A Comparative Study of Sustainable Packaging in the Functional Food Industry

Lappeenranta–Lahti University of Technology LUT

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Amir Reza Mohseni

Examiners: Professor Ville Ojanen / Dr. Sina Mortazavi

ABSTRACT

Lappeenranta–Lahti University of Technology LUT
LUT School of Engineering Science
Industrial Engineering and Management

Amir Reza Mohseni

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This master's thesis conducts a comprehensive evaluation of the present status of three prominent companies specializing in sustainable packaging solutions. The objective is to elevate the reader's awareness of noteworthy initiatives and research within this domain, while also identifying potential gaps and issues. The study employs a dual methodology, comprising in-depth interviews with industry experts and a meticulous review and evaluation of the latest published documents. By synthesizing these insights, the research aims to enhance the depth and validity of its findings, ultimately providing a strategic overview or research plan for each of the examined companies.

The culmination of this thesis includes a succinct summary and a comprehensive integrated table for improved accessibility. The article concludes with specific findings derived from the research and a robust set of references, contributing to the academic discourse in the field of sustainable packaging solutions.

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Abbreviations

Fig	Figure
RFID	Radio frequency identification
FDA	U.S. Food and Drug Administration
EPC	The Electronic Product Code
SusAF	The Sustainability Analysis Framework
Mton	Million tons
CNF	Cellulose nanofiber
HDPE	High-density polyethylene
wt	Weight
EU	The European Union
PET	Polyethylene Terephthalate
PolyAl	Polymer-aluminium
EBIT	Earnings Before Interest and Taxes
SDG	Sustainable Development Goals

Abstract

Acknowledgments

Symbols and abbreviations

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1 Introduction

In the ever-evolving world of the food industry, two vital factors have risen to prominence, creating the atmosphere that today's consumers desire and the products they love. The first of these factors is the age-old practice of fermentation, a process deeply rooted in history, possibly tracing its origins back to the Indian civilization. This age-old technique harnesses the metabolic properties of microorganisms within various foods. Interestingly, it's a practice that may still hold untapped potential (Farnworth and Edward, 2008).

On the flip side, the contemporary consumer market is undeniably influenced by the art and science of packaging. The choice of packaging materials and design exerts a significant influence on consumers' purchasing decisions. Beyond its primary role of protecting the product, packaging communicates its purpose and appeals to consumers, profoundly shaping their perception. Furthermore, it substantially contributes to opening profitable markets for businesses (Peters, Higgins and Richmond, 2013). In addition, "Functional foods," often vaguely defined, are those believed to extend beyond basic nutrition for positive health effects. A suggested definition describes them as novel foods intentionally formulated with safe and potent concentrations of substances or microorganisms to enhance health or prevent diseases. These added components may include nutrients, fibre, phytochemicals, or probiotics (Temple, 2022), Packaging for food has become crucial in fulfilling both functional and essential purposes, encompassing preservation, containment, transportation, storage, and marketing. Additionally, it serves to provide information about the packaged product. Functional packaging offers extra advantages, such as enhanced convenience and user-friendliness, while essential packaging components are indispensable for ensuring the quality and safety of the food (Government Services Canada, 2022). Food packaging relies on materials like metal, glass, plastic, paper, and composites. Choosing the right material involves considering product nature, nutritional content, shelf life, target audience, storage, consumer perception, and regulatory compliance. This selection is integral to processing operations (Temple, 2022).

In our discussion, we delve deep into the crucial facets of food innovation, with a specific focus on functional foods and sustainable packaging. These facets are intricately linked to Sustainable Development Goals 2, 3, and 12 for 2030, as illustrated in Figure 1. First and

foremost, the emphasis on functional foods underscores the paramount importance of ensuring accessible and nutritious food sources, aligning perfectly with: Zero Hunger. Functional foods, with their positive impact on human health and overall well-being, also resonate with SDG 3—good health and well-being. Secondly, the sustainable packaging methods and materials we explore here closely align with the principles of SDG 12 (Responsible Consumption and Production). These innovations promote responsible and sustainable practices within the food industry. They not only contribute to reducing food waste but also advocate for the adoption of environmentally friendly packaging solutions. In doing so, they actively contribute to fostering a healthier and more sustainable future, in line with the objectives outlined in the United Nations' 2030 Sustainable Development Goals (UNITED NATION, 2023).

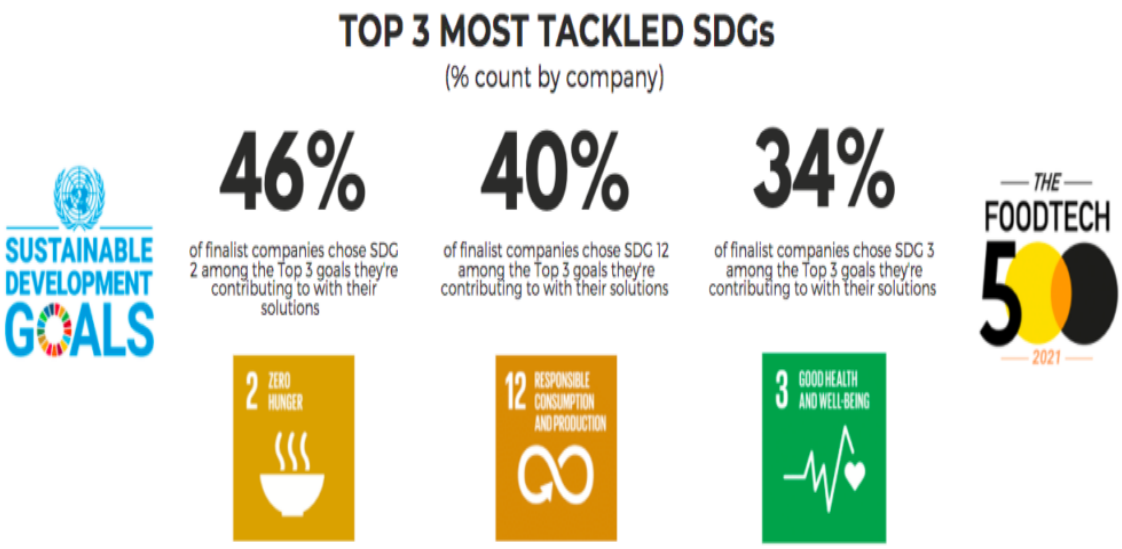

Figure 1,Related Sustainable development goals2030, ***(Forwardfooding Admin, 2022)***

Food packaging stands as an indispensable facet of modern life, continually adapting to meet the needs of consumers and the demands of society. Its role in preserving the quality of commercial food products cannot be overstated, as inadequate packaging is estimated to contribute to over 25% of food loss. Consequently, there is an increasing emphasis on the ongoing development of packaging materials and methods to minimize food wastage. A notable trend is the growing use of renewable, edible agricultural materials, which hold great promise in the food industry. Research is actively focused on enhancing the properties of

these edible polymers to extend the shelf life of food products. Edible films, crafted from natural and non-toxic materials, have gained popularity for their ability to enhance nutritional value, control moisture content, and protect against flavour loss. These films offer cost-effective solutions and contribute to environmental sustainability by reducing pollution. Particularly, edible, antioxidant, and antimicrobial membranes are indispensable for safeguarding sensitive food products like meats from oxidation and microbial contamination. Innovative trends in food packaging research aim to elevate food quality, safety, and shelf life while adhering to international quality standards. This involves the development of multifunctional packaging materials that utilize renewable, biodegradable substances and natural additives to fulfill traditional packaging functions and meet consumer expectations (Mahmed, Mohammed and Hassan, 2021).

1.1 Research Objectives and Questions

The research aims to examine how the use of innovative materials in functional food packaging affects economic viability, profitability, and social factors. This investigation specifically focuses on the preservation of shelf life. The research is designed to answer the following critical questions:

1. How does using new packaging materials affect the cost and profit, and make customers happy by keeping food fresh longer?
2. How do top companies in food packaging make their products better for the environment, and what special features do they add to help with sustainability?

1.2 Scope of Study

Years of intensive research have led to significant advances in sustainable packaging solutions within the functional food industry. Beyond distinguishing functional food packaging from conventional methods, it is imperative to explore the environmental potential of new technologies to understand their role in promoting sustainability. This study aims to assess the impact of advanced packaging on the shelf life and quality of food products, investigate the integration of contemporary innovative methods or technologies to

enhance package material and structure and develop a versatile packaging solution for optimizing both packaging and information distribution.

The scope of this study extends to a comparative analysis of three leading companies in the functional food packaging field. This comparison seeks to attain integrated data on the current state of technology, identify limitations faced by these companies, and establish a foundation for future advancements. The ultimate goal is to provide insights that can guide further research and improvement efforts to address challenges within this field.

1.3 Structure of the Thesis

This represents the thesis structure designed for a comprehensive framework aimed at improving understanding and precision.

1. Introduction: Presents the foundational framework of the research, outlining research objectives, addressing main problems, engaging in discussion and the purpose along with research questions.

2. Literature Review: Facilitates a profound comprehension of sustainability and functional food packaging, along with pertinent theories, through a comprehensive literature review.

3. Methodology: Emphasis will be placed on elucidating the research design and methodology utilized to fulfil the objectives of this thesis.

4. Primary and Secondary Data Research: This master's thesis delves into sustainable food packaging, drawing on years of research and insights from industry leaders such as VTT, Stora Enso, and Huhtamaki. Grounded in empirical evidence from sustainability-focused companies, the study aims to enhance sustainable packaging development. Utilizing real-world examples and industry cases, the thesis aims to unveil valuable insights and empirical evidence to inform the sustainability of packaging types. Through meticulous data collection and analysis, this study seeks to contribute meaningful knowledge to both researchers and practitioners.

5. Analysis and Discussion: Provides the analysis and discussion of the thesis based on the results.

6. Conclusion, Theoretical Impact, Managerial Recommendations, and Limitation: Presents the conclusive findings, practical implementations, and managerial recommendations, and outlines avenues for future research.

2 Literature Review

A literature review is a critical and educational summary of a particular subject. It seeks to give a summary of the known and unknown in that field (Bolderston, 2008).

In this section of the master's thesis, the researcher endeavoured to gather crucial information pertaining to functional food, packaging, and materials.

2.1 Revisiting Sustainability: Examining the 'Three-Pillar' Framework and Its Evolution

Sustainability, as a policy concept, traces its roots back to the remarkable Brundtland Report of 1987. This seminal document grappled with the fundamental tension between humanity's yearning for a better life and the stark constraints imposed by our natural environment. Over time, sustainability has transformed, expanding to encompass three dimensions: social, economic, and environmental. However, this evolution has led to certain unintended consequences (Kuhlman and Farrington, 2010).

Firstly, it has blurred the real conflict between our collective welfare aspirations and the imperative of environmental conservation. Secondly, it risks downplaying the critical significance of the environmental dimension. Lastly, it artificially separates social concerns from economic ones, even though these facets are intricately interconnected. Considering

these concerns, it is proposed that we return to the original essence of sustainability, where our foremost consideration is the well-being of future generations, with a particular focus on safeguarding irreplaceable natural resources. This contrasts with the current emphasis on satisfying immediate needs under the banner of well-being. Striking a balance between these two objectives is imperative, but it should not come at the cost of conflating them as if they were indistinguishable. While we undoubtedly deplete natural resources, we also generate capital, including knowledge, which holds the promise of enhancing future well-being. A pivotal question arises: to what extent can one compensate for the other? This complex debate hinges on the concept of substitutability, often framed as the distinction between 'weak' and 'strong' sustainability. The argument put forth here is that these two paradigms need not be adversarial but can instead serve to complement one another (Kuhlman and Farrington, 2010).

As depicted in Fig. 2, this visual representation appears in various forms across academic literature, policy documents, business texts, and online sources. While it is often referred to as a 'Venn diagram,' it frequently lacks the stringent logical properties typically associated with such diagrams. Alternatively, it is portrayed as three nested concentric circles or represented as literal 'pillars.' In some cases, it's used as a framework to categorize sustainability goals or indicators. Despite its visual appeal and simplicity, the conveyed meaning of these diagrams and the broader concept of 'pillars' is frequently unclear, making it challenging to translate into practical applications. If we are willing to overlook the semantic ambiguity and the clash of competing terms, it can be argued that the 'three-pillar' interpretation of 'sustainability' (or 'sustainable development' holds a dominant position in the literature. However, the origins of this conceptualization and its entry into the mainstream remain obscure, and its precise interpretation is a subject of debate. Much of the discourse surrounding sustainability revolves around the 'three-circle' framework, often without a thorough consideration of how it contributes to a more comprehensive understanding of sustainability. (Altieri, 1977).

Also, the Sustainability Analysis Framework (SusAF) is a tool with five dimensions—individual, social, financial, technical, and environmental—aimed at capturing capacity system outcomes (appendix 1). It evaluates aspects like personal freedom, social interactions, economic factors, technical sustainability, and responsible environmental management. SusAF provides a comprehensive perspective on sustainability dimensions in

case studies, addressing issues such as human rights, economic value, technological evolution, and environmental impact (Becker et al., 2016).

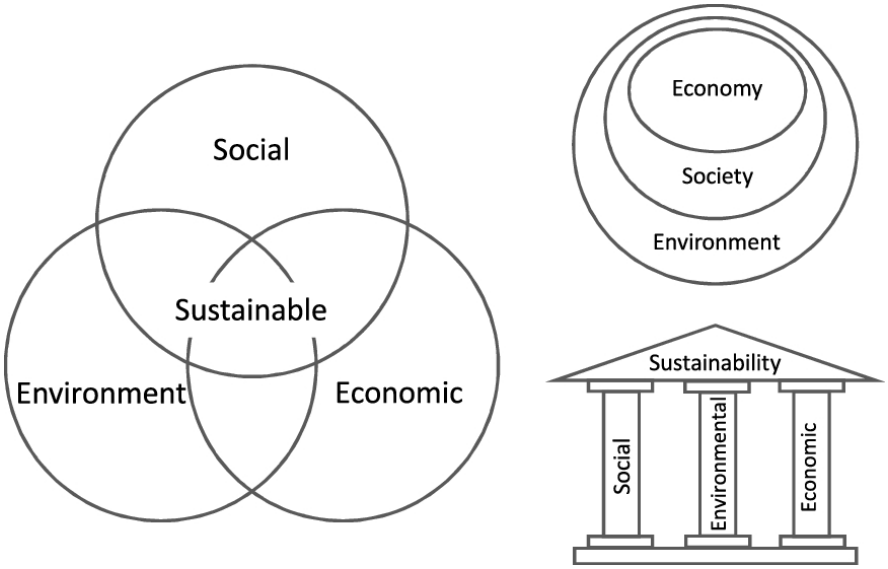

Figure 2, Left, typical representation of sustainability as three intersecting circles. Right, alternative depictions: literal 'pillars and a concentric circles approach, (Becker et al., 2016)

2.2 Functional Foods and Their Significance in Modern Nutrition and Health

Functional foods play a vital role in promoting human health as they serve as a primary source of essential nutrients and can be utilized as dietary supplements (Topolska, Florkiewicz and Filipiak-Florkiewicz, 2021). This category encompasses a wide array of natural sources, including fruits, vegetables, grains, fish, dairy products, and meat, all of which contribute significantly to nourishing the human body (Alongi and Anese, 2021). Additionally, certain beverages like tea and chocolate are recognized as functional foods due to the presence of bioactive compounds (Idowu et al., 2020).

Maintaining a balanced diet holds immense importance throughout an individual's life, as it directly impacts both mental and physical well-being, ensuring the body functions optimally (Rashwan et al., 2020). Functional foods have a positive impact on the body, fulfilling its basic requirements and safeguarding against malnutrition while aiding in the removal of harmful substances. These foods can also enhance the body's metabolic rate without disrupting its normal functions, contributing to physical well-being (Plasek et al., 2019). In the modern era, functional foods provide the energy needed for the seamless growth and development of the human body. Moreover, they possess the potential to modulate the

immune response, reducing the risk of various health complications such as cardiovascular diseases, osteoporosis, obesity, and cancer, thereby promoting overall health (Vigar et al., 2019). Examples of functional foods encompass vitamins, fortified food products, dietary fiber, minerals, peanuts, fruits, and grain seeds (Ghazanfar et al., 2022).

Food packaging in Finland involves three different industries: materials, packaging, and the food industry. The materials industry is involved in developing sustainable innovations to replace plastics, and the packaging industry is involved in innovating ways to use and form materials into packages that use less material, create less waste, and protect food (Bor, OShea and Hakala, 2024).

2.3 Sustainable Packaging Landscape: Materials, Challenges, and Key Criteria

In food packaging, sustainability is pivotal and characterized by criteria such as environmental responsibility, cost-effectiveness, and efficient material usage. It's shaped by global legislation like the European Commission's Packaging Directive, corporate initiatives, and retailer-driven efforts, as seen with Wal-Mart's environmental scorecard. Sustainability also extends to material sourcing; international organizations collaborate to verify the sustainability of materials like paper. Overall, sustainability is a guiding force transforming the food packaging landscape, driven by multifaceted initiatives and considerations (Brody et al., 2008a)

Sustainability encompasses human well-being, the economy, and the environment. Packaging materials play a vital role in preserving products during handling, transportation, and storage. They contribute to product costs and environmental impacts, with plastic being widely used. However, only 2% of plastic packaging materials are recycled globally, and certain packaging items are challenging to recycle. Sustainable approaches include material recycling, selection, and the use of bio-based materials. Glass bottles are considered more environmentally sustainable than aluminum cans and plastic bottles. While packaging materials present challenges, they remain essential for product preservation and promotion, emphasizing the need for sustainable packaging solutions (Ibrahim et al., 2022).

Petroleum-based polymeric materials like Polyethylene, Polypropylene, Polystyrene, and Polyethylene Terephthalate are widely used in packaging due to their good barrier properties,

lightweight quality, and low cost. However, the production and improper handling of plastic packaging materials have negative environmental impacts, including the release of CO2 and pollution of land and oceans. To address these issues, there is a growing need for sustainable and environmentally friendly materials in packaging. Biodegradable polymers, which can be of natural or synthetic origin, are being researched to enhance the physical and mechanical properties of bio-based packaging materials (Malathi, Santhosh and Nidoni, 2014; Popa et al., 2011).

Paper and paperboard find widespread use in packaging across industries like food, furniture, and machinery, primarily for safety, convenience, and information purposes (Cela and Kaneko, 2011). While these materials offer sustainability benefits and cost advantages over plastics, metals, and glass, they have drawbacks like poor water resistance and strength (Chen et al., 2013). Despite environmental concerns, plastic packaging prevails due to its strength, stability, sterilization ease, transparency, and liquid resistance (Muller, González-Martínez and Chiralt, 2017). To mitigate paper's moisture susceptibility, laminations and coatings are applied, expanding applications, and increasing product shelf life (Coles, 2013; Riley, 2012). Fig. 3 demonstrates the versatile forms of paper and paperboard usage.

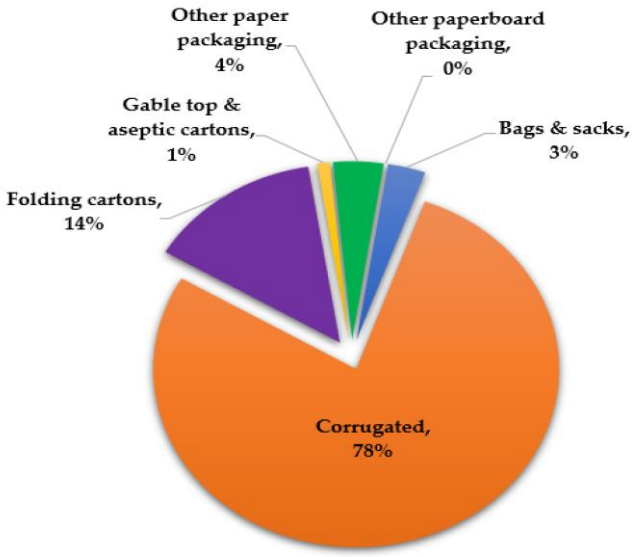

Figure 3, The utilization of paper and paperboard for packaging purposes in the United States, ***(Selke, 2016)***

Glass is still widely used in the food and pharmaceutical industries for packaging due to its benefits such as food safety, preservation, and resistance to chemical attacks. Glass containers can be made through recycling or by heating a mixture of silica, sodium

carbonate, and limestone/calcium carbonate (Marsh and Bugusu, 2007). The shapes, sizes, and colours of glass bottles are used to communicate messages to consumers (Corso et al., 2015; Kobayashi and Benassi, 2015).

In the context of packaging, particularly for canned beverages, there is frequent direct contact between the packaging material and its contents. Manufacturers prioritize consumer health and safety, particularly in the case of metal-based packaging materials (Whitaker, 2007). To ensure this, they must adhere to fundamental regulations and regularly conduct risk assessments to prevent any adverse interactions between the contents and the container. Various metals find extensive use in packaging, including aluminium, tin, lead, chromium, and others. Among these metals, aluminium is the most prevalent choice due to its inherent advantages, such as cost-effectiveness, lightweight nature, flexibility, recyclability, and high resistance to heat (Whitaker, 2007).

Sustainable packaging is characterized by eight key criteria. These criteria encompass the packaging's ability to promote environmental well-being, ensure safety and health at all stages of its lifecycle, meet performance and cost standards in the market, and use renewable energy in sourcing and production. While the criteria for sustainable packaging primarily revolve around measures that companies can adopt to create environmentally responsible packaging, they do not directly consider consumer perceptions and values. In examining eco-friendliness in packaging, it's crucial to differentiate between governmental, scientific, and consumer perspectives. Among these, the consumer perspective holds particular significance as it sheds light on how consumers perceive and value eco-designed packaging (NewsRx, 2019).

2.4 Enhancing Food Packaging: Synergies, Advancements, and Sustainability

This section explores the dynamic realm of active and intelligent packaging systems, aiming to revolutionize the preservation and quality of food products. Active packaging, characterized by its ability to interact with the product and environment, actively manipulates conditions to extend shelf life. It employs substances that influence physiological, chemical, physical, and microbiological processes within the package. The incorporation of additives into packaging materials constitutes active packaging, further

contributing to the longevity of food products. (Borowy and Kubiak, 2008; Dobrucka, 2014; Janicki, 2013).

Intelligent packaging, on the other hand, detects characteristics of the food or its environment and communicates this information to relevant stakeholders. While distinct, the attributes of intelligent packaging play a pivotal role in evaluating the efficiency and reliability of active packaging systems (Hutton, 2003).

The second transformative aspect delves into the strategic utilization of relationships along the packaging development value chain to gain a competitive edge. Suppliers in the food packaging industry are increasingly adding value through collaborative efforts across various stages, from raw materials to disposal. This shift transforms the traditional linear supply chain into an integrated sphere, facilitating idea exchange among different functions. Strengthening relationships with packaging suppliers opens avenues for focus, innovation, and technology transfer, ultimately leading to a competitive advantage. Case studies, such as Starbucks' collaboration for an FDA-approved coffee cup with recycled materials and Green Mountain Coffee Roasters' introduction of a compostable cup, exemplify how effective collaboration can streamline packaging processes and enhance consistency across global locations (Brody et al., 2008a).

The final important change in food packaging relates to food service packaging's evolution. As consumer spending on food service continues to rise, packaging plays a crucial role in ensuring food safety and convenience. Proper labelling helps food preparers by providing information about the food source and necessary temperature requirements. Easy-to-open packaging reduces the need for utensils, minimizing contamination risks. While technologies for tracking and extending shelf life are used to enhance food safety, achieving proper heating and heat retention remains a challenge. Innovations like CuliDish, which uses varying levels of aluminium to heat foods requiring different temperatures in a single tray, aim to address this issue (Brody et al., 2008b).

Additionally, two convenience trends—meals eaten on the go and multi-component meals—have significantly impacted food service packaging. The popularity of on-the-go meals has led to packaging innovations like edible films and wraps for diverse foods. Modular folding cartons easily opened pouches, and reusable packaging have facilitated eating while in transit. Multi-component meals, often ordered at quick-service restaurants, have reduced

food preparation complexity and waste. Packaging solutions such as reusable trays, customizable dip strip cartons, and folding trays for carrying multiple beverages have simplified the consumption of multi-component foods (Brody et al., 2008a).

Advances in food packaging distribution involves optimizing the distribution processes for food products, from manufacturers to consumers, to ensure product quality and sustainability while meeting consumer demands for convenience and safety. This field focuses on innovations in logistics, transportation, and supply chain management (Brody et al., 2008a).

Radio frequency identification (RFID) is a wireless tracking system employing tags, readers, and computer systems. RFID's flexibility, activated by readers when objects with tags enter their electromagnetic zone, makes it ideal for food packaging. RFID operates at different frequencies, with lower frequencies for short reading ranges and higher frequencies for longer ranges and faster speeds, and microwave frequencies requiring active tags (Brody et al., 2008a; Schneider and Xhafa, 2022).

The Electronic Product Code (EPC) is an ID on RFID tags used mainly in logistics and supply chains. EPC global developed it, and it's a promising internet of thing technology due to its open, scalable, and reliable nature. EPCs have 64-bit, 96-bit, and 204-bit formats. RFID systems consist of tags with unique IDs and readers communicating via radio waves. Object-Naming Services identify products using these IDs. The EPC global Network has components like EPC, ID-System, Middleware, Discovery Services, and Information Services. Gen. 2 EPC tags, introduced in 2006, are widely adopted for their interoperability, performance, reliability, and affordability (Schneider and Xhafa, 2022).

Nanotechnology holds significant promise for the future of food packaging materials, potentially bringing notable improvements in barrier and mechanical properties, pathogen detection, and smart, active packaging for enhanced food safety and quality. An example of nanotechnology in current food packaging is the thin aluminium nanolayer inside snack food packages. Various techniques exist for producing nanomaterials, including both top-down methods, such as grinding and laser use, and bottom-up methods like solvent extraction, crystallization, and self-assembly. These techniques are under investigation for potential future use in food packaging. Nanocomposites, a particular group of nanomaterials, are at the forefront of research and development in the field of food packaging (Brody et al., 2008a).

One of studies, conducted through ten Zaltman Metaphor Elicitation Technique (ZMET) interviews, explores consumer perceptions of environmentally friendly packaging. Despite valuing traditional packaging aesthetics, consumers express reservations about eco-friendly alternatives. Issues include the perception of reduced quality in simple and color-limited environmental packaging, concerns about compromised product integrity, and the prevalent belief that eco-friendly options are costlier. Hygiene worries, influenced by the theory of tactile contact affecting product evaluation, add to consumer skepticism. The research also focuses on "eco-designed" packaging, considering structural, graphical, and informational cues. The cost-benefit approach aims to unravel consumer assessments and identify potential barriers to widespread adoption of ecological packaging (Magnier and Crié, 2015).

In a separate academic investigation on incumbent firms' roles in innovation, the study highlights the proactive stance of food producers in advocating sustainable packaging innovations and shaping the supply chain. Five strategic actions, termed Signposting, Demanding, Incubating, Orchestrating, and Integrating, are identified, collectively fostering sustainability in food packaging, and steering the innovation demand-pull process.

In conclusion, the research emphasizes how food companies drive sustainability through strategic innovation, underscoring the importance of demand-pull mechanisms in sustainability transitions. Policymakers are urged to recognize the substantial influence of major food companies on the supply chain and implement supportive policies for research, development, and environmental benefits. Further insights, including a detailed figure, can be found in Appendix 1. The study sheds light on food companies' proactive role in advancing sustainability in packaging and their potential to create opportunities for innovators (Bor, OShea and Hakala, 2024).

Packaging plays a crucial role in protecting and distributing products efficiently, but it also contributes to the issue of municipal solid waste. To address this environmental concern and achieve sustainable materials management, a multifaceted approach is needed. This involves establishing economically viable closed-loop systems for packaging recovery, aiming to efficiently recover and recycle materials to reduce landfill impact. Sustainability in materials management extends to ethical considerations, such as corporate social responsibility and fair wages for workers. Sustainable packaging focuses on the use of biodegradable and recyclable materials to minimize long-term environmental impact. Additionally, it integrates

alternative energy sources in the production and transportation processes (Devi and Usha, 2023).

3 Methodology

Research methodology entails systematic decisions on data collection and analysis, incorporating qualitative, quantitative, or mixed methods. Selections in sampling, data collection, and analysis techniques align with research goals, determined by the research type (exploratory/confirmatory) and scholarly aims (Grad, Derek and Kerryn, 2020). *This master's thesis utilizes abductive reasoning and thematic analysis to explore complex phenomena, extracting insights from qualitative data sources. The integrative method involves conducting expertise interviews in the primary section and analysing relevant and updated documents in the secondary phase, aiming to generate discussion topics and categorize material for a comprehensive understanding.*

3.1 Qualitative method versus quantitative research method

Researchers' methodological choices are influenced by their own training and background. For instance, individuals with expertise in engineering, scientific writing, statistics, and computer programming may lean towards quantitative journals for their familiarity with these methods. On the other hand, those inclined towards literary expression, personal interviews, or close observation may opt for a qualitative approach. A mixed methods researcher combines both quantitative and qualitative research, considering factors like data quality and the availability of outlets for mixed methods studies (Bryman and Bell, 2011).

Abductive reasoning, used in case studies and qualitative-thematic analysis, aids researchers in developing the best explanations for observed phenomena. In this research, methodological choices should be explicitly outlined, focusing on the reasoning behind the selection of specific methods to enhance clarity and transparency (Dubois and Gadde, 2002).

For the purpose of this thesis, I have identified packaging companies and organizations involved in packaging processes in Finland. Subsequently, I reached out to these firms and established connections with the individuals responsible for packaging within each organization. Ensuring that each company's representative possessed the requisite

knowledge to address the key questions integral to my research, I initiated contact by emailing them my inquiries.

Upon mutual agreement that the questions pertained to their roles and responsibilities within the company (Incorporated within Appendix 2 is a table comprising interview questions), I proceeded to organize interviews with the identified individuals. This methodical approach aimed to gather comprehensive insights and perspectives from industry professionals, contributing to the robustness of my research findings.

3.2 Primary and Secondary Sources in Research

Researchers have the option to gather data from two distinct types of sources, namely primary and secondary, and on occasion, they may utilize both simultaneously (Saunders, Lewis and Thornhill, 2016). Primary data is obtained directly from individuals, businesses, or organizations through techniques such as surveys, one-on-one interviews (including focus groups and participant observation), and other relevant methods. The goal is to address the research objectives, as described by (Bryman and Bell, 2011). On the other hand, the process of obtaining secondary data sources is not confined to the field of statistics. It clearly attracts interest from various academic disciplines, as a wide range of fields leverage the information found in secondary sources (Daas and Arends-Tóth, 2012). These methods all fall under the academic domain of secondary research, which entails using existing data for a purpose different from their original collection (Golden, 1976). In this study, the comprehensive approach includes conducting expert interviews during the initial phase and analysing pertinent and up-to-date documents in the subsequent stage. The goal is to foster discussions and classify materials for a thorough comprehension.

3.0 Thematic analysis

Thematic analysis is an approach used in qualitative research to identify patterns and themes within a dataset. It involves systematically analysing qualitative data, such as interviews or focus group discussions, to identify recurring ideas, concepts, or patterns. The process typically involves several steps, including familiarizing oneself with the data, generating

initial codes or categories, searching for themes, reviewing, and refining themes, and finally, reporting the findings. Thematic analysis allows researchers to gain insights into participants' perspectives, experiences, and ideas, and it can be used to explore a wide range of research questions. It is important for researchers to be familiar with the dataset and avoid making unnecessary inferences about participants' perspectives or ideas. Thematic analysis helps researchers understand the (dis)similar perspectives and experiences of participants (Lochmiller, 2021). In this thesis, following the collection of qualitative data through documents and interviews, an integrated model was developed to propose a functional food packaging solution. The aim is to raise awareness about the current state of the industry, facilitating informed decision-making for the future.

3.1 Validity and reliability

The terms validity and reliability are very important when it comes to social science research. (Bryman and Bell, 2011) offer a thorough framework for comprehending these ideas.

Validity is defined by (Bryman and Bell, 2011) as the "integrity of the conclusions drawn from a research study." To put it another way, it has to do with how well the study measures the same thing it is trying to evaluate. In this scholarly context, a series of internal validity checks were utilized in this research. In terms of internal validity, the author shared the questionnaire designed for interviews with fellow researchers to assess its accuracy. During this process, my supervisors provided feedback on the questionnaire through multiple rounds to ensure precise measurement. Following these iterations, I finalized the questionnaire, making it ready for the interviews. A crucial component of research is validity, which guarantees that the conclusions are trustworthy and significant (Firdaus, Aksar and Gong, 2022).

Reliability refers to the stability and consistency of research measurements. It assesses if the research regularly yields comparable outcomes when the same measurement is used repeatedly. To reduce random mistakes in the study and ensure that the results are not just repeatable, reliability is essential (Nelson, 1980), Fellow scholars in the field are encouraged to review the research process and ensure the reproducibility of results when necessary. Also, in qualitative research, triangulation refers to the application of many techniques or data

sources to achieve a thorough understanding of the phenomenon being studied (Patton, 1999). Converging data from several sources has also been seen as a qualitative research strategy for validity verification. Four types of triangulations were identified by (Denzin, 1978) and (Patton, 1999), technique triangulation, investigator triangulation, theory triangulation, and data source triangulation (Carter et al., 2014). This study employed triangulation to validate specific project names, events, or research findings mentioned during interviews.

3.2 Research Strategy

Within the context of scholarly investigation, the choice of a research methodology requires a rigorous assessment of variables including the amount of prior information, the distribution of resources, the time allotted, and the researcher's philosophical understanding of the field. Prominent academics have distinguished seven distinct research methodologies that are available to researchers: they include survey, action research, ethnography, grounded theory, case studies, experimental, and archive research (Saunders, Lewis and Thornhill, 2016).

The selected research approach in this master's thesis is abductive reasoning in combination with theme analysis. This approach was chosen for its versatility and profundity, which allows for the investigation of complex phenomena and the extraction of insightful findings. The author intends to use thematic analysis within an abductive framework to reveal fundamental patterns and themes in qualitative data from both primary (interviews) and secondary (internal and external data). This integrative method improves comprehension of the subject and enables the construction of complete narratives and hypotheses that are firmly anchored in real-world observations and experiences. The overall purpose is to generate discussion topics from existing literature and then use them to categorize both primary and secondary material in the thematic analysis method.

4 Primary and Secondary Data Research

In the context of a master's thesis, empirical evidence comprises data and information gathered from observations or experiments, encompassing both primary and secondary sources of three leading company in field of packaging solution. This body of evidence serves as the foundation for addressing the research question presented in the thesis. (Institut für Soziologie, 2023). *Consequently, presented herein are interviews conducted as primary data from each respective company, complemented by pertinent and up-to-date documents sourced from these three companies.*

4.1 VTT Company

VTT, the Technical Research Centre of Finland, stands as a key player in European research, committed to innovation and sustainability. With a diverse staff of 2,213 individuals from 55 nationalities, VTT exemplifies global collaboration. Under the leadership of Antti Vasara, the President and CEO, VTT focuses on harnessing science and technology to address global challenges and foster sustainable growth (VTT research center, 2023).

VTT's commitment is reflected in three core areas:

When glancing through the secondary data sources for VTT the following themes related to packaging and sustainability were highlighted.

Carbon Neutral Solutions: Pioneering carbon-neutral technologies, VTT works towards decarbonizing the economy and society, aiming for systemic solutions.

Sustainable Products and Materials: VTT strives to create sustainable processes, technologies, materials, and products, contributing to a more sustainable future across various industries.

Digital Technologies: With a focus on breakthrough digital technologies, VTT supports the development of a safe and interconnected society, enabling a seamless, digitally connected world (VTT research center, 2023).

4.1.1 Primary data set of VTT

In this section, the author reveals the primary data collected through interviews which lasted around 2 hours. The interview highlights several themes of discussion related to sustainable strategies and operations in the packaging sector.

Overview of VTT and Participant's Role

He serves as the research team leader for the cellulose films and coatings team at VTT.

VTT's Impact on Functional Food Packaging

In the dynamic landscape of technology and innovation, VTT has significantly influenced functional food packaging over the past 15 years. The institution, known as the Technical Research Centre of Finland, has collaborated across disciplines to reshape food packaging with a focus on innovation, sustainability, and efficiency.

Pioneering Sustainable Practices

VTT excels in developing cost-effective and environmentally friendly materials, creative package designs, and advanced preservation methods. Their commitment to international sustainability standards, backed by science and technology, has led to remarkable contributions, including patents, research papers, and practical solutions that drive the evolution of functional food packaging.

Noteworthy Projects and Achievements

VTT has spearheaded impactful projects such as "Package Heroes," emphasizing sustainable material solutions, and "F3 Films for Future," an ongoing initiative with 34 industrial partners working on cellulose-based films for packaging. Additionally, the "SUSBINCO" project, supported by Business Finland, aims to create sustainable binder and coating materials for barrier applications in packaging.

Addressing Challenges and Shifting Paradigms

As leaders in the field, VTT is cognizant of challenges posed by single-use plastics and environmental littering. They actively work towards shifting from fossil-derived materials to sustainable, biobased alternatives, addressing concerns like microplastic pollution. VTT listens to customer feedback, steering research to align with evolving public sentiment.

Sustainability as the Core of Innovation

For VTT, sustainability is not just a buzzword; it permeates their packaging innovation. From material development to processes and end-use practices, every solution undergoes rigorous life cycle analysis to ensure sustainability and minimize the carbon footprint.

Collaborative Approach and Industry Impact

Collaboration is integral to VTT's mission. They work hand in hand with stakeholders across the industry spectrum to shape sustainable packaging solutions. Customer collaboration is key, and VTT pioneers the development of special sensors to track gases in food packages, enhancing food safety.

A Vision for an Ideal Future

VTT envisions a future where packaging is fully recyclable, biodegradable, and safe for food contact. With their leadership, this sustainable dream is on the path to becoming a reality, ensuring that food packaging protects what we eat and safeguards the world we call home.

4.1.2 Secondary data set of VTT

It involves gathering information from diverse sources using the most recent valid documents of a company.

Sustainable Breakthroughs: Transforming Packaging and Coatings Initiatives in Finland - Validation of Primary Data

VTT Technical Research Centre of Finland has invested €1.5 million in their Cellulose Films pilot facility, which aims to produce renewable cellulose alternatives to replace plastic film in food packaging. This initiative addresses the environmental issues caused by single-use plastic packaging, which is a major source of pollution in oceans. The new facility is set to test and develop processes for mass-producing sustainable cellulose-based films. Thin plastic films, commonly used in food packaging, are challenging to recycle and often end up in landfills. The goal is to provide a more environmentally friendly option for the food packaging industry, reducing the environmental impact of plastic film use. This innovation has the potential to significantly contribute to solving sustainability challenges related to plastic packaging materials. VTT is collaborating with numerous companies to advance

sustainable film solutions and aims to have these materials in extensive industrial use within five years (Kuusisaari, 2023).

Dealing with the global challenge of recycling and reusing plastic films has become increasingly complex due to the difficulty in separating different types of plastics. The European Union is implementing stricter regulations on plastic usage. Cellulose films, as biodegradable bio-based materials, present a promising alternative to traditional cellophane. To decrease plastic consumption, it is essential to develop innovative cellulose films that mimic plastic's desirable attributes, like moisture resistance. Employing modular pilot lines can greatly assist in efficiently scaling up cellulose film production, allowing experimentation with materials, speeds, and temperatures to identify cost-effective and eco-friendly manufacturing methods. Furthermore, VTT offers expertise in discovering novel applications for sustainable materials and optimizing the characteristics of cellulose films. This comprehensive approach aims to tackle the challenges of plastic reduction with advanced technology and innovative thinking (Kuusisaari, 2023).

Successful packaging not only ensures the safety of food but also plays a vital role in reducing food wastage. However, the consumption of food generates a significant volume of waste daily. In the Package-Heroes initiative, we focus on researching and developing packaging solutions that address two critical aspects: safeguarding food and tackling the growing global concern related to plastic packaging waste. To achieve this, we recognize the need for more scientific insights into the environmental impacts of various materials and solutions, the strategies for bringing new packaging innovations to the market and understanding consumer preferences. The Package-Heroes project is financially supported by the Strategic Research Council, operating under the Academy of Finland. This five-year project commenced in early 2019 and is set to conclude at the end of 2023 (VTT, 2019).

The SUSBINCO (Sustainable binders and coatings) initiative seeks to pioneer eco-friendly alternatives to conventional binders and coatings, substituting fossil-based materials. These sustainable solutions can be employed in a range of sectors, such as packaging, paint, adhesives, sealants, and abrasives. The project's primary goals are to address the demand for safer and environmentally responsible options, curb greenhouse gas emissions, and reduce reliance on fossil resources. Its focus lies in developing bio-based binders and coatings applicable in diverse areas while also enhancing global business prospects for Finnish

enterprises. The project is structured into several work packages, covering tasks such as raw material production, formulating aqueous bio-based dispersions, innovating non-toxic crosslinking methods for lignin-based coatings, testing, and fine-tuning bio-based dispersions, and assessing the environmental and safety aspects of the newly developed materials (CLIC Innovation Ltd, 2023).

Precision Food Packaging: Insights from VTT Paper and Implications for Shelf-life Modelling and Optimization

In the VTT paper 'Toward Precision Food Packaging by Optimization,' we gain crucial insights into the pivotal role of package design in food product success. The paper emphasizes the meticulous development of packages for enhanced consumer convenience and a festive atmosphere. Precision packaging, a novel approach outlined in the paper, targets optimizing shelf-life and package design, crucial for market strategies. Mathematical modeling's significance in understanding packaged food shelf-life is underscored, acknowledging the complexity of generalized models. Our study builds on these insights, aiming to deepen our understanding of precision food packaging and its impact on product success. (Lyijynen, Hurme and Ahvenainen, 2003). A valuable resource for researchers and food manufacturers, the paper provides comprehensive information on factors affecting the shelf life of packaged foods. It underscores the critical role of packaging choices in safeguarding foods from spoilage (Lyijynen, Hurme and Ahvenainen, 2003).

In Analysis, recognizing the multifaceted nature of factors impacting shelf life, the study emphasizes their significance in guiding the selection of packaging materials. This consideration aims to improve the shelf life of packaged foods and identifies areas for enhancing existing packaging to fortify food product protection, Outlined in Appendix 1, elaborating further on the subject (Lyijynen, Hurme and Ahvenainen, 2003).

The study distinguishes between discrete and continuous models for shelf-life analysis, noting their trade-offs in information reliability and detail confidence. Both models excel in detecting the fastest signal loss (Varsanyi and Somogyi, 1983). The conditions influencing shelf-life determination include food composition, relative humidity, temperature, packing material, packing method, and light (Gacula and Kubala, 1975). Shelf-life modelling approaches encompass theoretical modelling, applying established kinetic and mass transfer

equations, and experimental modelling involving extensive storage tests with isolated factors affecting product quality. (Lyijynen, Hurme and Ahvenainen, 2003).

Multivariable models are crucial for assessing the impacts of multiple factors, offering a comprehensive approach with three fundamental types: linear, interaction, and quadratic equations. Adopting a system-based approach for environmentally sensitive packaged foods involves modelling product, packaging, and environmental conditions, necessitating organizational collaboration (Gyeszly, 1991).

The VTT method for shelf-life determination involves seven key steps, emphasizing factor selection, experimental design, analysis, and the identification of packaging and storage combinations. The VTT method integrates statistical analysis and experimental approaches, balancing model complexity and prediction accuracy. In packaging optimization, the focus is on creating a decision-making tool for new products, benefiting manufacturers and packaging suppliers. Fig. 4 highlights factors in the optimization process, addressing logistics, marketing, consumer convenience, costs, and environmental considerations (Lyijynen, Hurme and Ahvenainen, 2003). The overarching goals are cost-effectiveness and minimizing environmental impact.

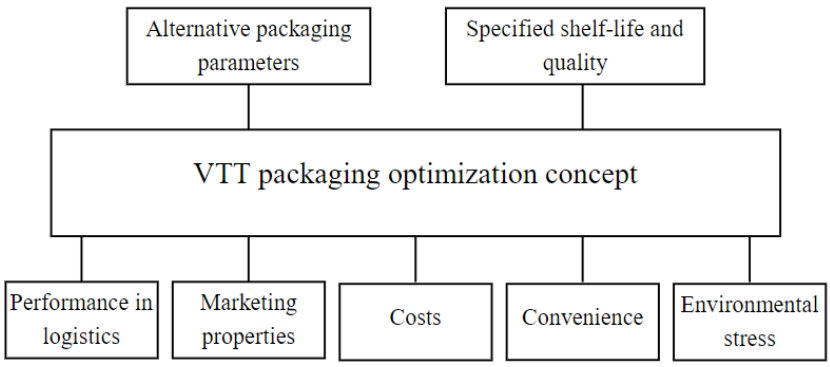

Figure 4, VTT packaging parameters, (Lyijynen, Hurme and Ahvenainen, 2003)

Food packaging is crucial for protecting and preserving food quality against environmental factors. The industry's focus on thinner materials with adequate strength aims to reduce costs and minimize waste. Effective packaging involves collaboration among designers, manufacturers, and users to meet marketing requirements. Cost reduction remains a priority,

with innovations like environmentally friendly seals and thinner materials favored for their potential to enhance cost-effectiveness. Optimizing food packaging aims to create a decision-making tool for new products, benefiting manufacturers and suppliers. The VTT method for package optimization follows a 4-step system, involving scoring, assessing, calculating coefficients, and computing optimization results. This systematic approach guides the selection and improvement of packaging solutions. Evaluation of package characteristics, encompassing mechanical strength, suitability to standards, weight ratios, waste volume, incineration possibility, marketing, consumer convenience, material cost, and indirect costs, informs the optimization process.

Empirical tests, like the one on chicken balls, identify key factors influencing acceptability. Mathematical models assess quality parameters, emphasizing storage time's impact. Package optimization combinations use mathematical models to predict oxygen transmission rates, considering carbon dioxide levels and the oxygen absorber's capacity. Comparing packaging types reveals flow packs excel in economical material and indirect costs. However, issues with leaking seals suggest structural adjustments are needed.

In conclusion, a holistic approach to food packaging, considering logistical, marketing, cost, consumer, and environmental factors, is crucial. The VTT method provides a systematic framework for optimizing packaging, contributing to the development of more efficient strategies aligned with industry needs and consumer expectations (Lyijynen, Hurme and Ahvenainen, 2003).

Revolutionizing Plastic Production: Advancements in Sustainability through Cellulose-Based Packaging Innovations

VTT Pilot Plants, established in 2018, provides a platform for developing packaging materials and technologies with practical applications. The growing consumer demand for sustainable and bio-based packaging materials, driven by environmental and health concerns, highlights the need for these materials in the packaging industry. Simultaneously, the packaging industry is adapting to the trend of eco-friendly materials, responding to consumer preferences and regulatory requirements. This shift emphasizes the practical implications for brand owners and the industry. Sustainable packaging plays a vital role in food preservation, waste reduction, and efficient resource use.

Additionally, the Bioruukki Pilot Centre, Northern Europe's largest open pilot facility for bioeconomy, accelerates sustainable technology and process development. It fosters stakeholder collaboration and focuses on high-value opportunities within the bio and circular economy. This ecosystem expedites innovation by offering advanced facilities and expertise, aligning with a broader initiative for sustainable technologies in packaging and bioeconomy.

Plastic production has grown significantly, reaching an estimated 400 Mton by 2025. To manage this growth, leveraging existing plastics and polymers capacity can enhance recycling rates, reduce waste generation, increase biodegradable plastic production, and increase bio content. Cellulose, a versatile material, is being explored for various packaging structures, including paper-like pouches, moldable board trays, and clear packaging films, Additionally, illustrated in Fig. 5 is the progression in the biodegradability of thermoplastics. Cellulose nanofiber (CNF) films are being used in optoelectronics and smart packages, while Bio-High-Density Polyethylene (HDPE) films with CNF coating reduce mineral oil migration and oxygen transmission. Stand-up pouches from renewable materials and CNF showcase high-performance barrier properties. The biodegradability of cellulose-based materials varies, with pure lignocellulosic materials being naturally biodegradable, regenerated cellulose films requiring dissolution processes, and cellulose derivatives soluble in common solvents being biodegradable. Incorporating biodegradable wet strength agents or adopting an all-cellulose approach can retain material biodegradability, indicating a shift towards sustainable packaging practices (Harlin et al., 2018; Tamellin, Salminen and Hippi, 2019).

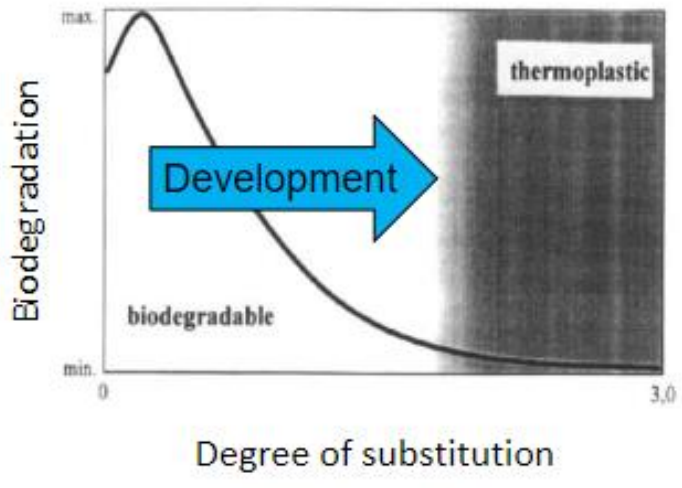

Figure 5, Development of Biodegradability of thermoplastics, ***(Harlin et al., 2018)***

Evolution and Challenges in Contemporary Food Packaging: Materials, Recycling, and the Crucial Role in Sustainable Practices

The packaging industry has evolved significantly, focusing on lightweight materials, improved barrier properties, and end-of-life cycle considerations. Plastics remain dominant in food packaging, with paper and metals also widely used, while glass is losing prominence. Packaging materials often include laminates and coatings to enhance functionality and shelf life. Packaging plays a crucial role in protecting food and addressing logistical, economic, and environmental challenges in distribution and waste. Both the European Commission and the United States have set recycling targets for packaging waste, emphasizing plastics and paper/cardboard. Recycling rates vary between the EU and the US, with the latter generating higher per capita plastic waste (Arnold, 2022). The EU aims to achieve 65% recycling by 2025, with major companies committing to recyclable packaging. However, the main challenge lies in inadequate collection and sorting infrastructure in many countries. Currently, only 80% of packaging waste is collected, leaving 20% in landfills or energy recovery processes (Clar and Steurer, 2019).

Solving Packaging Recycling Challenges: Citizen Involvement, Innovation, and Sustainability

Packaging recycling requires more than just technical waste management systems; citizen involvement is crucial for reducing confusion and inconvenience in sorting materials like used paper and plastic packaging. Currently, only 15% of plastic waste in the EU is recycled, with safety concerns limiting most plastic food packaging recycling. Renewable materials like micro fibrillated Cellulose are gaining traction for resource efficiency. Advanced technologies like near-infrared and hyperspectral cameras are needed for sorting and recovery of post-consumer packaging. Membrane treatment technology is emerging to close water loops in paper mills, while chemical recycling methods are gaining prominence for mixed plastic waste, with water-based technologies emerging as alternatives to pyrolysis. (Arnold, 2022; Canadian Plastics, 2021; Leardini et al., 2021; Ossama Al Kadouci, 2020; Staub, 2021; Waste360 (Online)Informa, 2019).

Advancements in Sustainable Practices: PolyAl Recovery and PET Recycling

Energy recovery in polymer-aluminum composite recycling has given way to material recycling, producing thermoplastic composites and strong boards from repurposed beverage containers. A 30% recycling rate for non-fiber components in beverage cartons has been attained by successful European projects, yielding an annual production of 50,000 tons. Recycling plants in the Netherlands and Italy have creatively generated polymer-aluminum products by applying techniques including water-based washing for polyethylene and aluminum fractions at Palurec and formic acid and water for aluminum separation at Plastigram (Dow Jones Institutional News, 2021).

One important source of food-grade polymers is PET, which is recycled via processes like washing, separating, and grinding. Pellets made from refined PET are used in textile and packaging products. More recycling activities are being driven by industry alliances and new legislation, notwithstanding the difficulties in getting post-consumer PET material. Inadequate infrastructure, however, continues to be an obstacle, highlighting how crucial consumer involvement and environmental knowledge are to the effectiveness of recycling. Packaging manufacturers are concentrating on designs that improve recyclability and on sorting systems for handling mixed plastics waste to overcome these issues (Arnold, 2022; Mapleston, 2021).

Table 1, Comprehensive Empirical Table Summarizing Primary and Secondary Data of VTT

Variable/Category	Interview Excerpt
Interviewee Information	- Role: Research Team Leader at VTT -Expertise: Sustainable cellulose-based materials for packaging - Years of involvement in research: More than 15 years
VTT's Role in Packaging	-Focus on developing sustainable cellulose-based materials for packaging and other applications. - Emphasis on material development, process innovation, and understanding the value chain.
Notable Projects/Achievements	-Mentioned "Package Heroes" project focused on sustainable material solutions.

	- Highlighted "F3 Films for Future," an ongoing project for cellulose-based films. - Mentioned " SUSBINCO " Business Finland project for sustainable binder and coating materials.
Current Trends/Challenges	- Challenges include single-use plastics and their environmental impact. - Littering issues and the resulting microplastic pollution. - Focus on replacing fossil-derived materials with sustainable, recyclable alternatives.
Consumer Feedback	- Emphasized the role of customer feedback in shaping research directions. - Use customer feedback from brand owners and industry stakeholders to understand consumer preferences.
Sustainability Approach	- Sustainability is a key criterion for VTT's research. - Approach involves material development, process sustainability, and converting processes. - Conducts life cycle analysis studies to minimize carbon footprint.
Collaboration with Industry	- Collaboration with industry stakeholders throughout the value chain. - Customer collaboration is a central part of VTT's operations.
Advancements in Technology	- Developing special sensors to enhance food safety, tracking gases in food packages. - Focus on materials safe for food contact.
Future of Sustainable Packaging	- Envisions a future with fully recyclable, biodegradable, and safe packaging with no littering or harmful chemical release.

4.2 Stora Enso Company

Stora Enso, a leading provider of sustainable materials, plays a pivotal role in various sectors, notably packaging. With a global focus, the company specializes in developing and supplying wood and biomass-based solutions to meet global industry needs. Stora Enso is committed to advancing bioeconomy, offering environmentally friendly, renewable products to support clients worldwide. Their extensive product range includes formed fiber and wood items, smart packaging solutions, bio composites, pellets, lignin, bio-based chemicals, and other renewable alternatives. Significantly, Stora Enso is involved in every stage of the value chain, from pulp production and material processing to packaging production and recycling. Established in 1996, the company, headquartered in Helsinki, Finland, and Stockholm, Sweden, employs approximately 20,879 people as of 2023. With a production capacity of 5.4 million cubic meters of sawn wood products, including 2.5 million cubic meters of value-added products, Stora Enso recorded sales of EUR 11.7 billion in 2022. This highlights their substantial contribution to sustainable practices in the packaging industry (Global data, 2023; Stora Enso, 2023).

4.2.1 Primary data set of Stora Enso

In the interview with the Technical Customer Service Manager at Stora Enso Company, several key points were discussed.

Company Overview

Stora Enso is comprised of five divisions: Packaging Materials, Packaging Solutions, Biomaterials, Wood Products, and Forest. The company serves a diverse customer base, including the packaging, joinery, and construction industries, as well as publishers, printing houses, and paper merchants.

Company Strategy

The company's strategy revolves around expanding its relative market share in profitable niches within the consumer board business and growth in the fluting and kraftliner markets.

Competition

Stora Enso faces competition from various companies depending on the product category. In consumer board products, the main competitors in Europe include Billerud Korsnäs, Metsä Board, and Iggesund. Outside of Europe, Klabin, Evergreen, Georgia-Pacific, and International Paper are significant competitors. In containerboard products, competition primarily comes from Mondi, Prinzhorn, Billerud Korsnäs, SCA, SAICA, International Paper, and WestRock.

Packaging Solutions

The Packaging Solutions division of Stora Enso focuses on developing and selling premium fiber-based packaging products and services. These eco-friendly packaging products cater to various market sectors, including retail, e-commerce, and industrial. The division offers a range of products, design and sustainability services, and circular and automation solutions.

Market Growth

The Packaging Solutions division aims to capitalize on the growth in the e-commerce sector and the increasing trend to replace plastics with renewable materials.

Competition in Packaging Solutions

The Packaging Solutions division is strong in corrugated packaging within the Nordics, Baltics, and Poland. Major competitors in these markets are Smurfit Kappa and DS Smith.

Transition to Renewable Materials

Stora Enso recognizes the importance of transitioning from fossil-based packaging materials to renewable alternatives. Papira®, a lightweight cellulose foam material, offers a natural, bio-based, and recyclable option for protective and cushioning packaging materials.

The interview also addressed various questions and challenges faced by the company:

- Camfil's Sustainability Project: Stora Enso is working with Camfil to explore the potential reduction in CO2 emissions by switching from white to brown boxes. This project aligns with the company's sustainability efforts.

- Challenges: Stora Enso acknowledges that their products are niche and more expensive compared to traditional plastic alternatives. They emphasize the importance of raising awareness about the value of reusable products.

- Customer Feedback: The company values customer feedback, obtained through surveys and other means, as it plays a pivotal role in shaping their products and services.

- Food Packaging Safety: Stora Enso places great importance on safety in food packaging and obtaining FDA certification before producing such packaging.

- Sustainability Goals: Stora Enso has ambitious sustainability goals and aims to offer 100% regenerative solutions by 2050. They emphasize that government regulations support their sustainability initiatives.

- Internal Sustainability Policies: The company has implemented internal policies to promote sustainability, including the use of reusable materials in the office and encouraging remote work.

4.2.2 Secondary data set of Stora Enso

It is referring to collecting information from the latest valid documents of a company from various sources.

Packaging Solutions (Delivering customer value through Logistical Packaging)

This paper delves into the role of packaging within the realm of logistics and supply chain management, shedding light on the prior research's insufficient attention to packaging as a central element. It underscores the crucial need to consider both the logistics-oriented packaging and its impact on delivering value to customers, aiming to enhance the efficiency of inbound and outbound logistics operations. To conduct this investigation, the study applied a qualitative research approach, coupled with an abductive research method, employing a case study methodology centered around Stora Enso's packaging practices. The outcomes of this analysis demonstrate that the packaging solution significantly influences the performance of various activities along the logistics chain, and Stora Enso effectively tailors packaging to meet customer demands, thus delivering value through logistics-oriented packaging.

In the context of supply chain and logistics, packaging assumes a multifaceted role, encompassing both functional and marketing dimensions throughout the upstream supply chain. This integration of logistics and packaging, commonly known as logistical packaging, holds the potential to substantially enhance the efficiency of logistics operations and, consequently, bolster overall business performance. The primary objective of logistical packaging is to develop packaging solutions that seamlessly align with the intricacies of the logistics chain while also meeting the evolving demands of customers.

The importance of efficient packaging solutions becomes particularly pronounced in scenarios characterized by complex and high-paced logistics and distribution processes. A pivotal aspect of this relationship is the recognition that understanding customer needs and delivering value through packaging is essential for maintaining a competitive edge in the business landscape. It is worth noting that packaging exerts a significant influence on nearly every facet of customer value within the downstream supply chain. In addition, the manufacturing process for packaging must take into account technical attributes that facilitate the agile movement of packaging units along the logistics chain. This integration of packaging, logistics, and customer-centric considerations underscores the critical nature of packaging in modern supply chain management (Shan and Julius, 2015).

Stora Enso (Annual Report 2022)

Stora Enso remains dedicated to sustainable business practices, actively substituting fossil-based materials with renewable alternatives and upholding the principles of the UN Global Compact. Their commitment to sustainability extends to their corporate structure, as they transitioned to a decentralized decision-making model, enhancing adaptability and agility in their operations. Furthermore, a significant development in their corporate strategy was Stora Enso's announcement in early March to exit the Russian market, aligning with their core values and commitment to ethical business practices. This move reflects their steadfast commitment to doing what is morally right (Antti Mäkinen and Håkan Buskhe, 2016).

Stora Enso’s Sustainability Policy

Stora Enso's comprehensive commitment to sustainability, as outlined in its policies and guidelines, carries significant practical implications. Their dedication to upholding human rights, ensuring workplace safety, and addressing climate change underscores their holistic approach. Furthermore, their emphasis on responsible natural resource utilization, including

efficient water and material management, as well as active support for reuse and recycling, yields tangible benefits. Additionally, their unwavering commitment to environmentally responsible emissions and waste management, along with their proactive approach to biodiversity and sustainable forestry practices in wood and fiber sourcing, has profound implications for ecological sustainability. Furthermore, their continuous improvement in sustainability management processes and active engagement with stakeholders ensures ongoing relevance and the effectiveness of their approach. Lastly, the selection of sustainability-aligned partners, guided by their Supplier Code of Conduct, offers practical advantages. Stora Enso's unwavering commitment to leading the way in delivering 100% regenerative solutions by 2050, guided by its core values and policies, is central to its sustainability mission. Their holistic approach, firmly rooted in principles and actions, emphasizes fairness, transparency, and continuous improvement. Engagement with a diverse range of stakeholders and collaboration with like-minded partners is at the core of their strategy. They proudly publish their tax footprint, showcasing their commitment to financial transparency. Their dedication to helping customers be sustainable, rewarding shareholders sustainably, supporting communities, and respecting human rights is central to their business ethos. Their responsible use of natural resources, environmentally responsible emissions and waste management, and their commitment to combating climate change are pivotal in their environmental stewardship. Stora Enso's commitment to sustainability extends to its actions and innovations, all geared toward making a positive impact on the environment and reducing its carbon footprint. In summary, Stora Enso's commitment to sustainability is an integrated approach that underlines its dedication to building a more sustainable and regenerative future for all (Stora Enso policy department, 2022).

Table 1, Synopsis of Critical Insights from Stora Enso Company

Topic	**Key Points**
Company Divisions	- Stora Enso consists of five divisions: Packaging Materials, Packaging Solutions, Biomaterials, Wood Products, and Forest.
Customer Base	- Customers include the packaging, joinery, construction, publishing, printing, and paper industries.

Company Strategy	- Focus on expanding relative market share in profitable niches in consumer board business and growth in the fluting and kraftliner market.
Competition	- Competes with various companies depending on the product category and location. Includes BillerudKorsnäs, Metsä Board, Klabin, Mondi, and more.
Packaging Solutions	- Develop premium fiber-based packaging products and services for retail, e-commerce, and industrial sectors. - Offers design, sustainability, and automation solutions.
Market Growth	- Capitalizing on the growth in the e-commerce sector and the shift from plastics to renewable materials.
Competition in Packaging Solutions	- Strong presence in corrugated packaging in specific regions, with Smurfit Kappa and DS Smith as key competitors.
Transition to Renewable Materials	- Papira® is introduced as a natural, bio-based, and recyclable alternative to fossil-based foam materials in packaging.
Camfil's Sustainability Project	- Collaboration to investigate the reduction of CO2 emissions by switching from white to brown boxes.
Challenges	- Niche products are more expensive compared to traditional plastics. - Emphasizing the importance of raising awareness about reusable products.
Customer Feedback	- Valuing customer feedback through surveys and other means for product and service improvement.
Food Packaging Safety	- Ensuring safety in food packaging and obtaining FDA certification before production.
Sustainability Goals	- Aiming for 100% regenerative solutions by 2050, supported by government regulations.
Internal Sustainability Policies	- Implementing internal policies, such as using reusable materials in the office and promoting remote work for sustainability.

4.3 Huhtamaki

Huhtamaki stands out as a beacon of hope and transformation in a world where sustainability is not merely a trend but a moral necessity. This multinational corporation, with a century-long history and deep Nordic roots, has nearly 18,000 dedicated employees across 37 countries. Their impressive 2022 net revenues of EUR 4.5 billion underscores their financial resilience. However, Huhtamaki's steadfast dedication to sustainability is what makes them who they are. They want to be at the forefront of environmentally friendly packaging solutions, promoting a circular economy, addressing climate change, and considering the moral and ethical implications of their business practices and output. Their commitment to changing the world is demonstrated by their aggressive climate ambitions and acknowledgment from groups like MSCI, Eco Vadis, and the Science Based Ambitions program. This is about transforming the world, not just business. Beyond their operations, Huhtamaki hopes to encourage a wider shift towards responsible practices by having 70% of its supplier’s line with science-based standards by 2026. Huhtamaki excels in the SP Global Corporate Sustainability Assessment, earning 67 points and taking the eighth place spot out of 77 businesses in the container packaging Industry. They stand out for being a live example of sustainability, not simply talking the talk. Huhtamaki is more than simply a business; it's an agent of goodwill and a beacon of hope in a world working toward a more promising and sustainable future (Huhtamaki, 2023).

4.3.1 Primary Data Set of Huhtamaki

It involves interview with an expert related to this topic from Huhtamaki company.

Introduction

He is a key figure at Huhtamaki Company, working at the Corporate Head Office and being a part of the wider strategy, M&A, and innovation team. He is currently specializing in digital innovation, with a focus on digital solutions for packaging across various substrates. This unique perspective is valuable for understanding the latest trends and innovations in the packaging industry.

History and Achievements

Huhtamaki's history dates back more than 100 years, showcasing its longevity and experience in various industries. However, it wasn't until the 1960s that the company made a significant shift in packaging. Around the year 2000, Huhtamaki shifted its sole focus to packaging. Their journey of over 60 years in the packaging industry is marked by an evolution towards becoming a sustainable company, with a more dedicated focus on sustainability commencing approximately five years ago.

Notable achievements include the introduction of the Blue Loop innovation, a significant breakthrough in the flexible food packaging segment. This innovation transformed complex, multilayer plastic packaging into a mono-material solution, rendering it recyclable. This initiative addresses both environmental concerns and operational efficiency. Another remarkable achievement was the collaboration with Nestle on a biodegradable version of coffee capsules for Nespresso. This involved replacing the traditional aluminum capsules with a molded fiber alternative. The result is a product that is fully biodegradable and compostable, aligning with the growing emphasis on sustainability.

Consumer Behavior and Challenges

One of the most significant challenges in the industry, as highlighted by him, is consumer behavior. Consumers are often guided by convenience, and their readiness to pay extra for sustainable packaging remains a challenge. This reluctance is common, even when consumers express a desire for sustainability in surveys or polls. Additionally, issues related to recycling infrastructure and consumer awareness are pertinent. In some regions, there is a lack of recycling infrastructure, making it difficult for consumers to participate in recycling efforts. Moreover, education on recycling, especially regarding new sustainable packaging options, is crucial. Even if a packaging solution becomes more environmentally friendly, consumers may not understand how to recycle it correctly.

Addressing Challenges

To address these challenges, Huhtamaki is implementing several strategic initiatives. Firstly, the company is dedicated to assisting its customers in effectively and accurately communicating sustainability claims on their packaging, demonstrating a proactive approach to heighten consumer awareness. Additionally, Huhtamaki has made a firm commitment to ensuring that all its products are recyclable or compostable, reflecting a tangible and enduring dedication to sustainable packaging practices. Furthermore, the company actively

participates in pilot projects focused on waste collection and recycling, aiming to contribute to the comprehensive management of waste. Recognizing the significance of consumer education, Huhtamaki emphasizes the need to educate consumers about sustainable packaging options and proper recycling practices, viewing this as a pivotal step in fostering behavioral change and enhancing the effectiveness of recycling efforts.

Government Regulations

He acknowledged the significance of government regulations, such as the EU's Plastics Waste Regulation (PWR). These regulations can play a pivotal role in steering the industry towards more sustainable solutions. Regulations provide a clear framework and standards, which can be particularly effective in accelerating the transition to eco-friendly packaging.

Advancements in Packaging Technology

While the interview didn't delve deeply into advancements in food safety and quality, He highlighted that their focus primarily centers on sustainability. In the pursuit of this goal, the company aims to maintain or enhance the performance of packaging while reducing its environmental impact. This emphasis aligns with broader industry trends, where maintaining performance while improving sustainability is a core objective.

Collaborations and Partnerships

Huhtamaki engages in collaborations and partnerships with industry peers. These collaborations can help leverage collective expertise and resources to drive innovation and sustainable practices. While collaborations with research institutes were mentioned, they currently constitute a smaller part of Huhtamaki's open innovation efforts. However, there is a growing emphasis on expanding these collaborations, particularly with research institutes, to foster further innovation.

Reaching SDG 2030

The extent to which the industry can achieve the Sustainable Development Goals was not explicitly discussed in the interview. However, it can be inferred that Huhtamaki is committed to sustainability and believes that regulations and industry efforts will be instrumental in realizing these global goals. The company's commitment to making products recyclable or compostable and its emphasis on sustainability align with the broader

objectives of SDGs, particularly those related to responsible consumption and production (SDG 12) and climate action (SDG 13).

Future Direction

His insights suggest that the future of functional food packaging innovation will revolve around sustainability. The industry aims to sustain current performance levels while making packaging more eco-friendly. Although various directions are being explored, sustainability remains the central theme. The industry is in a phase of exploration, and it is expected that over time, some sustainable solutions will gain traction and become standard. These solutions have the potential to unlock significant environmental benefits and move the industry closer to its sustainability goals.

4.3.2 Secondary Data Set of Huhtamaki

A scholarly review assesses Huhtamaki's recent packaging technology innovation, analyzing its features, implications, and contributions to the field. The aim is to elucidate the academic significance of this advanced technology.

Laser Technology Advancements in Food Packaging: A Case Study of Huhtamaki's Sustainable Approach

The paper delves into the necessity of finding a reliable and environmentally friendly solution for perforation tasks in the packaging industry. It underscores the significance of employing energy-efficient processes free from toxic chemicals and having a minimal carbon footprint. Furthermore, it highlights the challenge of delivering a cost-effective product produced in high volume.

In addressing the challenges faced by the food packaging industry, which include cost sensitivity and the need for high process throughput, the paper discusses the utilization of laser technology for tasks like perforation and slitting of paper and plastic films. It also examines the installation of laser-based equipment in environments with limited space and ambient vibration. The specific focus of the paper is on Huhtamaki, a flexible packaging production company located in Ronsberg, Germany. It addresses their specific requirement to perforate paper-aluminum laminate packaging for sugar cone sleeves while preserving the

mechanical stability and barrier properties of the aluminum layer. The paper as illustrated in Fig. 6 explores the choice of CO2 laser technology for this perforation task, given its compatibility with paper and aluminum materials. The GEM-100 laser is highlighted for its compact design, stable power delivery, and long resonator supporting multiple longitudinal modes. The avoidance of paper discoloration during the laser-cutting process is emphasized.

In the broader context of challenges faced by the food packaging industry, including moisture and oxygen control, the paper underscores the advantages of laser technology. It stresses the importance of laser system designers considering factors like system size, cost of ownership, and reliability to successfully enter the market. The case study of Huhtamaki serves as a practical example of successfully integrating a laser system into existing production equipment, adding minimal unit cost to the product. CO2 laser technology allows for precise cutting through the paper layer while preserving the integrity of the aluminum layer, ensuring both mechanical stability and barrier properties. An environmentally safe process is developed, including the use of an air suction system to remove smoke, and cutting debris, ensuring the quality and safety of the food product (Gaebler and Büchter, 2010).

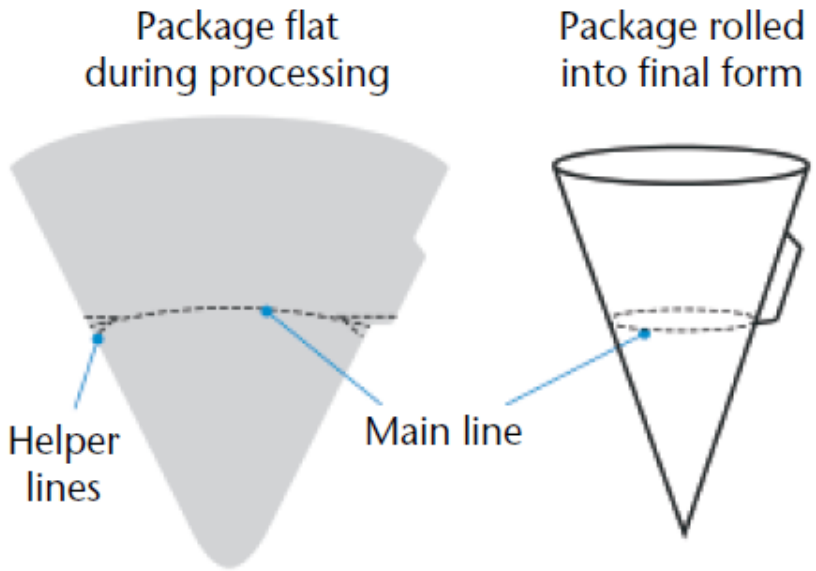

Figure 6, Laser-Cut Perforation Design Featuring Smooth Curved Main Line and Twin Assistance Lines, ***(Gaebler and Büchter, 2010)***

Table 2, Comprehensive Empirical Table Summarizing Primary and Secondary Data of Huhtamaki

Topic	**Key points**
Introduction	He is a part of the wider strategy, M&A, and innovation team at Huhtamaki Company, focusing on digital innovation in packaging.
History and Achievements	Huhtamaki has over 100 years of history and shifted its focus to packaging in the 1960s. The company has been highly focused on sustainability in the last five years. Notable achievements include the Blue Loop innovation and biodegradable coffee capsules.
Consumer Behavior	Consumers are convenience-driven and often unwilling to pay more for sustainable packaging. Lack of recycling infrastructure and consumer education are challenges.
Addressing Challenges	Huhtamaki supports customers in making sustainable claims, commits to making all products recyclable or compostable, conducts pilot projects, and focuses on consumer education.
Government Regulations	Government regulations, like the EU's Plastics Waste Regulation (PWR), play a crucial role in pushing the industry towards sustainability.
Advancements in Technology	The focus is on sustainability, maintaining or improving packaging performance while reducing environmental impact.
Collaborations and Partnerships	Huhtamaki collaborates with industry peers and is expanding collaborations with research institutes to foster innovation.

Reaching SDG Goals	The extent to which the industry can achieve Sustainable Development Goals (SDGs) was not explicitly discussed, but Huhtamaki's sustainability efforts align with SDG objectives.
Future Direction	The future of functional food packaging innovation is centered on sustainability, aiming to maintain performance while improving eco-friendliness.

5 Analysis and Discussion

In this chapter, the author compares what they found in the study with what other experts have said in simpler terms. They organize this by looking at a table that shows how the ideas from theories connect to what they saw in real situations. Then, they talk about what they found and what other studies say, especially focusing on the theories they used. The goal is to show how the real results connect to the theories. They also discuss the main topics that came up in their study in an easy way. They look at what others have already studied and point out what their cases showed in those areas. Overall, they found three main topics that were the same in all the cases: using eco-friendly packaging, coming up with new ideas for eco-friendly packaging, and dealing with challenges and opportunities in functional food. They organize all this info in a simple table, to sum up the chapter.

5.1 Sustainable Packaging Initiatives

The topic of sustainable packaging has been under the scrutiny of scholars in the past few years (Brennan et al., 2021). In this study, our objective is to delve deeper into the essence of sustainable packaging by examining specific cases. The subsequent section elucidates the individual perspectives of each case on sustainable packaging and delineates the steps taken in this direction.

Case 1; VTT

The VTT representative considers sustainability to be a pivotal force driving the packaging industry. According to the VTT case representative, several elements contribute to the formulation of successful sustainable packaging strategies. Firstly, the company must allocate resources to Research and Development (R&D) to enhance innovativeness and technological advancements. Secondly, the implementation of a tailored strategy is deemed crucial for establishing an effective value chain in sustainable packaging. Lastly, the phase of material development holds an important factor in fostering sustainability. For instance, the interviewee mentions:

"*VTT focuses on developing sustainable cellulose-based materials for various applications, including packaging, electronics, and filtration membranes".*

Furthermore, VTT actively participates in various sustainable packaging projects, including Package-Heros, F3, and SUSBINCO. This underscores the significant role of VTT as a research institute acting as a third party in devising solutions for bio-based packaging. The discovery emphasizes that achieving sustainable packaging is not solely an internal undertaking for the company but rather a collaborative process that necessitates partnerships with different organizations.

Case 2; Stora Enso

Packaging is critical in logistics, especially in delivering consumer value. The goal of logistical packing is to increase operational performance by streamlining operations. Sustainable packaging is a major priority, addressing environmental responsibilities as well as logistical concerns. It is a strategic requirement that connects with conscious consumption, not only an environmentally beneficial decision. Understanding the demands of the consumer is critical in producing packaging solutions that go beyond conventional confinement. Packaging that is efficient and informed by sustainable principles adds value across the supply chain. The Sustainable Packaging Initiative is a game-changing concept that blends logistical acumen with environmental responsibility, building brand loyalty and addressing the needs of environmentally concerned customers. Organizations can build a future where every item delivered is a testament to ethical, value-driven logistics practices by fusing logistical efficiency, customer-centric packaging, and sustainability. This strategy combines logistical expertise with responsibility for the environment, ensuring that every item delivered is a monument to ethical, value-driven logistics methods.

Case 3; Huhtamaki

The Sustainable Packaging Initiative is a multifaceted approach aimed at promoting sustainable practices in the packaging industry. Notable achievements include the development of the Blue Loop innovation, a recyclable flexible food packaging, and the collaboration with Nestle on biodegradable coffee capsules. These partnerships demonstrate a proactive approach to environmental concerns within the industry. The integration of laser

technology has proven effective in overcoming challenges in perforation and slitting tasks for paper and plastic films, enhancing the efficiency of packaging processes and demonstrating a commitment to exploring cutting-edge solutions for sustainable packaging practices. For example, the interviewee emphasized:

"***Notable achievements during this period include the introduction of the Blue Loop for recyclable food packaging and a strategic collaboration with Nestle on biodegradable coffee capsules, showcasing our enduring commitment to innovation and sustainability within the packaging industry."***

The initiative reflects a commitment to fostering a more sustainable future within the packaging industry through innovation, collaboration, and advanced technologies.

5.2 Innovations Related to Sustainable Packaging

Innovation is seen as an important element in fostering sustainable packaging (Lestari and Sunyoto, 2023). The study explores how the selected companies foster innovation, examining it at two distinct levels: the product level, involving novel approaches to raw material production, and the strategic level, encompassing partnerships in diverse projects.

Case 1; VTT

The "F3 Films for Future" project, involving 34 industrial partners, is focusing on sustainable packaging solutions. The project uses Cellulose Nanofiber (CNF) films and bio-HDPE films to reduce mineral oil migration and oxygen transmission, enhancing the protective qualities of packaging materials and minimizing environmental impact. The use of nanocellulose films, crafted through a SutCo surface treatment pilot line, is a cutting-edge approach to bolstering packaging sustainability.

This project demonstrates a commitment to technological advancement and environmental stewardship.

Case 2; Stora Enso

Pioneering advancements in sustainable packaging, our company specializes in the development and sale of premium fiber-based packaging products and services. Catering to

diverse sectors including retail, e-commerce, and industrial, we are committed to providing eco-friendly packaging solutions.

As mentioned by Stora Enso's expert:

"*Papira, our lightweight cellulose foam material, presents a natural, bio-based, and recyclable option for protective packaging.*"

One notable innovation is Papira, a revolutionary lightweight cellulose foam material. This cutting-edge product not only offers superior protection for various goods but also embodies a natural, bio-based, and recyclable option for protective packaging. Through such innovations, we strive to redefine industry standards, contributing to a more sustainable and environmentally conscious future.

Case 3; Huhtamaki

Huhtamaki, a major producer of flexible packaging, has begun on a trailblazing journey toward sustainable packaging. The business has strategically used CO2 laser technology, namely the GEM-100 laser, to perforate paper-aluminum laminate packaging for sugar cone sleeves.

This decision is supported by the laser's small design, which ensures efficient space usage, consistent power supply, and compatibility with both paper and aluminum materials. The utilization of CO2 laser technology is a cutting-edge solution to improve packaging process sustainability, demonstrating Huhtamaki's dedication to creative and eco-friendly methods in the domain of flexible packaging production.

5.3 Challenges Related to Functional Food

In addressing challenges related to functional food packaging, innovation plays a central role (Brennan et al., 2021). Companies focus on two key levels of innovation: at the product level, involving novel approaches to raw material production, and at the strategic level, through collaborations in diverse projects. This includes the adoption of eco-friendly materials and partnerships across the value chain, contributing to sustainable solutions in functional food packaging. Embracing these innovative approaches is crucial for overcoming

the multifaceted challenges associated with packaging in the dynamic domain of functional foods.

Case 1; VTT

The challenge of plastic recycling in functional food packaging is crucial for sustainable waste management. Safety concerns, particularly in post-consumer packaging, have led to the exploration of innovative technologies like near-infrared and hyperspectral cameras. These tools help improve recycling efficiency by identifying and separating different plastic materials. Polymer-aluminium composite layers have also proven effective, particularly in beverage cartons, with a 30% recycling rate for non-fibre components. This approach combines polymers with aluminium, addressing the unique challenges of functional food packaging. In conclusion, a multi-faceted approach is needed to tackle these challenges in plastic recycling. Utilizing technological innovations and exploring composite materials can enhance efficiency and sustainability, ensuring the safe handling of plastic food packaging and contributing to environmental conservation and circular economy principles.

Case 2; Stora Enso

Camfil is collaborating with the consumer board business to address environmental concerns by transitioning from traditional white boxes to environmentally friendly brown boxes. This initiative aligns with sustainability goals and demonstrates the company's commitment to corporate responsibility. The collaboration also targets growth in the fluting and kraftliner market, aiming to capitalize on emerging opportunities in sustainable packaging materials. By proactively resolving CO2 emissions through innovative packaging solutions, the company aims to position itself as an industry leader in environmental stewardship and contribute to fostering sustainability within the consumer board business. These efforts are expected to enhance the company's competitive edge and resonate positively with environmentally conscious consumers.

Case 3; Huhtamaki

Functional food packaging innovation is increasingly linked to sustainability, ensuring eco-friendliness and performance. However, challenges exist, such as consumer reluctance to pay extra for sustainable packaging, insufficient recycling infrastructure, and the need for consumer education. Huhtamaki, a key player in this domain, has addressed these challenges

by adopting a customer-centric approach and demonstrating a strong commitment to sustainability. For instance, during the interview, the following point was raised:

"Huhtamaki addresses challenges through customer support, sustainability commitments, pilot projects, and consumer education."

The company engages in pilot projects to test and refine sustainable packaging solutions, contributing valuable insights to the industry. Additionally, Huhtamaki actively participates in initiatives aimed at informing and empowering consumers to make environmentally conscious choices in functional food packaging. By addressing these challenges, Huhtamaki is demonstrating its commitment to sustainability and promoting eco-friendly choices in the functional food packaging industry.

5.4 Critical Analysis Derived from Literature Review: Unveiling Insights and Perspectives

The literature review discusses sustainability, its three-dimensional framework, and its potential to prioritize the well-being of future generations. It presents the Sustainability Analysis Framework, a tool for stakeholder discussions, incorporating individual, social, financial, technical, and environmental aspects. The review explores the role of functional foods in promoting human health and sustainability initiatives in the Finnish food packaging industry. It discusses the challenges posed by petroleum-based materials, the potential of biodegradable polymers, and the criteria for sustainable packaging. The review also highlights the need to consider consumer perceptions alongside governmental and scientific perspectives. The review differentiates between active and intelligent packaging, emphasizing their dynamic influence on the food environment. The review highlights the role of collaboration in packaging development value chains, the optimization of processes, RFID technology, and nanotechnology's potential for future applications. The review also discusses the evolving landscape of food service packaging, including innovations for food safety, convenience, and trends like on-the-go meals.

Innovations in recovering PolyAl and advancements in paper cup recycling are discussed, showcasing progress in recycling methods for plastic packaging. The challenges in PET recycling are outlined, emphasizing the need for improved recycling systems and sustainable

designs. Also, emphasizes how food companies drive sustainability through strategic innovation, underscoring the importance of demand-pull mechanisms in sustainability transitions.

5.5 Examining VTT Company: A Comprehensive Analysis in the Context of this Research VTT - Functional Food Packaging

VTT's initiatives in functional food packaging, including the Cellulose Films pilot facility, exemplify a commitment to sustainable cellulose-based materials. The alignment with EU regulations and the focus on recyclability contribute to international sustainability standards.

VTT Paper on Precision Food Packaging

The VTT paper on precision food packaging is analysed, emphasizing the intricate relationship between shelf-life, market strategies, and packaging design. The study proposes models for shelf-life analysis and advocates for a system-based approach, providing a decision-making tool for new product introduction.

VTT Pilot Plants and Bioruukki Pilot Centre

The role of VTT Pilot Plants and the Bioruukki Pilot Centre in developing sustainable packaging materials is discussed. The utilization of cellulose-based structures, including nanocellulose films, showcases adaptability in various packaging applications.

5.6 Exploring Stora Enso Company: A Comprehensive Analysis within the Scope of this Research - Stora Enso's Functional Food Packaging Initiatives

This section provides a comprehensive analysis of Stora Enso Company, focusing on its initiatives in functional food packaging. It reviews technological advancements, sustainability practices, and market positioning, aiming to provide a detailed understanding of Stora Enso's role and strategies in the functional food packaging industry and Stora Enso - Packaging in Logistics. Stora Enso's qualitative case study emphasizes the importance of efficient logistical packaging tailored to customer demands, highlighting its integration for improved business performance in complex distribution processes. Stora Enso's robust

financial performance in 2022 and commitment to sustainability are analysed. The company's strategic emphasis on sustainable practices, customer feedback integration, and a commitment to achieving 100% regenerative solutions by 2050 is highlighted.

5.7 Exploring Huhtamaki Company: A Thorough Analysis within the Framework of this Research - Huhtamaki's Functional Food Packaging

Huhtamaki's evolution toward sustainability and its adoption of CO2 laser technology for sustainable perforation tasks are discussed. The introduction of sustainable alternatives, such as paper-based ice cream containers, showcases a commitment to circular economy principles.

5.8 Summary of the Analysis and Discussion

The discussion section of this thesis focuses on three key themes: "Sustainable Packaging Initiatives", examining eco-friendly materials and recycling efforts; "Innovations Related to Sustainable Packaging", exploring cutting-edge solutions in the industry; and "Challenges and Opportunities Related to Functional Food", assessing the balance between packaging, and preserving food functionality. Together, these themes offer a comprehensive view of the current landscape of sustainable food packaging, covering initiatives, innovations, challenges, and opportunities in this crucial field.

Based on the information acquired in the analysis phase, the author has carefully created a table that highlights the key findings about each of the three themes that are being studied. This extensive table functions as a visual aid, providing a concise and well-structured synopsis of the principal findings from the analytical investigation in each subject area.

Table 15 encapsulates the author's findings derived from the cross-case analysis, encompassing both empirical and theoretical outcomes.

Also, In Figure 7, a model is presented illustrating the approach to achieving sustainable food packaging. The progress model unfolds in a strategic sequence, beginning with a foundational understanding of sustainability principles. This initial step lays the groundwork for an exploration into various facets of sustainability, identification of industry leaders, and

alignment with the latest sustainable development goals outlined in SDG2030. As this knowledge base solidifies, the model advances to decision-making regarding the type of food packaging, emphasizing considerations of sustainability criteria and environmental impact. Moving forward, the incorporation of functional food concepts introduces an innovative dimension, exploring ways in which packaging can contribute to the functionality and health aspects of food products. The subsequent methodological phase defines the research approach, and the subsequent breakdown into specific materials and methods categories—Bio-base, Cellulose, Laser, and Fiber—provides a structured framework for the packaging development process. The innovation stage emerges as a focal point, encouraging creativity in design, functionality, and eco-friendliness within the sustainable food packaging domain. Partnership establishment becomes crucial, involving collaborations with relevant stakeholders, academic projects, engagement with science laboratories, and solicitation of survey feedback to enhance the overall development and adoption of sustainable packaging solutions. The model culminates in the synthesis of findings and innovations into a comprehensive framework for sustainable food packaging. This final step emphasizes the holistic integration of various elements, ensuring alignment with overarching sustainability goals and criteria. In essence, the model represents a systematic and collaborative journey, from conceptualization to practical implementation, underscoring the importance of innovation and sustainability principles in shaping a more environmentally conscious future.

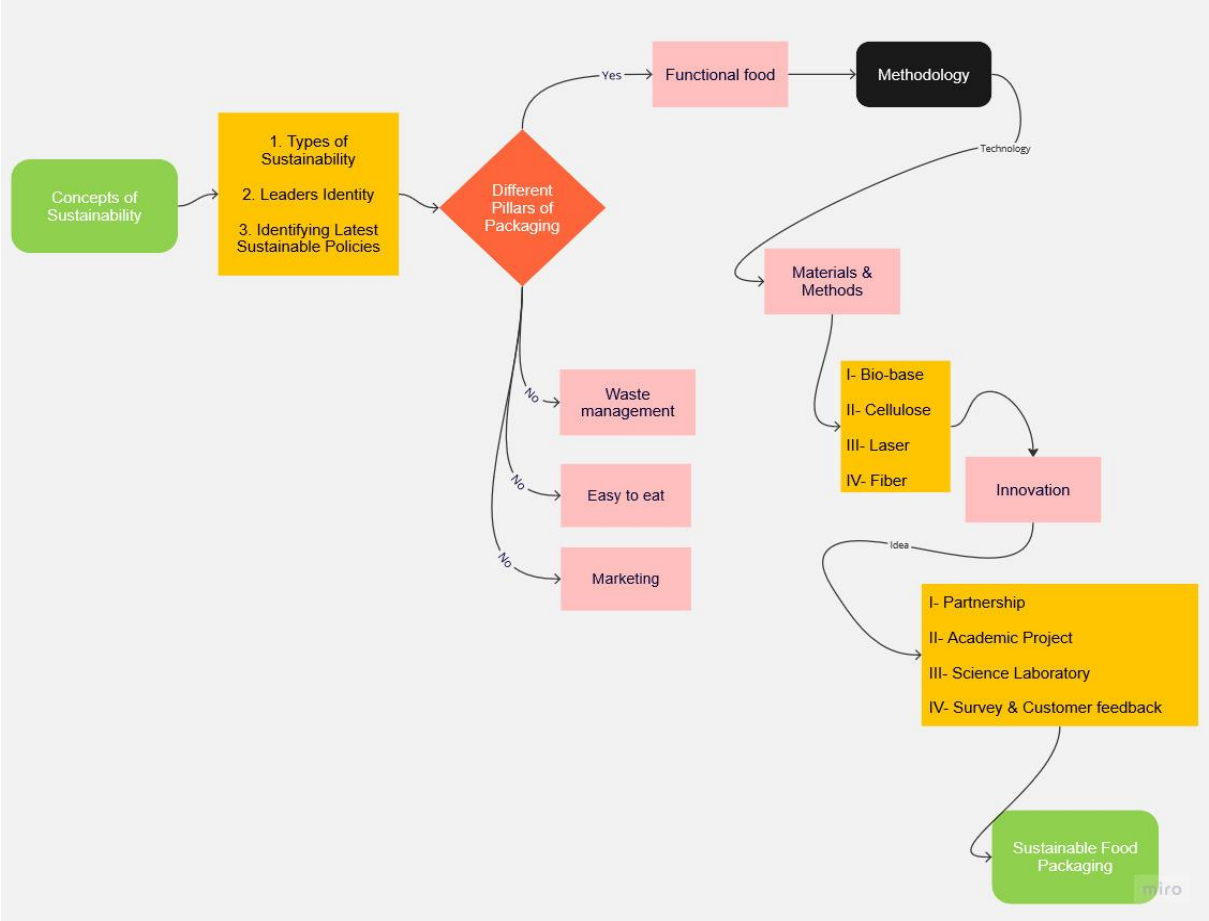

Figure 7, Sustainable Food Packaging: An Integrated Model for Innovation and Environmental Impact

Table 3, Author's Findings from Cross-Case Analysis - Integrating Empirical and Theoretical Outcomes

Sustainability Initiatives	***Innovations and Practices***	***Challenges and Opportunities***	
Advocates closed-loop systems for packaging recovery in alignment with global circular economy trends.	*Innovations include sustainable cellulose-based materials, as seen in "Package Heroes" and "F3 Films for Future" initiatives.*	*Challenges in recycling, particularly in multilayer packaging. Strides in recovering PolyAl and advancements in PET recycling.*	***VTT Company***

Integrates alternative energy sources, showcasing a commitment to sustainable practices and reducing carbon footprint.	*Emphasis on regenerative solutions highlights a shift towards eco-friendly alternatives in the industry.*	*Challenges and prospects of diverse packaging materials, including chemically recycled polypropylene and digital watermark technologies.*	***Stora Enso***
Pioneers' sustainable innovation with the adoption of CO2 laser technology and the introduction of eco-friendly alternatives like paper-based ice cream containers.	*Industry leader contributing to environmentally responsible solutions and driving sustainable practices.*	*Significance of consumer education and awareness in overcoming challenges related to eco-designed packaging.*	***Huhtamaki***

6 Conclusion & Contribution

The thesis addressed a gap in the literature by advancing empirical studies on strategy, innovation, and sustainability. The primary goal was to understand how businesses perceived sustainability within the realm of functional food packaging, along with the challenges they encountered and the creative solutions they employed. Information for the study was gathered from both primary and secondary sources, including reputable organizations such as VTT, Stora Enso, and Huhtamaki. The research procedure aimed to offer valuable insights into the effectiveness of sustainability innovations and initiatives in the functional food packaging sector.

1. ***How does using new packaging materials affect the cost and profit, and make customers happy by keeping food fresh longer?***

The adoption of new packaging materials is inextricably tied to the economic feasibility and profitability of functional food items. The use of these materials not only affects the cost-effectiveness of packaging solutions but also plays an important role in protecting product shelf life. VTT, for example, highlights the relevance of sustainable cellulose-based materials in a variety of applications, including packaging, which leads to increased innovation and technical breakthroughs. The utilization of innovative materials in the "F3 Films for Future" project, such as Cellulose Nanofiber (CNF) films and bio-HDPE films, shows how technical innovation may improve protective properties while minimizing environmental effects and perhaps boosting consumer satisfaction. The economic and social elements are inextricably linked. Investments in new materials may have an immediate cost effect, but they can contribute to long-term profitability and excellent consumer views. Camfil is working with the consumer board industry to solve environmental issues by switching from standard white boxes to eco-friendly brown boxes. This program is in line with the company's sustainability aims and reflects its commitment to corporate responsibility. The alliance also aims to increase the fluting and kraftliner markets, capitalizing on new potential in sustainable packaging materials. By proactively reducing CO2 emissions through creative packaging solutions, the company hopes to establish itself as an industry leader in environmental stewardship and help to develop sustainability in the

consumer board sector. These initiatives are anticipated to strengthen the company's competitive position and appeal to environmentally concerned consumers.

2. ***How do top companies in food packaging make their products better for the environment, and what special features do they add to help with sustainability?***

VTT, Stora Enso, and Huhtamaki, industry pioneers in functional food packaging, display a commitment to sustainability through their packaging products. These items include new characteristics that are in line with the overall aims of sustainable packaging solutions. Stora Enso's Papira, for example, is a lightweight cellulose foam material that not only provides outstanding protection for items but is also a natural, bio-based, and recyclable solution for protective packaging. Huhtamaki's Blue Loop invention and partnership with Nestle on biodegradable coffee capsules, for example, demonstrate a holistic approach to sustainability. These programs promote environmental stewardship and are well-received by customers. Huhtamaki's use of laser technology in perforating paper-aluminum laminate packaging for sugar cone sleeves demonstrates how technical innovation may be used to improve sustainability. Industry leaders use new features strategically in their functional food packaging products, harmonizing with the larger objective of sustainable packaging solutions.

6.1 Theoretical Impact

In numerous respects, this thesis makes a substantial contribution to the body of knowledge on sustainable packaging options for functional foods. In the first place, it fills a research vacuum by illuminating the motivations behind and difficulties with sustainable packaging. Utilizing an extensive examination that employs primary and secondary data, this study substantially contributes to the comprehension of sustainable methodologies in functional food packaging. Furthermore, the results add to the body of knowledge on collaboration and innovation management about functional food packaging. Furthermore, the study provides important insights and recommendations for future studies, which will be further discussed in the limitation and future research section. In addition, the study empirically and theoretically addresses the call for additional research on environmental sustainability in the packaging industry (Afif, Rebolledo and Roy, 2022; Meherishi, Narayana and Ranjani,

2019; Tran Dinh et al., 2022). However, our study focuses both on primary data and secondary data from case companies.

6.2 Managerial Recommendation

In this qualitative case study, managers can gain valuable insights for businesses like those examined. Sustainable packaging goes beyond internal efforts, requiring strategic collaboration with external entities. The key lies in collaborative innovation to enhance the entire value chain. Balancing environmental concerns and profitability mandates a strategic approach to packaging integrated with operational costs. Fostering consumer education on ethical practices, including clear instructions on packaging disposal, empowers ecologically conscious decisions. Practical implications for similar businesses include effective partnerships, a focus on collaborative innovation, strategic attention to packaging solutions, and clear consumer instructions for sustainability.

6.3 Limitations and Future Research

The research is not without its limitations, and a comprehensive understanding of these constraints is crucial. Firstly, the resource constraints were a substantial hurdle, given that the research was self-funded. This financial limitation restricted the ability to travel and conduct face-to-face interviews with other companies, which could have added depth and diversity to the data collected. Secondly, the dynamic nature of technology management presents a challenge, as the continuous evolution of technology may render some of the investigated methods and technologies outdated, thereby impacting the sustained relevance of the research findings. Another significant limitation arises from the diversity in international trade regulations and intellectual property rights, which vary considerably from one region to another. Obtaining firsthand data on technological documents and patents proved challenging, as companies often guard this information closely. Furthermore, temporal constraints within the standard six-month timeframe for finalizing a master's thesis limited the opportunity for a more extensive longitudinal study. A longer duration could have facilitated the collection of data over multiple years, enabling the mapping of shifting trends in sustainable packaging. The restricted time also hindered the comprehensive

execution of quantitative research methods, leaving room for future researchers to employ survey-based methodologies to delve deeper into the findings.

Lastly, while this thesis focused on functional food packaging through the lenses of sustainability and innovation, there remains an unexplored avenue for other researchers. They could investigate the topic from the perspective of institutional theories, shedding light on the policy frameworks that either offer opportunities or pose challenges within the realm of functional food packaging. Acknowledging these limitations not only adds transparency to the research process but also provides valuable insights for future researchers seeking to build upon this study.

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Appendix 1.

Appendix 1 contains supplementary tables providing additional in-depth information for the master's thesis.

Table 4, Deteriorative Effects on Foods: A Table Summary (Lyijynen, Hurme and Ahvenainen, 2003)

Deterioration due to	Deteriorative effect on foods	Type of packaging protection/function
Oxygen	Lipid oxidation, Vitamin destruction, Protein loss, Pigment oxidation	Oxygen barrier
Moisture	Nutritional quality loss, Organoleptic changes, Browning reactions, Lipid oxidation	Moisture barrier
Light	Oxidation, Rancidity, Protein and amino acid changes, Vitamin destruction, Pigment changes	Light barrier
Microorganisms/ Macroorganisms	Food spoilage, Nutritional and quality loss, Potential health hazard	Hermetic containment
Mechanical abuse (dropping, compression, vibration, abrasion and rough handling)	Organoleptic changes, Spoilage and other quality changes due to failure of seals, pinhole formation, etc.	Material and sealing properties
Odorous substances Toxic chemicals	Off-flavour formation, Taste deterioration, Chemical changes, Toxic hazards	Barrier properties, Chemical resistance
Tampering	Product loss, Quality changes, Potential heath hazard	Tamper proof/ evident/- resistant
Consumer handling, Abuse, Misuse	Product loss, Quality changes, Nutritional changes, Organoleptic changes	Mechanical properties, Clear information (labelling)

Table 5 The combinations of different carbon dioxide concentrations and oxygen (Lyijynen, Hurme and Ahvenainen, 2003)

Storage time (d)	CO_2 (%)	Oxygen transmission rate of packaging material (cm^3/m^2d) Aerobic plate count (log(cfu/g)) < 7	Yeast and mould count (log(cfu/g)) < 5
7 days	0	10 - 1000	10 - 1000
	30	10 - 1000	10 - 1000
	60	10 - 1000	10 - 1000
14 days	0	10 - 1000	< 530
	30	10 - 1000	10 - 1000
	60	10 - 1000	10 - 1000
21 days	0	< 50	< 100
	30	10 - 1000	< 640
	60	10 - 1000	10 - 1000

Table 6, Optimizing Shelf Life: Balancing Oxygen Absorbers and Packaging Material Transmission Rates, (Lyijynen, Hurme and Ahvenainen, 2003)

Storage time (d)	Oxygen absorbing capacity (cm^3)	Oxygen transmission rate of packaging material (cm^3/m^2d) Aerobic plate count (log(cfu/g)) < 7	Yeast and mould count (log(cfu/g)) < 5
7 days	0	10 - 1000	10 - 1000
	100	10 - 1000	10 - 1000
	200	10 - 1000	10 - 1000
14 days	0	10 - 1000	-
	100	10 - 1000	< 340
	200	10 - 1000	10 - 1000
21 days	0	10 - 1000	-
	100	10 - 1000	-
	200	10 - 1000	< 160

Table 7, Optimizing 400g Gas-Packed Roasted Chicken Balls with Reusable Boxes (Lyijynen, Hurme and Ahvenainen, 2003)

Feature	Package 1	Package 2	Package 3	Package 4	Package 5	Package 6	Package 7	Package 8
Package type	flowpack	flowpack	tffs	tffs	tffs	preformed tray	preformed tray	preformed tray
Monomaterials used in package	PET, PE, EVOH	PE, PET	PA, PE	PA, PET, PE	PA, PET, PE, EVOH	PA, PE, PP	PA, PE, PP	PE, PS, EVOH
Package volume (cm^3)	≈1000	≈1000	≈800	≈1000	≈1100	≈1300	≈1200	≈1500
Weight of an empty package (g)	6	7	10	22	18	26	27	42
Transparency	clear	clear	clear lid and tray	clear lid and tray	clear lid, yellow tray	clear lid, opaque tray	clear lid, opaque tray	clear lid and tray

Table 8, Optimization Results for Gas-Packed Roasted Chicken Balls (Excluding Mechanical Strength and Packaging Standards) (Lyijynen, Hurme and Ahvenainen, 2003)

		Scores							
Characteristic	*1*	Package 1	Package 2	Package 3	Package 4	Package 5	Package 6	Package 7	Package 8
Mechanical strength	*0.10*	*5*	*1*	*5*	*3*	*5*	*3*	*5*	*1*
Suitability with respect to standards	*0.09*	*5*	*5*	*5*	*3*	*3*	*3*	*1*	*3*
Package weight/product weight	0.07	4.7	4.6	4.3	3	3.4	2.6	2.4	0.8
Volume of package waste	0.07	5	5	4	3	3	1	1	1
Possibility of incineration	0.07	3	3	3	3	3	3	3	3
Marketing properties	0.14	2	2	1.5	3	2.5	3	2.5	3
Consumer convenience	0.10	3.5	3.5	2	2.5	2.5	3.5	2.5	3
Cost of packaging material	0.14	5.14	5.57	5.53	4.33	4.5	3.7	3.15	0
Indirect packaging costs	0.23	5	5	3	3	3	2	2	2
Optimization result		**3.4**	**3.4***	**2.6**	**2.6**	**2.6**	**2.2**	**1.9****	**1.5***

* Packages 2 and 8 failed the simulated transportation test and, therefore, they were not acceptable.

** The dimensions of Package 7 were not suitable for the secondary package used for the product.

Figure 8, Collection and recycling of post-consumer plastic waste. PMD = plastic, (Arnold, 2022)

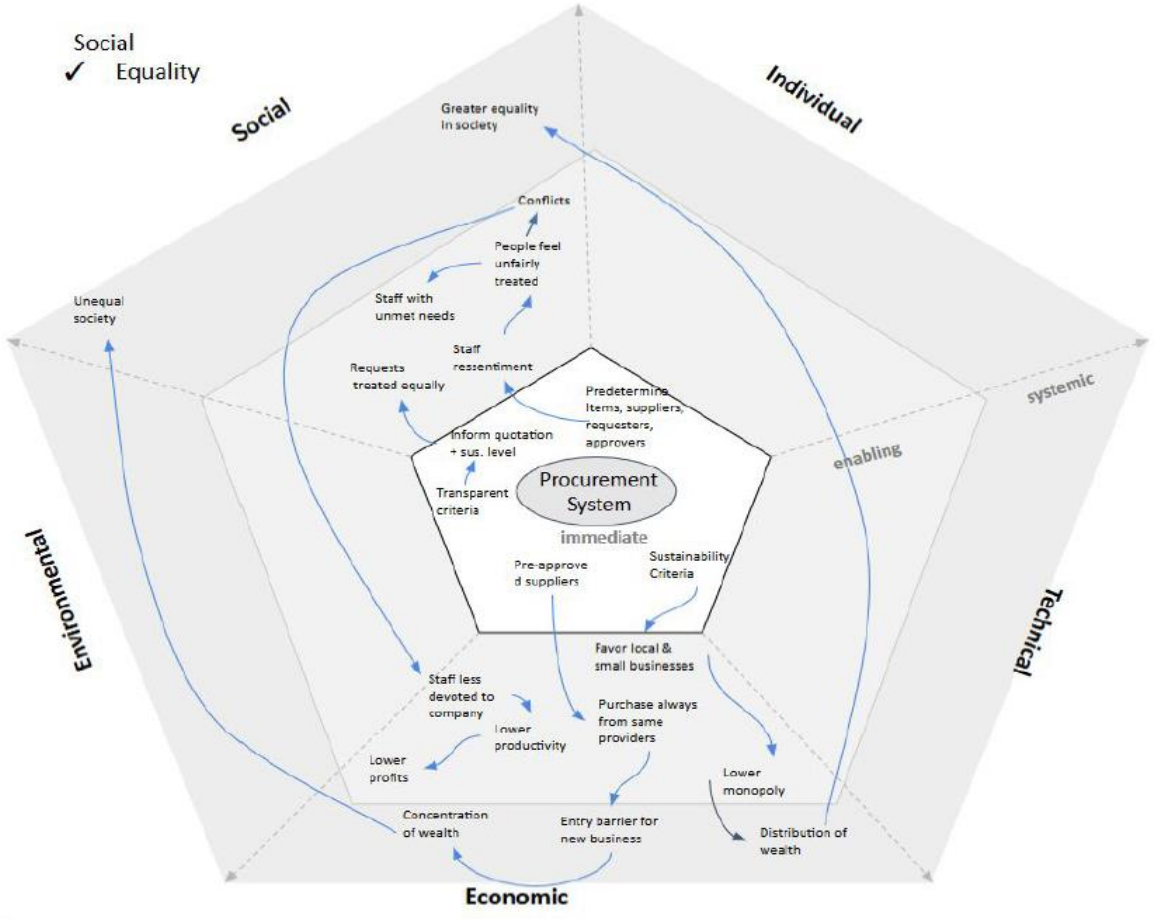

Figure 9, SusAF of procurement system, (Becker et al., 2016)

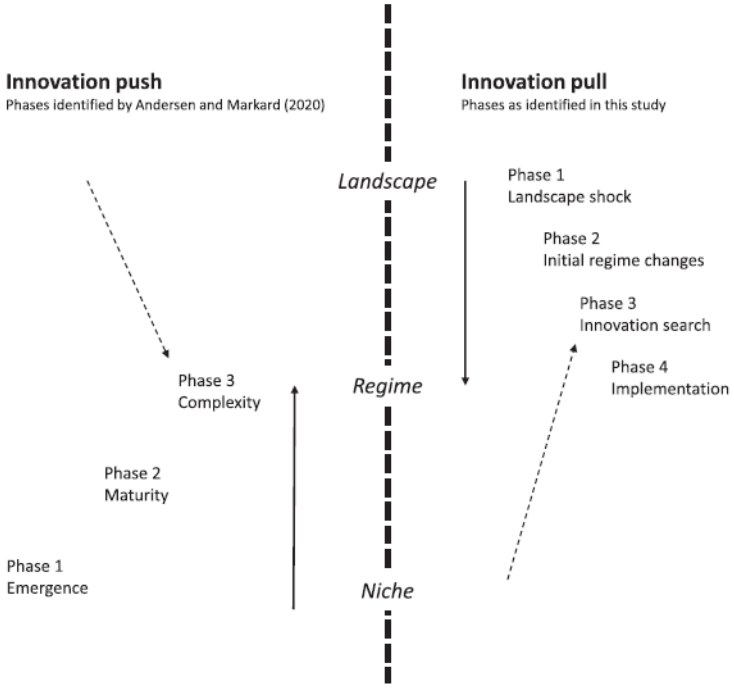

Figure 10, Transition phase, (Bor, OShea and Hakala, 2024)

Appendix 2

Table 9, Interview guide design (Author`s elaboration)

Concept	Questions
Background and Expertise	Could you please provide an overview of your role and responsibilities within the packaging department?
	How long has your company been actively involved in research and development related to functional food packaging?
	Can you share any notable achievements or projects that the company has been involved in regarding functional food packaging innovation?
	What are the key trends you've observed in the functional food packaging industry in recent years?

Current Trends and Challenges and gap area	From your perspective, what are the most significant **challenges** and **gap areas** that the industry faces in terms of packaging for functional foods?
	How is the company addressing these challenges and gap areas through its research and development efforts?
Innovations in Functional Food Packaging	Can you provide insights into the Company's approach to **sustainability in packaging innovation** for functional food products?
	What are the key **challenges** or **obstacles** that the company faces when developing innovative packaging solutions for the food industry, and how do they **address** these challenges?
	How does the Company stay updated on **emerging trends** and **technologies** in the packaging industry, and how does this influence VTT **innovation strategies**?
	Can you share any **examples** of successful collaborations between the Company and **food manufacturers** that have led to **innovative packaging solutions**?
	What role do **consumer feedback** and preferences play in shaping the Company's packaging innovation initiatives for functional food products?
	How does the Company assess the environmental impact and sustainability of its **innovative packaging solutions**, and what steps are taken to minimize negative effects?
	Could you share your approach to collaborating with others to address **challenges in the market**? If so, what strategies do you employ?
	In what ways do **government regulations** impact packaging in your industry, and what proactive measures should companies take to navigate these changes effectively?
Sustainability and Eco-Friendly Packaging	Sustainability is a growing concern in the packaging industry. How is the Company contributing to the development of eco-friendly packaging solutions for functional foods?
	Personally, are there any ongoing projects or research initiatives aimed at reducing the environmental impact of functional food packaging? What are the key and famous **functional food packaging products** used by the Company?
Safety	Can you discuss any advancements in packaging technology that enhance food safety and quality for functional foods?
Collaboration and Partnerships	Does your company collaborate with other research institutions, industry partners, or government agencies in the development of functional food packaging solutions?
	What do you foresee as the future directions or potential breakthroughs in functional food packaging technology and innovation?

Future Directions	Are there any upcoming projects or research areas within your company that will have a significant impact on the packaging of functional foods?