylactic acid) are

biodegradable, but their high cost prohibits their widespread commercial use, limiting them to niche applications (Volpe, Di Stasio, Paolucci, & Moccia, 2015).

Among the biomaterials currently on the market, those produced from renewable resources, such as starch-based products, are the most popular and cost-effective (Volpe, Di Stasio, Paolucci, & Moccia, 2015).

Unfortunately, starch has certain disadvantages, such as hydrophilic activity (poor moisture barrier) and mechanical properties that are inferior to traditional non-biodegradable plastic films used in the food packaging industry. These issues can be overcome by dispersing functionalized layered silicates (clay minerals) through melt processing techniques in thermoplastic starch (TPS)-based nanocomposites (Volpe, Di Stasio, Paolucci, & Moccia, 2015).

4.3.5 Currently available packaging materials and Producer's satisfaction

Plastic, paperboard, glass, aluminum, and other commercially existing packaging materials are considered to be highly functional. However, in terms of sustainability, these packaging materials have major disadvantages. Therefore, the interviewees, who are industrial experts were asked about their satisfaction with the current packaging materials and their viewpoint on it.

According to one interviewee, with increased market demand for sustainable products and packaging, manufacturers are finding it difficult to meet the requirements of sustainable labelling by using these materials (Widell, 2021).

Additionally, many small-scale innovators or producers are struggling to find good or suitable packaging. The aim of most of the small-scale producers is to produce sustainably and contribute to the circular economy (Thompson, 2021).

According to another interviewee, more innovations are taking place in meat products and packaging, despite the fact that meat products cause environmental impacts because meat is where the money is. Vegan foods are low in volume. As a result, there haven't been many advancements in vegan food packaging. However, the field is evolving, and several manufacturers are working towards striving for a circular economy by following sustainable food consumption and production (Erixson, 2021). However, there will be a greater emphasis on plant-based goods in the future. The goal for the future is to improve current packaging materials and introduce new packaging materials.

As a first step, producers make sure that they get sufficient shelf life for the food products to handle the logistics of the products and to avoid food waste. Once this criterion is fulfilled, producers work to optimize in order to have a little effect on the environment and shouldn't cost more (Ringdahl, 2021)

For example, IKEA is attempting to move away from glass and aluminum packaging and toward more recycled PET for drinks. The company is attempting to use more aluminum cans, which could have a lower overall impact when compared with plastics, as well as to place a greater emphasis on recycling in the United States (Ringdahl, 2021).

4.3.6 Consumer expectations and response to the current plant-based food packaging from the producer point of view

Consumers who are looking for plant-based protein options, according to the interviewee, are looking for smaller servings rather than family bags (Eerden, 2021). In general, consumers want products that are easy to handle and don't need a lot of packaging. However, certain items require the addition of packaging materials to secure them. Consumers might expect a plant-based product to come in natural-material packaging, such as a carton, and then realize that this isn't always true (Ringdahl, 2021).

But, at the very least, expect producers to do their best to promote development. Biobased plastics that are viewed from a market standpoint pose a significant challenge. It's beneficial because it's made of non-fossil materials. However, it also has a concern with plastic in terms of life cycle research (Ringdahl, 2021). The environmental impact of non-biodegradable plastics is equal if they end up in nature irrespective of if they are made from renewable or non-renewable sources. According to the interviewee, IKEA is more concerned about recyclability of packaging materials than about trying to find new biobased materials with sufficient barrier properties (Ringdahl, 2021).

5.Conclusion

This chapter restated the research objectives, methods used in the study and the summary of overall arguments and findings in the summary part. Finally, it is followed by reflection and further research part.

5.1 Summary

The consumption and production of unhealthy diets in any way is harmful to humans and the environment. A diet rich in plant-based protein with minimal animal sources confers both improved health and environmental benefits. The consumption of plant-based protein food, a sustainable diet which is produced and packaged in a sustainable way is considered as a win-win situation.

Animal-based proteins and plant-based proteins might have different product requirements, supply chain environments, and consumption patterns. This implies that the packaging of plant-based foods must now meet new standards.

The research studies how the requirements of the packaging materials change for plant-based protein diets. The objectives of the study include, understanding the consumer's opinion towards animal-based and plant-based proteins and understanding the requirements of the packaging materials of plant-based and animal-based protein food products from the perspective of consumer and industry.

In analyzing data and answering research questions, the research uses a mixed-methods approach. The quantitative data about the consumption perceptions is collected using the consumer survey whereas qualitative data about industry perception is collected using expert interviews. Since the data was collected using non-random snowball sampling techniques, the quantitative portion of the analysis results from the disadvantage of a non-representative sample.

Quantitative results showed that there is nutritional transition taking place and the consumers are trying to shift from animal-based to plant-based protein foods to create a sustainable future. However, due to various factors such as cost, unavailability of plant-based foods in their region, taste and protein content consumers tend to consume more animal-based products which can be seen in the increased meat production. It also showed the negative opinion about plastic packaging and the consumer's interest and need for sustainable packaging.

According to the qualitative findings, the packaging materials are chosen based on the physical and chemical properties of the food such as water activity, moisture content, fat content etc. how it is packaged, and the storage conditions. Different packaging materials have different barrier properties. Both animal-based and plant-based protein diets use the same form of packaging (plastic/paper in most cases), and the packaging varies depending on the specific product rather than solely on the protein source. So, barrier requirements of packaging material vary depending on the product.

To conclude, it can be said that the currently available packaging materials are sufficient for frozen plant-based proteins from the functional point of view, and there is a need for new packaging materials for packing ambient and chilled products to increase the shelf life of the product. From the sustainability point of view, there is a need for new sustainable materials that should offer good barrier properties as well as good recyclability without causing environmental effects.

5.2 Reflection

The study focusses on exploring requirements of packaging due to a shift to plant-based proteins from the perception of industry and consumers which would help in designing a sustainable packaging material for future diets with low environmental impact which could be plant-based diets. As stated previously, surveys and interviews were conducted to fulfill the objective. In this process, how to design survey questions specifically in relation to the subject of study and how to prepare simple and valuable questions for participant's convenience have been learnt. Additionally, knowledge about different modes of survey and the pros and cons of conducting a global survey has also been gained during this study. Furthermore, a picture of consumer's attitude and opinion towards different diets has been known. By conducting interviews, building appropriate questions, planning ahead, summarizing information obtained from the interview, taking proper notes and scripting them with minimal manual work (using software/applications), choosing interviewees relevant to the subject of the study have been learnt. In addition, knowledge has been obtained on how to compare and analyze different kinds of information collected during the survey and interview, and how to interrelate them to achieve the objectives of the study.

The survey provided limited generalizability since the sample was not representative mainly involving young respondents. The reason identified for the overrepresentation of young respondents was how and where the survey had been posted. In future, when conducting surveys, other sources than social media such as utilizing third party partners, seeking help from different websites, offering discount or gifts, e-mail group of respondents and so on should be used. The methodology in

this study doesn’t involve statistical analysis and thus, in future it would be advisable to conduct statistical analysis of survey results.

To better assess consumption trends of animal-based and plant-based protein diets, the survey questions might be structured and grouped more specifically. To increase the number of respondents, the survey could be released in multiple languages. Because only seven interviews were conducted throughout this study, if the study was repeated, a larger number of participants, notably from varied industrial backgrounds, should be selected for the interviews. The interview questions could also be modified to gain a better understanding of the barrier needs for the packaging of a specific plant-based product, which would aid in drawing more detailed conclusions.

However, this research study can be considered as a starting point in this area of study and the purpose was considered not to draw conclusions.

5.3 Further Research

Given the study's limitations, future research should concentrate on a specific plant-based protein product. It should also compare and contrast specific animal and plant proteins, as well as their packaging requirements. Dairy milk and dairy milk substitutes are one example (cow milk and oat milk). It would be interesting to do a more detailed comparison of the product characteristics of cow milk and oat milk and their relation to shelf life and choice of packaging.

Furthermore, because this study looked at the packaging requirements for plant-based and animal-based protein products from the consumer and industry perspectives, future research could include conducting a life cycle analysis (LCA) for the packaging of a specific plant-protein product to better understand the environmental impacts throughout the product's life cycle. This could include analyzing different packaging options for a given plant protein and developing a better solution that can be further refined to have a lower environmental impact. This would help in the development of appropriate sustainable packaging for sustainable products in the future.

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