FIPDes

Food Innovation & Product Design

FIPDes Day 2025
International talents in Food Innovation and Product Design

Students' Book of Executive Summaries

Erasmus Mundus

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Congratulations to the FIPDes Cohort 12!

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Introduction

It is always a great pleasure to comment on the work of our FIPDes students and colleagues!

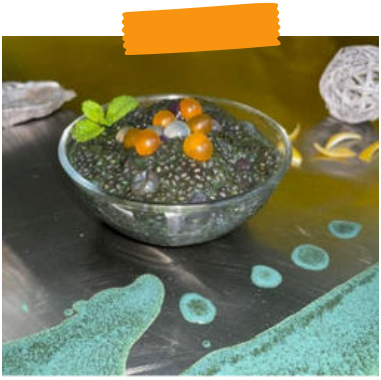
You are holding in your hands a great concentrate of the MSc. Thesis FIPDes adventure: the book of executive summaries. This book was edited over the summer thanks to the dedication of our students and the careful work of Lucile Deloince, who was in charge of the publication.

Why this book?

It is a tangible way to demonstrate the variety of topics covered by the FIPDes students in their MSc. theses, ranging from food engineering and packaging to reformulation, food nutrition, and ingredient evaluation. They take the perspective of sustainable food systems, spanning from pilot plants to public policies, and from by-product valorization to environmental assessment.

If you attended the 2025 FIPDes Day, this book contains the conference proceedings of the students' flash presentations and posters. Otherwise, this small book offers a taste of the cutting-edge research carried out in public and private laboratories across Europe, which the students had the opportunity to join during their MSc. Thesis internship.
Our best partners and collaborators will also receive this gift, which is a great way to keep track of FIPDes alumni, who will most probably be their future colleagues and employees.

Looking at the picture of the 2025 cohort brings back lots of memories...



One of the finest was the mentoring on an extraordinary FIPDes "Junior Project" on spatial food.
FIPDesers designed and realized amazing prototypes, and perhaps your grand-grandchildren will taste them en route to Mars?
From a closer perspective, a lot of work is waiting to be done by FIPDes graduates to improve food on Earth... now!

The innovative, cooperative, responsible and ethical mindset of our FIPDes alumni is therefore more than necessary. Looking at the work done during these 2 years of the FIPDes program and to their MSc. Thesis projects, I am happy to say that they are already making a significant contribution!

Congratulations to the 2025 FIPDes graduates!
Happy reading to all!

Prof. Barbara Rega

Comparatively Exploring the Effect of Yeast on Oven Spring Using Conventional and Ohmic Baking

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Introduction

Loaf volume is a key quality parameter in bread for consumers (Marshall, 1988). Most of the volume increase in a loaf of bread occurs within the first minutes of baking, during a phenomenon commonly known as “oven rise” or “oven spring” (Le-bail et al., 2011). Although no real-time measurements of oven spring have been cited in literature, current mathematical models suggest that the accelerated rate of production of CO_2 during the initial stages of baking and the subsequent expansion of entrapped CO_2 in the gluten network accounts for most of the effect (Zhang & Datta, 2006).

As the primary source of CO_2 during proofing and baking, yeast is thought to be a key formulation component affecting oven spring in pan bread. Furthermore, the metabolites produced by yeast during dough fermentation have been found to affect the rheological properties and extensibility of dough (Meerts et al., 2018; Jayaram, et al. 2014), which may in turn influence the evolution of loaf volume (Tietze et al., 2016). To better understand the impact of yeast on oven spring, an assortment of 12 commercially available strains used for different applications, including winemaking, brewery, bioethanol production, and breadmaking were tested. The gassing power and metabolite production of each strain were assessed, after which baking trials were conducted.

To aid in the real-time measurement of oven spring, a Dynamic Baking Camera (DBC) capable of following the changes of volume in bread inside a convection oven throughout the baking process was developed and implemented. Oven spring values were also measured inside an internally developed Electric Resistance Oven (ERO) capable of producing crustless bread through ohmic baking (Gally et al., 2016), maximizing loaf volume through the elimination of crust pressure (Zhang et al., 2007). The oven spring measurements of both baking methods were contrasted, and the resulting loaves of bread were characterized using texturometry and imaging techniques.

Research Objectives

The project aims to:
-Compare the oven spring measurements obtained with the dynamic baking camera to those obtained with the electric resistance oven.
-Analyse how these measurements relate to the properties of the yeast strain (gassing power and metabolite production), and the attributes of the resulting loaf of bread.

Strategy and Methodology

As detailed in figure 1, the experiment can be broadly divided into three stages.

Stage 1: Fermentative qualities are assessed on each strain.
→ *Proofing efficiency* - Rate of CO_2 production per minute is measured in fermented dough.
→ *Metabolite analysis* - Ethanol and glycerol is quantified from fermented dough samples.

Stage 2: Oven spring is measured during baking on two types of bread.
→ *Conventional Bread Test* - Produced in a convection oven and measured with the DBC.
→ *Crustless Bread Test* - Produced in the ERO and measured with infrared height sensors.

Stage 3: Bread loaves obtained from baking tests are characterized.
→ *Volumetric Scanning* - Volume of bread loaf is measured after 2h of rest at 21°C
→ *Bread Imaging* - Loaf is sliced, and each slice is scanned to characterize its gas cells.
→ *Texture Profile Analysis* - A double compression test is conducted on each slice.

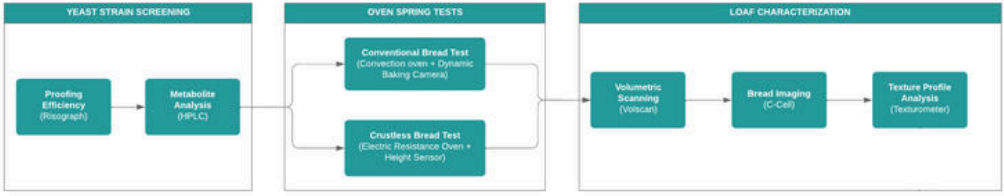

Figure 1. Experimental strategy followed throughout the project. The method used for each experiment is indicated between parenthesis for each case.

Results and Discussion

The fermentation time for each strain was calculated as the time required to produce 120ml of CO_2 as measured with a Risograph (National Manufacturing Co., USA). ANOVA treatment of the data reveals statistically significant differences between strains ($p=0.00$, $R^2=99.39\%$), with half of the quickest-fermenting strains being all used for breadmaking. Conversely, brewery, winemaking, and bioethanol production strains were all within the slowest 50% of strains (Table 1). Analysis of ethanol and glycerol concentrations revealed a consistent positioning of S7, S2, and S10 as the most productive and S3 and S8 as the least productive strains, with most breadmaking strains showing no significant difference from each other.

Yeast Strain	Application	Grouping[a]	Average Time (hh:mm:ss)	Coef. Variation (%)	Position[b]
S1	Breadmaking	EF	01:18:40	3,61	2
S2	Breadmaking	CD	01:44:50	7,35	8
S3	Breadmaking	B	02:07:10	0,23	10
S4	Breadmaking	EF	01:23:10	1,74	4
S5	Breadmaking	F	01:17:50	0,74	1
S6	Breadmaking	EF	01:21:50	1,96	3
S7	Breadmaking	EF	01:23:50	0,91	5
S8	Brewery	A	03:15:30	2,88	12
S9	Winemaking	D	01:36:40	2,6	7
S10	Bioethanol	C	01:50:50	2,48	9
S11	Non-Saccharomyces/Brewery	A	03:14:10	1,19	11
ST[c]	Breadmaking	E	01:26:18	1,72	6

Table 1. List of yeast strains and their average fermentation time.
a: grouping as calculated with Tukey's Range Test (CI = 95%). b: positioning of strain from quickest to slowest. c: "ST" denotes experimental autocontrol strain.

Unlike the convection oven, which creates large temperature gradients that encourage the rapid expansion of entrapped CO_2 (Purlis & Salvadori, 2010), ohmic ovens were conceived to evenly heat the loaf resulting in a more uniform baking process (Gally et al., 2016). As a result, the loaf of bread expands gradually, only slowing down as the crumb sets, near the end of baking (Zhang & Datta, 2006), as opposed to the sharp volume increase observed in the case of convection ovens (Figure 2).

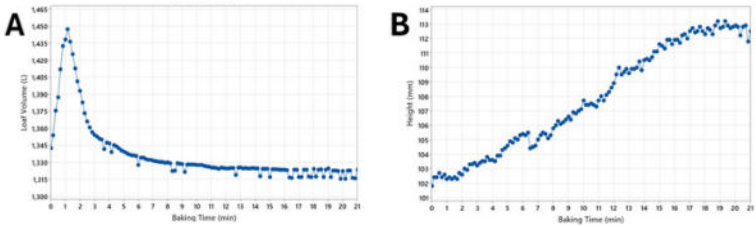

Figure 2. Evolution of bread loaf dimensions during baking.
A: volume change in a bread loaf fermented with strain S7 inside of the convection oven
B: height change in a bread loaf fermented with strain S7 inside of the ERO.

The sharp decrease in volume following oven spring in the convection oven trials deviates from previous experiments, resulting from the removal of bread improvers from the tested recipe. Work by Silva et al. (2022) illustrates that, at the tested temperature (200°C), the stress of gas expansion during oven spring can more easily rupture gluten cells, affecting volume and stability. Bread improvers help reduce this effect by decreasing the resistance to extension and increasing the maximum extensibility of dough (Tebben et al., 2018).

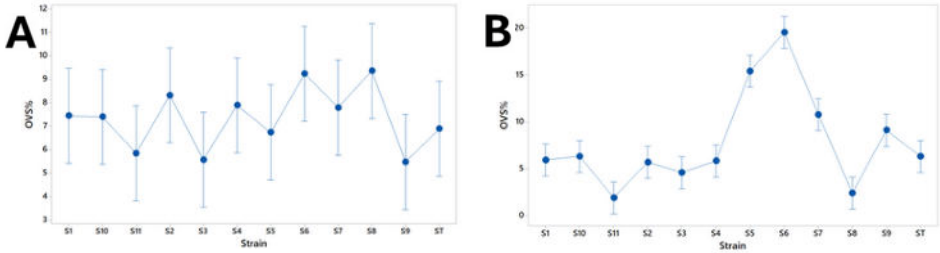

Figure 3. Interval plot of oven spring percentages (OVS%) per strain.
A: values measured in convection oven (pooled St. Dev. = 1.7)
B: values measured in ohmic oven (pooled St. Dev. = 1.43)

No significant difference in oven spring was found between strains in the convection oven tests, as opposed to the results obtained in the ohmic baking tests (Figure 3). Likewise, oven spring and fermentation time were found to be moderately correlated in the ohmic baking tests (r=-0.615, p=0.00), though not so in the convection oven tests. Research by Vandenbosch et al. (2025) suggests that yeast survivability and gas production rate under heat stress are important variables influencing oven spring, explaining the performance gap, as ohmic ovens allow yeast to more optimally produce CO_2 for longer (Gally et al., 2017).

In both cases, no relation between glycerol and ethanol concentrations to oven spring was found, though glycerol concentration showed a moderate correlation to final volume in both ohmic baking (r=0.575, p=0.00) and convection baking tests (r=0.689, p=0.00). Although both metabolites have been identified as important to ensure adequate proofing (Aslankoohi et al. 2015; Jayaram et al., 2014), organic acids have been found to specially contribute to the development of loaf volume (Su et al., 2019), highlighting the need to consider these metabolites for further studies relating to oven spring.

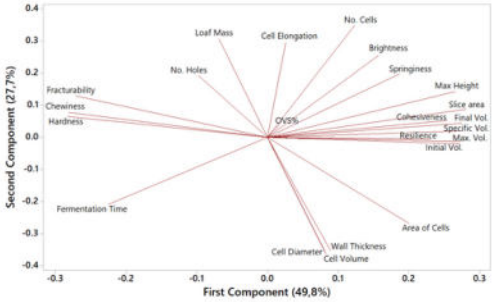

Figure 4. PCA loading plot (convection oven tests).

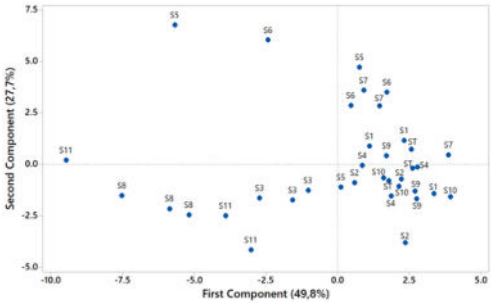

Figure 5. PCA score plot (convection oven tests).

Principal component analysis of the bread characterization parameters revealed springiness, brightness, cell elongation, and number of gas cells to be the most correlated to oven spring in ohmic baking trials, though only marginally so in convection oven trials (Figure 4) owing to the sharp volume collapse observed in the latter case which effectively undoes the effect of oven spring. Meanwhile, hardness and chewiness were the most strongly related to bread volume in both tests, matching observations in literature (Dessev et al., 2020). In the convection oven trials, the brewing strains S8 and S11 spread away from the main cluster of data in the score plot (Figure 5). This trend is also observable in the ohmic baking trials, though to a lesser extent.

Conclusion

Techniques like ohmic baking may be helpful to evaluate the potential of different yeast strains with regards to oven spring, but the performance under such conditions does not necessarily reflect the performance observed when yeast is implemented in traditional baking processes. In this respect, the Dynamic Baking Camera has been proven to be a helpful and innovative tool to further validate yeast performance under practical conditions. Moreover, the study of oven spring may also benefit from additional techniques such as dynamic rheological measurements, yeast survivability tests, and organic acid profiles.

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Performance Evaluation of Sugar Alternatives in No Added Sugar Muffins

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Excessive sugar consumption is linked to adverse health outcomes, prompting global efforts to reduce added sugars in food products. In bakery applications, sugar plays multifaceted roles beyond sweetness, including texture, volume, and shelf-life enhancement. Reformulating baked goods like muffins without compromising sensory and structural quality remains a significant challenge.

This thesis aimed to evaluate the performance of selected polyol and fiber based sugar alternatives in a no added sugar (NAS) muffin recipe, assessing their impact on physical, textural, and sensory attributes. Studies done as a part of this thesis showed that various physio-chemical factors had a high effect on the overall acceptability of a NAS muffin. A consumer panel evaluated the muffins on a Just About Right (JAR) scale to determine sweetness perception in the finished product.

There was therefore a hypothesis formed about the use of polyols and fibre as a potential sugar replacement in bakery products and with the help of this study, a benchmarking was set in place to extend the range of Healthy & Well-Being products under sugar reduction in Patisserie.

CONFIDENTIAL TOPIC

Optimisation of the Technological and Organoleptic quality of lean bread enriched with seeds and grains

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The study involved the incorporation of grains and seeds which are reported to increase bread freshness, nutrition and flavours of lean bread, but also may limit its dough handling and final quality. These hinder their feasibility in bakery operations.

So, the goal was to optimise enriched bread for similar or better dough consistency, volume and softness to the control. Hydration values, grain addition timing and grain dosage were phase by phase evaluated to achieve this goal.

Hydration levels adjustment was helpful though initially didn't significantly and positively improve dough handling. Subsequent water level variation achieved optimal dough handling and bread quality significantly similar to the control. Introducing grains before the end of mixing improved bread quality. Lower grain dosage produced bread with most physicochemical properties similar to the control bread.

The study results indicated the successful enrichment of bread with the grains and seeds products. The insights obtained will be useful for launch of bread enriched with the scope of grains and seeds products that have improved freshness, volume and dough handling.

CONFIDENTIAL TOPIC

Towards the use of sustainable alternative caseins: optimization of the stretching properties of cheese analogues hybrid matrices

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Milk and dairy products have long been key sources of high-quality nutrients, with cheese standing out for its cultural and functional versatility. Today, global demand for dairy is rising, especially in developing countries, while environmental and ethical concerns are pressuring the dairy sector to evolve. Plant-based cheese substitutes (PBCS), though emerging, still fall short in mimicking the sensory and functional qualities of traditional cheese, such as meltability and stretchability, because of the many differences in structure and functionalities between plant-based and dairy proteins.

Precision fermentation offers there a promising solution by producing animal-free dairy proteins with identical structures to their natural counterparts. In this context, the Bel Group, a global leader in branded cheese committed to sustainable innovation, partnered with the French start-up Standing Ovation (SO) to produce and use alternative proteins to develop vegan cheese analogs with good organoleptic properties, improved nutritional value and reduced environmental impact.

CONFIDENTIAL TOPIC

Physicochemical Evaluation of Crackers Enriched With Mealworm (*T. molitor*) Meal: Influence of Nutrient Composition and Storage

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Introduction

Mealworms (*Tenebrio molitor*) are edible insects approved in Europe as Novel Foods since June 2021 (Regulation (EU) 2021/882). They are valued for their high-quality protein, essential amino acids, and healthy fats, including omega-3 and omega-6 fatty acids, which are comparable to those found in meat and fish (Djouadi et al., 2022; van Huis et al., 2013).

Due to these nutritional benefits, mealworms are gaining attention as food ingredients. However, their nutritional composition can vary significantly depending on factors such as diet and weight (Kröncke & Benning, 2023; Toviho & Bársony, 2022). These inconsistencies may impact the quality of the final food products in which they are used. On the other hand, this variability could also be used advantageously to tailor the requirements of a product, for instance, to increase protein or fat content depending on the formulation goals.

This study aims to analyse how three different nutritional compositions of mealworms (resulting from different diets and individual weights) affect the quality of crackers enriched with 15% mealworm meal. The parameters evaluated include colour, dimensions, water activity, moisture content, texture, and lipid oxidation during storage.

Figure 1. Processing of mealworms into meal to be introduced in crackers.

Methodology

Differences in the nutritional composition of mealworms were achieved through different feed and individual mealworm weights: Std_80 (wheat bran, 80 mg), StdA_80 (wheat bran + Chlorella + spelt husks, 80 mg), and LPHF_100 (wheat bran + rice bran + apple pomace, 100 mg). This was conducted prior to the present study.

Crackers were evaluated at four timepoints (24 hours (t0), 7 days (t1), 28 days (t2), and 42 days (t3) after baking) during an accelerated storage test at 40 °C.

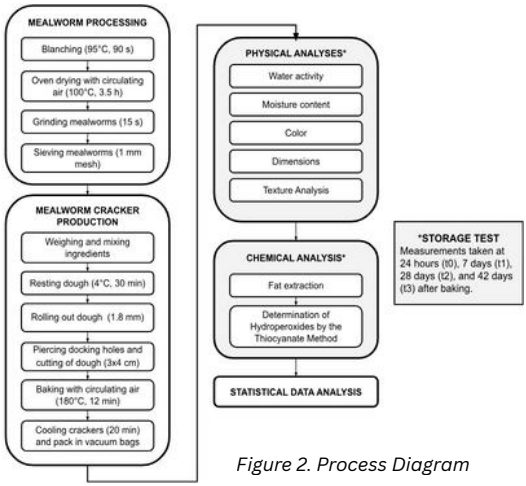

Figure 2. Process Diagram

Colour was measured with a colorimeter using Lab* values, from which the Browning Index (BI) and Colour Change (ΔE) were calculated. Dimensions (length, width, and thickness) were measured using a digital caliper, and the spread ratio was subsequently calculated. Moisture content was determined using a halogen moisture analyser, while water activity was measured with a hygrometer.

Texture was assessed using a Texture Analyser with a three-point bend rig (Figure 3.). Lipid oxidation was evaluated with the thiocyanate method, which measures hydroperoxide concentration in fat extracted from the crackers (Figure 4.).

Figure 3. Texture Analyser with three-point bend rig

Figure 4. Sample during Thiocyanate method

Results and Discussion

Colour: Mealworm crackers were darker (lower L* values, and higher BI values) compared to the control, mainly due to the natural pigment of insect meal and increased Maillard reaction due to higher protein content (Djouadi et al., 2022). No significant difference (considering colour change, ΔE) was observed between mealworm treatments (Figure 5.).

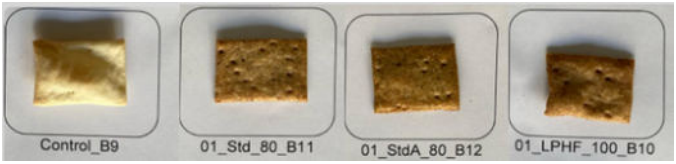

Figure 5. Different treatments of crackers produced.

Dimensions: Control crackers were thicker and showed more air bubbles, likely due to a stronger gluten network (Figure 5.). Mealworm particles and proteins disrupted the gluten network formation (Xie et al., 2022) making the crackers thinner.

%MC and aw: Mealworm crackers had lower %MC and aw, due to reduced water and gas retention from weakened gluten network in mealworm dough (Djouadi et al., 2022; Xie et al., 2022). All treatments showed aw values below the microbial stability threshold (0.6) and within the typical cracker range (0.01–0.3) (Nakamura et al., 2012) (Figure 6.).

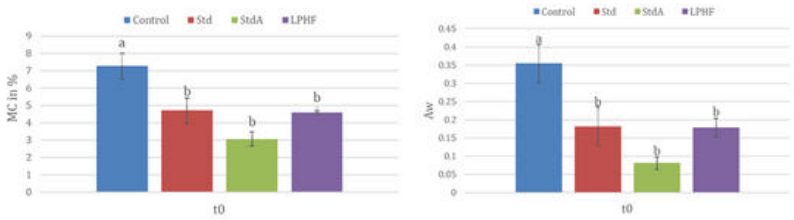

Figure 6. MC% and aw of crackers at t0.

Texture: Control crackers were harder and less fracturable, while mealworm crackers were softer and more fracturable. This indicates a higher crispiness in mealworm crackers, which is a desired textural attribute. This is likely due to the higher fat content in mealworm crackers, which weakened the gluten network, contributing to a more tender structure, reduced moisture and enhanced crispiness. This was also observed by Djouadi et al. (2022).

Lipid oxidation: Mealworm crackers showed better oxidative stability, possibly due to antioxidant effects of the mealworm meal (Figure 7.). Mealworm crackers had higher oleic acid and lower linoleic acid compared with the control, improving oxidative stability. Adding to this, proteins (Elias, Kellerby, & Decker, 2008), reducing sugars (Vu et al. 2020), and Maillard reaction products (melanoidins) (Baek et al. 2019) from the mealworm meal could have also contributed to the observed antioxidant effect. This oxidative stability is desired for avoiding early rancidity and therefore extending the product's shelf life.

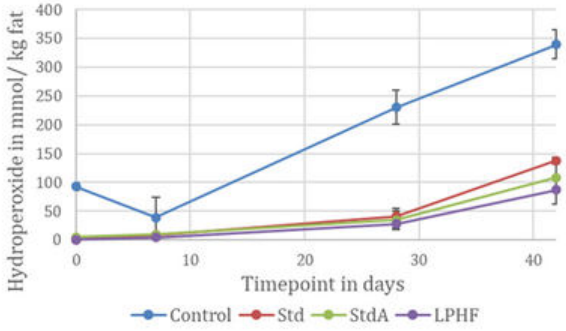

Figure 7. Lipid oxidation of crackers during storage.

Conclusion

The enrichment of crackers with mealworm meal can improve the nutritional profile, crispiness and oxidative stability of crackers, improving shelf life and quality of the product. However, no significant differences were observed in the quality parameters among the different mealworm treatments, indicating that differences in nutritional compositions did not have an impact on the quality of the crackers with 15% mealworm meal.

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Thermal Processing Effects on Pulse Matrix: A Multiscale Approach

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Introduction

With the rising demand for sustainable and nutritious plant-based beverages, pulses are gaining attention as alternatives to soy. Pulses are particularly attractive due to their high protein content, low allergenicity, and favorable agronomic profile. The use of whole pulses, rather than protein isolates or concentrates, preserves nutritional integrity but introduces processing challenges due to their complex structure. It affects the final product's texture, stability, and sensory attributes. Moreover, off-flavors commonly associated with pulses, such as beany or grassy notes, further limit their acceptance in beverage applications. This thesis investigates how thermal treatments, with a focus on high-temperature pretreatment steps, affect the physicochemical, functional and sensory properties of beverages made from whole pulses.

Unlike conventional approaches that rely on fractionated ingredients, this study adopts a multiscale perspective to evaluate the transformation of the native matrix during processing. The study aims to:

- Understand how thermal treatments influence protein characteristics, starch behavior, and functional properties (e.g., foaming, emulsification).
- Use a multiscale approach to analyze changes from molecular to macroscopic levels.
- Provide insights for optimizing processing conditions to improve product quality.

CONFIDENTIAL TOPIC

Impact and Lifecycle of New Barrier Polymer in Beverage Carton Recycling
A Lab-Scale Experimental Study

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Introduction

The global shift toward sustainable packaging has accelerated the development of new materials for beverage cartons. These multilayer systems—typically paperboard, polyethylene (PE), and aluminum—offer strong protection but are hard to recycle due to the difficulty of separating layers (Bauer et al., 2021). To improve recyclability, the industry is testing alternative barrier layers that retain functionality while being recycling-friendly. One promising option is polyvinyl alcohol (PVOH), a water-soluble synthetic polymer known for its film-forming ability, low oxygen permeability, and biodegradability (Solaro et al., 2000).

Although PVOH is well studied in other industries like pharmaceuticals and textiles, its solubility and detectability in beverage carton recycling—particularly during hydrapulping—remain poorly understood. At present, no standardized methods are available for detecting or quantifying PVOH in recycling outputs such as process water or PolyAl residues.

This study addresses the methodological gap by experimentally evaluating the solubility and recycling behavior of PVOH under lab conditions that simulate hydrapulping. It also proposes a UV-Vis spectrophotometric method for detecting trace levels of PVOH in different streams. By investigating how variables like coating thickness and temperature affect solubility, the study contributes to better understanding PVOH's role in recycling systems and supports the design of more recyclable multilayer packaging.

Methodology

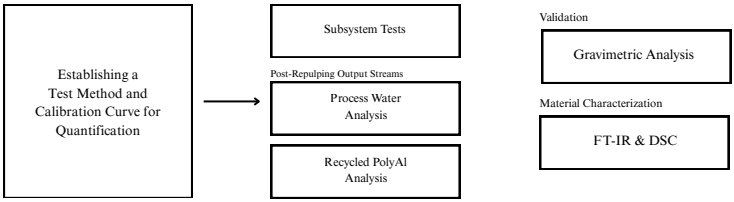

Figure 1. Two interconnected phases of Experimental Design

This study followed a two-phase experimental approach to investigate the recyclability and detectability of polyvinyl alcohol (PVOH) in beverage cartons. The first phase focused on developing a reliable method for detecting and quantifying PVOH in aqueous solutions. The Finley colorimetric method was selected, which forms a colored complex between iodine, boric acid, and PVOH, showing peak absorbance at 675 nm (Finley, 1961; Pritchard & Akintola, 1972). A calibration curve was established using UV-Vis spectrophotometry, and the method's accuracy was validated by calculating the limit of detection (LOD) and limit of quantification (LOQ) based on blank sample measurements (Thomsen et al., 2003).

In the second phase, the study focused on evaluating the behavior of PVOH under simulated hydrapulping conditions, with attention to its solubility and detectability in recycling streams such as PolyAl residue and process water. To assess recyclability, key variables—including coating thickness, drying temperature, and immersion time—were systematically varied to examine their influence on PVOH performance under conditions replicating industrial repulping. PET films were coated with PVOH on different thicknesses and cured at either 25 °C overnight or 100 °C for 12 minutes to produce samples. These films were immersed in distilled water at 20 °C or 45 °C and stirred at 900 rpm to simulate hydrapulping turbulence. This setup allowed for isolation of individual factors affecting PVOH dissolution.

Moreover, Fourier-transform infrared spectroscopy (FT-IR) and Differential Scanning Calorimetry (DSC) were employed to assess the presence of PVOH in both aqueous and solid fractions, and to validate the results obtained from UV-Vis spectrophotometry. A gravimetric approach was also used to estimate the amount of polyvinyl alcohol coated on PET films.

Results

Results were obtained through a stepwise approach, starting with the development of a spectrophotometric method to detect PVOH in aqueous solutions. A calibration curve using known PVOH concentrations complexed with iodine and boric acid showed a strong linear relationship (R^2 = 0.9987), confirming the method's reliability with a detection limit of 0.06 mg/L.

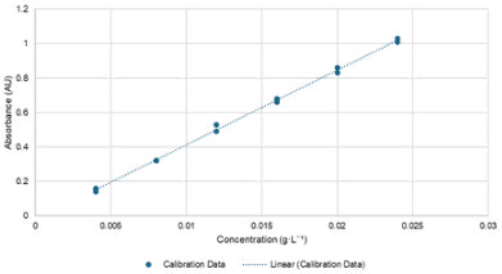

Figure 2. Calibration curve of PVOH solutions

Results showed that PVOH dissolves rapidly in water, with the majority of dissolution occurring within the first few minutes—particularly during the initial 60 seconds of immersion. Elevated water temperatures enhanced the rate of dissolution by increasing molecular mobility and film porosity, while films dried at higher temperatures (100 °C) showed slower dissolution rate. Thicker coatings also slowed dissolution, as water penetration into the denser polymer layer was more limited. Subsystem tests confirmed that both temperature and coating thickness are important factors influencing solubility.

UV-Vis spectrophotometry and gravimetric analysis produced consistent results, with closely matching trends, confirming the accuracy and reliability of the method.

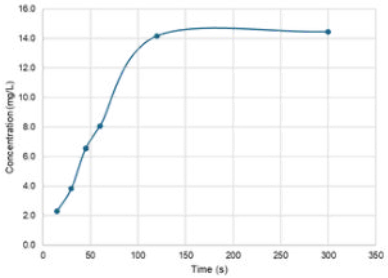

Figure 3. PVOH Dissolution During the First 300 Seconds of Immersion

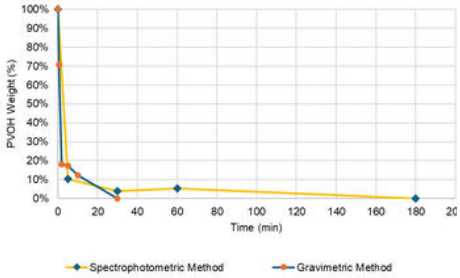

Figure 4. Comparison of Spectrophotometric and Gravimetric Methods

In CEPI recyclability trials, PVOH was primarily detected in the process water rather than in the PolyAl residue, confirming its dissolution pathway during simulated hydrapulping. These findings support the potential recyclability of water soluble barrier layers, especially since the concentration of polymer on the polyAl fraction remained well below the 1% limit set by Design for Recycling guidelines (RecyClass, 2024). However, one notable challenge emerged in the detection phase: residual starch from the paperboard also formed colored complexes with iodine, resulting in overlapping absorbance signals that interfered with accurate PVOH quantification.

Conclusion

This study successfully developed a lab-scale detection method for PVOH using UV-Vis spectrophotometry, demonstrating strong linearity and sensitivity. The Finley method proved suitable for low-concentration detection and was effectively used throughout the experiments. The developed UV-Vis spectrophotometric method—based on the Finley iodine is a fast, low-cost, and industry-adaptable approach for detecting PVOH in aqueous streams. Its simplicity and reproducibility make it suitable for routine lab applications. Subsystem and gravimetric tests showed that PVOH dissolution increases with temperature and is affected by coating thickness and drying conditions. CEPI recyclability tests confirmed that PVOH dissolves into process water, validating the detection protocol.

However, the study also identified limitations, particularly regarding the interference caused by starch present in paperboard layers. This interference can lead to overestimated PVOH concentrations due to overlapping absorbance signals in UV-Vis readings. Therefore, future research should incorporate the proposed correction strategies—such as the dual-wavelength method, acid hydrolysis, or enzymatic treatment—to improve measurement accuracy in more complex, real-world recycling matrices.

Overall, this research contributes valuable insights into the behavior of water-soluble barrier materials like PVOH and provides a foundation for developing standard detection and recyclability assessment methods that can support material design and packaging innovation.

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Quantification of Yeast Metabolites in Dough

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Master Thesis tutors:
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Introduction

Yeasted dough fermentation is a crucial step in the breadmaking process. The fermentative activity of Saccharomyces cerevisiae during this stage plays a vital role in determining the final bread characteristics (volume, aroma, rheology).

Despite significant research on the relationship between fermentation primary metabolites and textural changes in bread, more recent discoveries on the effects of secondary metabolites and their impact on the dough matrix have raised the concern that the effect and production rate of each compound has yet to be fully elucidated.

By assessing the metabolite production of S. cerevisiae, we can gain deeper insight into how these compounds shape bread characteristics. It is for this reason that a fully comprehensive analysis of the current analytical methods and their validity had to be performed.

CONFIDENTIAL TOPIC

Mono Material Lid Film Selection for Ready Meals

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Introduction

Sustainability has become a key driver of innovation in packaging and materials, fueled by rising environmental awareness and stricter regulations, like the Packaging and Packaging Waste Regulation (PPWR). Proposed by the European Commission, the PPWR aims to reduce packaging waste, improve recyclability, and support a circular economy (European Commission, 2022). One major focus is the shift from multi material packaging, structures made of several different plastic layers to mono material alternatives, which are made primarily from a single type of polymer such as polypropylene (PP). Mono materials are easier to sort and recycle using existing systems (Rizzo et al., 2024), while multi materials are difficult and costly to process, often ending up in landfill or incineration (Soares et al., 2022). This transition supports the creation of high-quality recycled materials and reduces environmental impact (Gonçalves et al., 2024).

This industry shift presents challenges for high-performance applications like microwaveable ready meals, where packaging must withstand cooking and reheating without compromising safety and food quality. Micvac, a company specializing in ready-meal packaging, has already transitioned its tray and valve to mono material PP, but the multilayer lid film remains a barrier to full recyclability (Micvac, 2024b). This thesis focuses on selecting a suitable mono material PP lid film for the Micvac FlexProcess™, a system where food is sealed, cooked in-pack using microwave energy, and later reheated by the consumer. The lid must seal securely, expand under steam (balloon), maintain vacuum after cooling, and open safely, all while working together with the tray and valve to ensure product safety and performance. Completing this transition would further position the company as a leader in sustainable innovation within the ready-meal sector.

Research Objective

Identify and validate a suitable mono material polypropylene (PP) lid film for use in the Micvac FlexProcess™ packaging system.

Research Questions

1. What are the essential design criteria for a mono material PP film in the Micvac FlexProcess™ package?
2. What critical parameters must be considered to validate the performance of the new lid film?
3. How do the available PP films compare in terms of the critical parameters?
4. What methodology can be used to develop a selection matrix for identifying the most suitable PP film?

Methodology

Five mono-material PP film candidates (M2, M20, M21, M22, M23) from three different suppliers were selected based on prior company screening, technical potential, and availability. Figure 1 illustrates the critical performance parameters used to evaluate these candidates throughout the Micvac FlexProcess™, which also served as key design criteria in this thesis. These parameters, such as sealing performance, processability, and peelability, were identified through literature review, supplier input, and internal screening. They were systematically assessed using a loop-based methodology, beginning with a Design of Experiments (DoE) on one film candidate (M20) to explore sealing behavior by evaluating internal pressure resistance. Once a minimum pressure threshold was established, this benchmark guided streamlined testing of the remaining films. The evaluation integrated both lab-based testing and tunnel trials under near-industrial conditions, along with consumer tests focusing on user-facing attributes such as peelability and ease of opening. Continuous feedback from suppliers and internal stakeholders supported the interpretation of results. A final selection matrix, based on Ulrich and Eppinger's method, facilitated comparison of candidates across technical and practical dimensions, ultimately guiding the identification of the most suitable film.

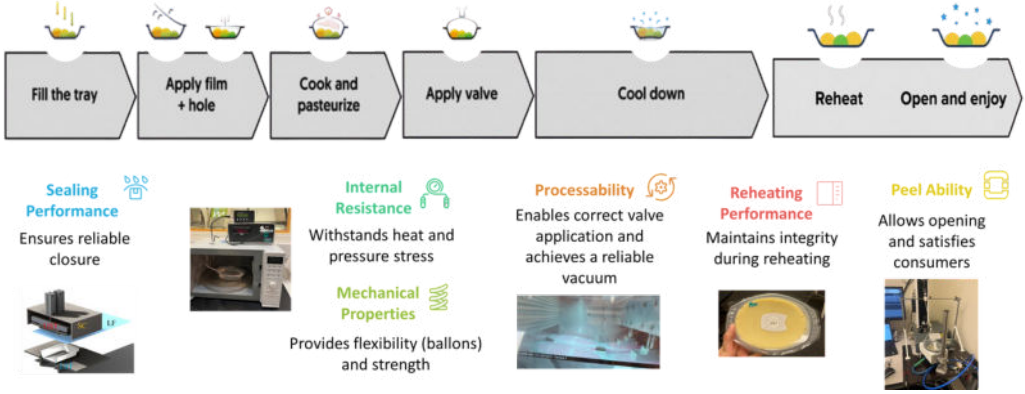

Figure 1. Overview of critical performance parameters evaluated across the Micvac FlexProcess™.

Results

RQ1 What are the essential design criteria for a mono material PP film in the Micvac FlexProcess™ package? Two main design criteria were established: **product requirements and process compatibility**. From the product perspective, the film must ensure food safety, user-friendly opening, and product integrity throughout storage and reheating. From a process standpoint, it must withstand high temperatures during sealing, microwave cooking, and reheating, while allowing controlled steam expansion (ballooning) and maintaining a vacuum seal after cooling

RQ2 What critical parameters must be considered to validate the performance of the new lid film? These needs were translated into six critical parameters: **sealing performance, pressure resistance, mechanical properties, processability, reheating performance and peelability**, which together guide the evaluation and selection of suitable PP lid films.

RQ3 How do the available PP films compare in terms of the critical parameters?
Lab Tests

- M22 performed best overall, with good sealing, ballooning, vacuum retention, and user-friendly peelability; except for reheating performance with popping events.
- M20 had good mechanical and thermal stability, but lower performance in reheating
- Other films (M2, M21, M23) had issues such as poor seal strength, excessive stiffness, or poor peel profiles
- All candidate films showed peel forces within acceptable user limits (15- 25N) (Nilmanee, Somporn, 2022). M22 offered the easiest opening (8.4 N) with smooth peeling.

Tunnel Tests (Figure 2)

- M22 exhibited satisfactory behavior (Figure 3), with pronounced ballooning, smooth valve application, and less than a 5% defect (trays with no vacuum). M20 had a poor performance, with most of the trays without vacuum (light blue trays).

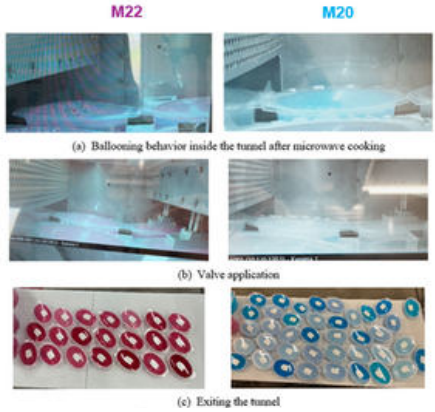

Figure 2. Parallel Comparison of Tunnel Performance for M22 and M20

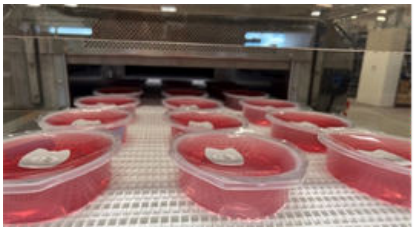

Figure 3. M22 Vacuum appearance at the tunnel exit

RQ4 What methodology can be used to develop a selection matrix for identifying the most suitable PP film? The Ulrich and Eppinger method was chosen for its structured and objective approach to decision-making, allowing complex trade-offs to be evaluated transparently.
A weighted matrix was created to compare one candidate per supplier based on three criteria: Functionality (63%), Financial (25%), and Supplier related factors (12%), and having the current film as baseline.

Conclusions

• **The study successfully identified M22 as the most promising mono-material PP lid film for the Micvac FlexProcess™.** Further improvements need to be made to improve seal strength after processing and during reheating.
• The Ulrich & Eppinger method enabled objective scoring of both quantitative data (seal strength, pressure resistance, ballooning, and peel ability) and qualitative factors (consumer usability). Optimal film choice depends on balancing process performance, seal integrity, and user experience rather than relying on a single property.
• Process window and robustness are very challenging with Mono materials; they are smaller and more sensitive to changes.
• Confidentiality restrictions limited access to precise seal layer compositions and material formulations.

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Exploring the capacity of a novel enzyme preparation to reduce the gluten allergenicity of foods during digestion

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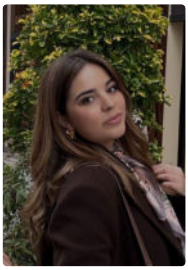

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Introduction

"Gluten" has become a common term gaining significant attention and widely used by the food industry. Driven by the media and the food industry's promotion of gluten-free products, the number of individuals reporting gluten-related health issues has significantly risen, leading them to seek or be referred for allergy testing. As a result, there has been an increased awareness of wheat-related disorders, including wheat allergy, celiac disease (CD), and the recently identified condition of non-celiac gluten sensitivity (Balakireva & Zamyatnin, 2016; Burkhardt et al., 2018). Nowadays, the safest treatment method for CD is the avoidance of gluten-containing foods (Moreno Amador et al., 2019), which is extremely difficult in practice due to the risk of cross-contamination, as products labeled as "gluten-free" can still contain up to 20 ppm of gluten (Food and Drug Administration, 2024).

Beyond gluten substitution and alternative processing techniques, enzyme therapy has emerged as a promising approach for gluten detoxification. Currently, various proteolytic enzymes, such as Neprosin from the pitcher plant (del Amo-Maestro et al., 2022), Aspergillus niger-derived endopeptidase (ANPEP), and PEP from Sphingomonas capsulata, have demonstrated effectiveness in degrading gliadin in gluten. Several of these enzymes are already available on the market as dietary supplements (Buriánek et al., 2024).
This thesis investigates enzyme-based strategies for gluten detoxification by focusing on the potential of recombinant Neprosin expressed in plant systems, in comparison with established commercial enzyme.

Research Objectives

The primary objective of this thesis was to assess the proteolytic activity and cleavage specificity of recombinant Neprosin on the immunogenic 33-mer peptide from gliadin under simulated gastric conditions. For this purpose, the degradation efficiency of Neprosin was directly compared to that of commercial ANPEP over time.
The secondary objective was to analyze the peptide fragmentation patterns generated during enzymatic digestion and to map the specific cleavage positions, thereby elucidating the enzymatic preferences of Neprosin and ANPEP.
The third objective was to evaluate the effect of Neprosin concentration on 33-mer degradation, in order to determine its dose-dependent efficiency as a candidate glutenase.
These objectives were addressed using a series of in vitro digestion assays followed by LC-MS/MS analysis, allowing for detailed profiling of peptide degradation and enzymatic performance under controlled, simulated gastrointestinal conditions.

Methodology

The 33-mer peptide substrate was prepared in distilled water (20 mg/mL) and stored at −20 °C. Recombinant Neprosin provided by Arterra Bioscience Napoli, Italy (0.35 µM in PBS) and commercial ANPEP (1 mg/mL in sodium acetate buffer, pH 4.5) were used as enzyme preparations. Enzymatic hydrolysis assays were conducted under simulated gastric conditions, adapting protocols from del Amo-Maestro et al. (2022) and Janssen et al. (2015). Reactions were incubated at 37 °C in either glycine buffer (pH 3.0, for Neprosin) or sodium acetate buffer (pH 4.5, for ANPEP), with samples collected at multiple time points (0, 10, 20, 45, 60 min, and overnight). Controls without enzyme were included for each condition. Following hydrolysis, peptides were purified by C18 solid phase extraction and dried under nitrogen. Samples were reconstituted and analyzed using UHPLC coupled to high-resolution Orbitrap mass spectrometry (UHPLC-HRMS, Exploris 120, Thermo Fisher Scientific). Peptides were separated on a Luna Omega Polar C18 column using a linear acetonitrile gradient. Data were acquired in positive ion mode and processed using MaxQuant software with a mass tolerance of ±5 ppm. Fragmentation profiles, cleavage site mapping, and enzyme efficiencies were assessed using LC-MS/MS data.

Results and discussion

Degradation of Immunogenic 33-mer Peptide by ANPEP and Neprosin, and Impact of Neprosin Concentration

Both Neprosin and ANPEP demonstrated strong ability to degrade the immunogenic 33-mer peptide over time, as shown in Figure 1. In the absence of enzyme, peptide levels remained unchanged, confirming that degradation was enzyme-specific. The analysis revealed that Neprosin initiated a rapid decrease in 33-mer abundance, with significant breakdown already evident after 20 minutes of incubation. ANPEP also showed high activity, with significant reductions observed as early as time zero and throughout all measured timepoints. By the end of the experiment, both enzymes had achieved substantial degradation of the target peptide. These findings confirm the effectiveness of both Neprosin and ANPEP in targeting gluten-derived peptides under simulated gastric conditions, highlighting their promise for enzyme-based gluten detoxification strategies.

The efficiency of 33-mer peptide degradation by Neprosin was strongly dependent on enzyme concentration as shown in Figure 2. Neprosin at a 1:500 ratio led to rapid and consistent 33-mer degradation, with statistically significant reduction observed from 20 minutes onwards ($p = 0.0014$), while the lower concentration (0.1:500) resulted in minimal hydrolysis across time points and only achieved significance after overnight incubation. Controls showed no significant change ($p > 0.2$). These findings confirm a dose-dependent effect, indicating that adequate enzyme levels are essential for efficient and timely cleavage of immunogenic gluten peptides under simulated gastric conditions (Figure 2).

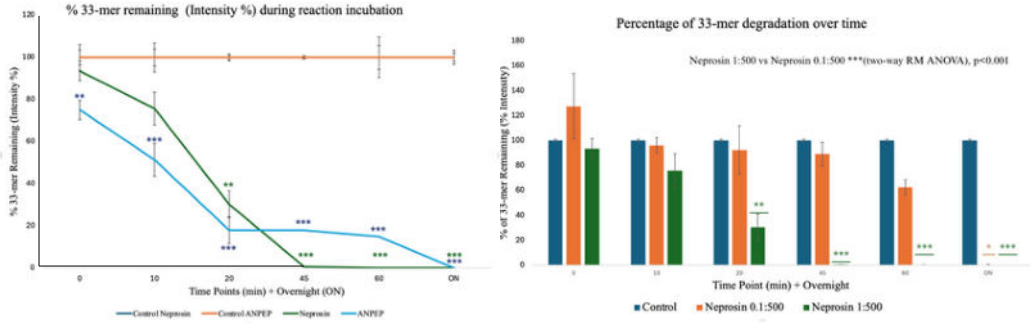

Figure 1. Degradation of 33-mer peptide by Neprosin and ANPEP over time

Peptide Length Distribution and Immunogenic Potential

The ability of the enzymes to reduce the immunogenic potential of the 33-mer peptide was further evaluated by analyzing the length distribution and abundance of peptide fragments generated during the reactions. Since peptides longer than 7–9 amino acids are considered more likely to retain immunogenicity, while shorter fragments are generally non-immunogenic (De Angelis et al., 2010), both the number and relative abundance of these peptide categories were assessed (Table 1, Figure 3).

Table 1. Number of peptides formed with a length ≤ or > than 9 amino acids

PEPTIDES	NEPROSIN	ANPEP
Total Peptides	**31**	**55**
≤9 amino acids (n)	12	19
>9 amino acids (n)	19	36

Both enzymes produced a mixture of short and long peptides, but ANPEP generated a greater total number of fragments. However, time-course analysis (Figure 3A, 3B) revealed that Neprosin rapidly produced a high proportion of short peptides early during the reaction, whereas ANPEP's generation of short peptides increased more gradually over 45 minutes. Area under the curve (AUC) analysis (Figure 3C, 3D) showed that short fragments were proportionally more abundant with Neprosin than ANPEP. These findings suggest Neprosin may be more efficient at quickly producing shorter, less immunogenic peptides

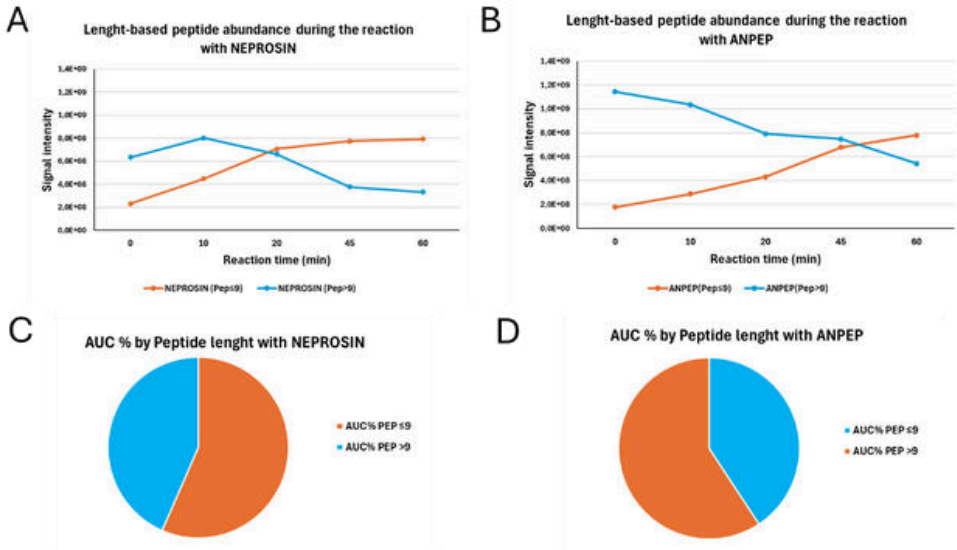

Figure 3. Abundance of peptides by length formed during the reaction with Neprosin (A) or ANPEP (B), and percentage of the area under the curve (AUC) corresponding to peptides identified

Cleavage Site Preferences

Cleavage site analysis revealed that both ANPEP and Neprosin predominantly target proline (P) residues within the 33-mer peptide, confirming their roles as proline-specific endopeptidases. Proline-directed specificity is in line with previous literature, where ANPEP has been shown to efficiently cleave immunodominant epitopes in gluten (Stepniak et al., 2006; Kumar et al., 2019), while Neprosin has been reported to act as a postproline-specific endopeptidase, as confirmed by both del Amo-Maestro et al. (2022) and the MEROPS database (2025).

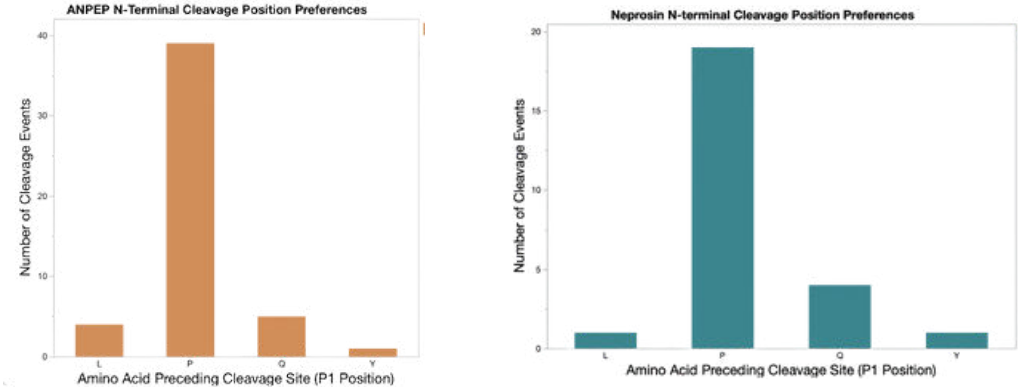

Figure 4. N-terminal Cleavage Position Preferences of Neprosin and ANPEP

Conclusions

In conclusion, this thesis demonstrated that both Neprosin, expressed in recombinant plants, and ANPEP, a commercially available enzyme from *Aspergillus Niger*, can degrade the immunogenic 33-mer gliadin peptide under simulated gastric conditions. Neprosin exhibited a

rapid degradation pattern, with significant reduction observed as early as 20 minutes under acidic conditions (pH=3). Statistical analysis confirmed significant differences between enzyme-treated and control groups, but no significant difference in overall degradation efficiency was found between Neprosin and ANPEP.

A dose-dependent effect was observed, as the diluted Neprosin (0.1:500) showed minimal activity. Although ANPEP generated more total peptides, Neprosin produced a higher proportion of short peptides (≤9 amino acids) earlier in the reaction, fragments generally considered less immunogenic, suggesting a potentially more efficient detoxification profile.

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Aseptic Packaging for Energy Efficiency and Resilient Food Supply: A Comparative Study of Milk Preservation

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Introduction

Global food systems are increasingly challenged by climate change, geopolitical instability, and energy volatility, which compromise the resilience of perishable supply chains and escalate food insecurity (FAO and WHO, 2023; GRFC, 2025; World Bank, 2025c). The dairy sector is particularly vulnerable, with refrigeration-dependent cold chains consuming high amounts of energy and contributing significantly to greenhouse gas (GHG) emissions (Ritchie, Rosado and Roser, 2022; Shabir et al., 2023). Additionally, logistical breakdowns and inadequate infrastructure exacerbate post-harvest losses, especially in perishable foods like milk.

In this context, aseptic packaging technologies, which integrate ultra-high-temperature (UHT) processing and sterile filling, offer a promising solution. These systems reduce energy usage by eliminating the need for refrigeration after processing, extend product shelf life, and enable more resilient logistics under disrupted conditions (MacVarish, 2025; Tetra Pak, 2025). For instance, aseptically packaged UHT milk can remain shelf-stable for 6–12 months at ambient temperatures, compared to only 7–14 days for conventionally refrigerated milk (Ziyaina et al., 2018; Hygiena International Ltd, 2021).
Despite these benefits, the adoption of aseptic technologies is limited by economic and regulatory challenges, particularly among small and medium-sized enterprises (SMEs) (Bashir et al., 2022; Jafri et al., 2024). This thesis, conducted in collaboration with the FORCE Center for Resilient Food Systems and partners including Tetra Pak, Orkla, and Lantmännen, explores the energy and resilience potential of aseptic packaging in European milk supply chains, with Sweden as a representative case.

Research Objectives

The overall aim of this research is to investigate the role of aseptic packaging technologies in enhancing energy efficiency and improving the resilience of food supply chains. Specifically, the thesis addresses the following five research questions:

1. **Energy Efficiency:** How do aseptic technologies compare to conventional preservation methods in terms of energy consumption?
2. **Food Quality and Suitability:** What are the effects of aseptic processing on the nutritional quality and sensory attributes of food, and which products are most suitable for such treatment?
3. **Supply Chain Resilience:** How could the adoption of aseptic technologies contribute to reducing food waste and enhancing supply chain resilience?
4. **Adoption Barriers:** What technical, economic, and regulatory challenges must be addressed to enable broader implementation of aseptic technologies?
5. **Scenario Performance:** How do aseptic and conventional preservation systems perform under different disruption scenarios, and what can be learned from comparative modeling?

The study contributes to sustainability goals, particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), by evaluating a practical solution to reduce waste, emissions, and energy dependency in the food sector.

Methodology

This study employed a mixed-methods approach combining literature review, energy benchmarking, and supply chain scenario modeling. The analysis focused on comparing aseptic (UHT) and conventional refrigerated (HTST) milk preservation systems from processing to retail stages within the Swedish and European context. Quantitative data were drawn from peer-reviewed life-cycle assessments, scientific studies, and industry reports, with key indicators including energy use (kWh/L), greenhouse gas emissions (gCO_2e/kg), spoilage rates, and shelf life.

To assess supply chain resilience, five disruption scenarios were modeled: transport delays, power outages, prolonged storage, extreme heat, and crisis stockpiling. These scenarios evaluated how aseptic and refrigerated systems perform under stress in terms of energy demand, food safety, and waste reduction. All analysis was grounded in verified literature, without introducing new data or assumptions, ensuring the reliability and validity of findings.

Results and Discussion

The findings show that aseptic UHT systems consume less total energy compared to conventional refrigerated HTST systems. Although both preservation methods require similar energy for thermal processing (~0.075–0.10 kWh/kg), refrigerated milk systems incur additional energy use from cooling, storage, and cold transport, especially under warm climate conditions (FAO, 1992; Tomasula et al., 2014). In contrast, UHT milk eliminates the need for refrigeration until opening, resulting in a 25–30% reduction in energy demand across the supply chain (González-García et al., 2013; Bertolini et al., 2016).

Shelf life emerged as a critical differentiator. UHT milk remains stable for 6–9 months, while HTST milk must be consumed within 7–14 days, even when refrigerated (Ziyaina et al., 2018; Karlsson et al., 2019). This extended shelf life significantly reduces food waste and increases logistical flexibility, particularly during disruptions. Scenario analyses confirmed that aseptic milk systems were more resilient across all five modeled disruptions. For instance, during

transport delays, HTST milk experienced up to 15% spoilage, while UHT milk remained unaffected (Figure 1). Similarly, under power outages, refrigerated storage failures resulted in 35% spoilage of HTST milk, whereas UHT systems remained shelf-stable (Figure 2).

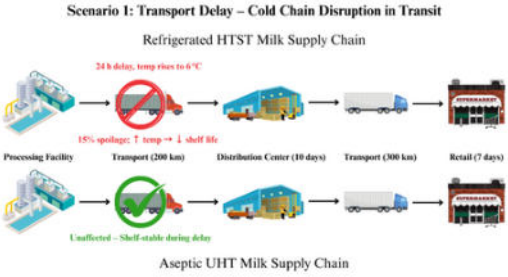

Figure 1. Illustration of a transport disruption where HTST milk spoils due to a rise in temperature, while UHT milk remains stable.

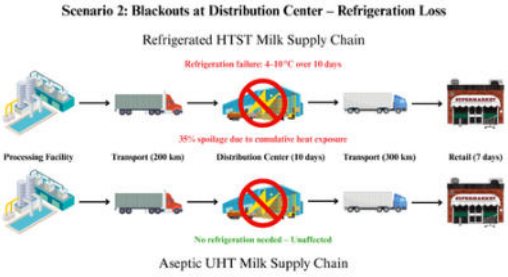

Figure 2. Depiction of how power outages spoil HTST milk due to lost refrigeration, while UHT milk stays unaffected.

In terms of nutritional quality, UHT treatment led to moderate losses in heat-sensitive vitamins like vitamin C, but retained over 90% of more stable nutrients such as folate and vitamin B_{12} (Wang et al., 2024; Krishna et al., 2021). Protein denaturation occurred, but casein micelles remained largely intact, preserving core nutritional value. Sensory evaluations noted differences in taste—UHT milk developed caramelised or "cooked" notes due to Maillard reactions, while HTST milk retained a fresher flavour (Rabbani et al., 2021; Su et al., 2022).

Environmental gains were also evident. By reducing refrigeration and spoilage, UHT systems lowered indirect GHG emissions. When including cold chain and waste-related emissions, aseptic systems demonstrated lower overall carbon footprints than HTST milk, especially in regions with weak energy infrastructure (Thoma et al., 2015; Ni et al., 2025). Despite these advantages, economic and regulatory barriers continue to limit widespread adoption. High capital costs, complex sterility validation, and stricter EU hygiene standards make aseptic systems less accessible for SMEs (Jafri et al., 2024; Melini et al., 2017).

Conclusion

Aseptic packaging technologies, particularly UHT processing, offer significant advantages in improving energy efficiency and strengthening resilience in milk supply chains. By eliminating the need for refrigeration after processing, aseptic systems reduce overall energy consumption and significantly extend shelf life. These attributes collectively contribute to lower food waste and reduced greenhouse gas emissions. The benefits are especially evident during supply chain disruptions such as power outages, transport delays, or extended storage periods, where aseptic systems preserve product safety and quality. At the same time, refrigerated milk becomes vulnerable to spoilage.

Although trade-offs exist in sensory quality and certain vitamin losses, the microbiological safety and overall nutritional integrity of UHT milk remain intact. The findings also show that adopting aseptic technologies could reduce supply-chain spoilage, improve stockpiling strategies, and support food security in crisis-prone or energy-constrained regions. However, widespread adoption is constrained by technical complexity, high capital investment, and regulatory compliance burdens—factors that disproportionately affect small and medium-sized enterprises. Addressing these barriers through targeted policy support and technological innovation will be essential to scaling aseptic solutions for a more resilient and sustainable food system.

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Understanding Oral Meltability of Chocolate: A Sensory and Instrumental Approach

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Introduction

Meltability is a critical sensory attribute in chocolate, significantly influencing mouthfeel, flavour release, and overall consumer satisfaction. It refers to the ease and extent to which chocolate transitions from a solid to a liquid state during oral processing—a process primarily governed by the fat phase. In chocolate, fat forms the continuous phase, playing a central role in dispersing non-fat ingredients and controlling melt behaviour (Lipp & Anklam, 1998).

Cocoa butter, the primary fat in chocolate, has a narrow melting range (~30–36 °C), which underpins the characteristic melt-in-the-mouth sensation. Its solid fat content (SFC) declines rapidly—from over 70% at 10 °C to nearly 0% at body temperature—contributing to the rapid and complete melt upon consumption (deMan et al., 2018; Suri & Basu, 2022). Partial replacement of cocoa butter with coconut oil has been explored due to its lower melting point and potential to alter meltability dynamics and sensory performance of chocolate.

Despite increased attention on flavour and aroma, texture—and in particular, meltability—has only recently been recognised for its vital role in food perception. Understanding how changes in fat composition affect melt behaviour is crucial for optimising consumer experience in chocolate products.

Aim

This study aimed to investigate how variations in chocolate formulation, specifically variations in coconut oil content and sample shape influence in-mouth meltability. It was hypothesised that increasing coconut oil would reduce structural integrity of the chocolate matrix, leading to a faster melt onset and greater perceived meltability. Additionally, it was anticipated that rounder shapes might enhance meltability perception due to cross-modal sensory associations. The study also sought to explore the relationship between instrumental measurements and sensory perception of meltability. It was hypothesised that increasing the coconut oil content would reduce the structural integrity

To achieve these aims, the following objectives were established:

To examine the impact of coconut oil concentration and chocolate shape on meltability using systematically formulated samples.

- To assess meltability perception through time–intensity analysis with trained judges and consumer testing using hedonic and intensity scales.

To characterise meltability through instrumental analyses, including thermal, rheological, and tribological methods, and to investigate their correlation with sensory outcomes.

Methodology

- Six chocolate formulations were developed by partially substituting cocoa butter with 0%, 2%, 4%, 6%, 8%, and 10% coconut oil. All other ingredients and processing conditions were held constant. The production process involved refining the ingredients for 20 hours, followed by tempering using the seeding method and moulded into its final shape.
- Instrumental analyses were conducted to characterise meltability. Differential Scanning Calorimetry (DSC) measured thermal properties using 6–12 mg samples heated from −40 °C to 50 °C at 10 °C/min. Rheological behaviour was assessed using a temperature sweep (20–40 °C) in a rheometer (P25 cell) with 1 N force to determine viscoelastic moduli (G′ and G″). Tribological performance was tested using a pin-on-disc setup at 37°C to simulate oral conditions, with sliding speeds from 10^{-5} to 10^{-1} m/s under a total force of 3 N.
- Sensory evaluation included time–intensity testing with 8 trained judges across all formulations. Samples were served at 20 ± 2°C, and time-intensity curves were analysed using a Boltzmann sigmoidal function. Additionally, a consumer study with 117 untrained participants evaluated the 0%, 6%, and 10% samples (in two shapes) using hedonic (LAM) and intensity (gLM) scales. PROP sensitivity and chocolate familiarity were also recorded.
- Statistical analysis included one-way and two-way ANOVAs, Tukey's HSD post-hoc tests, and multivariate techniques - PCA and PLS regression (Minitab 18 and XLSTAT 2019).

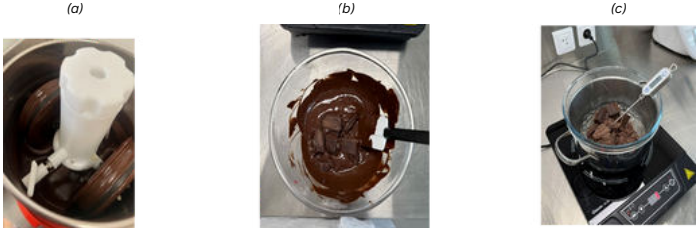

Fig. Chocolate Preparation: (a) Refining of ingredients, (b) Heating of chocolate using double boiler method for tempering, (c) Addition of 'seed' chocolate for tempering

Results and Discussion

The study demonstrated that increasing coconut oil in chocolate formulations affects meltability in multiple ways, as shown through DSC, rheology, tribology, and sensory evaluation.

Instrumental Characterisation

Melting Profile (DSC):

DSC analysis revealed distinct dual melting peaks and lower onset temperatures and a decrease in peak temperature in higher-fat formulations, which can be attributed to eutectic crystallisation between cocoa butter and coconut oil (Joshi et al., 2021; Jia et al., 2019). These thermal changes reflect the disruption of the fat crystal network, particularly in the 6%, 8%, and 10% samples.

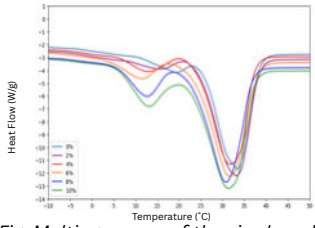

Fig. Melting curves of the six chocolate formulations

Viscoelastic Properties:

The oscillatory temperature sweep test showed that both storage (G′) and loss moduli (G″) declined more rapidly with increasing coconut oil, with the 10% sample softening fastest, transitioning quickly to a fluid-like state (Gao et al., 2015). However, the 6% sample retained greater elasticity, shown by the higher tan δ (tan δ= G”/G’), indicating higher thermal resistance and structural stability.

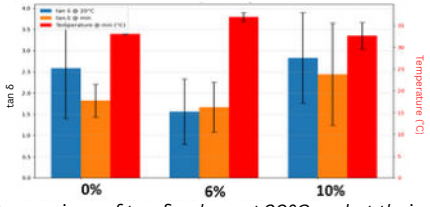

Fig. Comparison of tan δ values at 20°C and at their minima, and temperature at minima

Tribology

Stribeck curves showed that the 10% formulation had the lowest friction coefficient, indicating smoother lubrication (Jiménez-Galea & Gómez-Merino, 2024). The 6% formulation showed greater resistance, which may result from partial network disruption due to eutectic behaviour (Joshi et al., 2021).

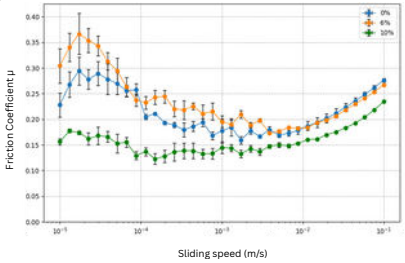

Fig. Stribeck curve for Formulations 0%, 6%, and 10%

Sensory Evaluation

Time–Intensity Sensory Analysis (Trained Panel):

The time-intensity curves were successfully modeled using a Boltzmann sigmoidal function, providing a good fit to the experimental data ($R^2 > 0.95$ in most cases). The sigmoidal model captures the progressive increase in perceived meltability until reaching a plateau, reflecting the stabilization of the sensory perception during oral processing. Samples with higher coconut oil content (notably Sample D and Sample E) exhibited a steeper rise and reached higher plateau intensities compared to the control (Sample A), indicating a stronger and faster melting perception. Conversely, the control sample (0% replacement) showed a slower onset and lower final intensity, suggesting a firmer structure and slower melting dynamics. Sample F (10%) displayed a rapid onset similar to intermediate samples but a slightly lower plateau than Sample E, possibly due to structural changes at higher fat substitution levelsThese results align with studies on cocoa butter substitutes that report a drop in solid fat content and structural integrity with excessive fat modification (Subroto et al., 2023; Jahurul et al., 2013).

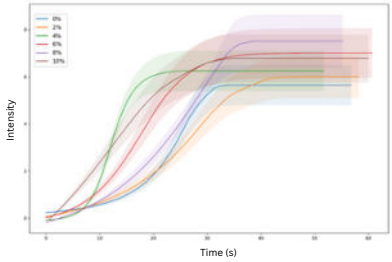

Fig. Time-Intensity measurements for meltability perception using Boltzmann sigmoidal function

Consumer Testing (Untrained Panel):

Consumers rated 10% chocolate as more meltable, focusing on fast melt onset, while trained judges valued sustained melt. No significant effects were found for shape or PROP taster status overall, though a significant interaction was noted at 10%: hemispheres were rated as more meltable than cubes. Familiarity with chocolate positively influenced meltability perception (Baptista et al., 2022; Lenfant et al., 2013). From the PCA, Meltability was positively associated with sweetness and flavour intensity, while bitterness negatively impacted liking. The 6% hemisphere sample best balanced meltability and hedonic attributes, while the 10% hemisphere, although high in meltability, was more distant from liking and flavour in PCA space.

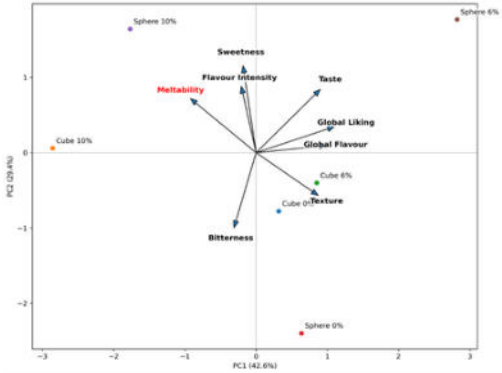

Fig. Principal Component Analysis of sensory attributes across formulation and shape

Conclusion

This study demonstrated that partially replacing cocoa butter with coconut oil significantly influences the meltability of chocolate. Increasing coconut oil content resulted in faster melting, lower onset temperatures, and reduced structural integrity. While the 10% formulation melted the quickest, it lacked sustained melt perception. In contrast, the 6% formulation achieved the best overall balance—retaining elasticity, delivering prolonged meltability, and receiving higher scores for sweetness, flavour, and overall liking.

Instrumental analyses supported these findings: higher coconut oil levels reduced friction, implying smoother texture, but also weakened the fat crystal network. Sensory evaluations revealed that perceived meltability does not increase linearly with coconut oil content. Additionally, sample shape and PROP status had minimal influence, whereas formulation and chocolate familiarity emerged as key factors affecting meltability perception.

These findings highlight the importance of optimising fat composition for desirable meltability and mouthfeel. Further research should explore fat crystal morphology, particle size distribution, and ingredient interactions to inform the development of chocolate products with enhanced sensory and nutritional profiles.

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Environmental assessment of packaged fresh chicken: A Life Cycle perspective on packaging and waste impacts

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Introduction

This research investigates the environmental impacts of packaged fresh chicken from a life cycle perspective, considering both packaging and food waste implications. Motivated by the sustainability challenges of the food system, it uses the Life Cycle Assessment (LCA) framework with the European Commission's Product Environmental Footprint (PEF) methodology to deliver a more comprehensive and comparable assessment.
Three Modified Atmosphere Packaging (MAP) configurations with the difference in their tray were compared: a baseline multi-material tray, and two alternatives - mono-material polyethylene (PE) and polyethylene terephthalate (PET) trays.

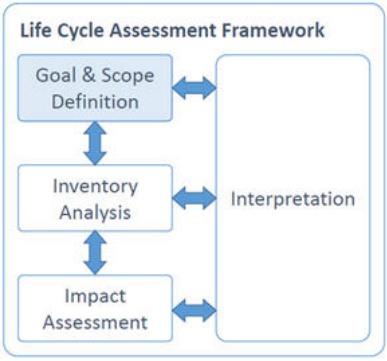

Figure 1. LCA framework

Methodology

The study applied a cradle-to-grave system boundary, incorporating chicken processing, packaging production and transportation, use phase including food waste quantified by a simple shelf-life model, and end-of-life disposal scenarios.
The attributional LCA model is built based on the EC PEF methodology using SimaPro 10.2.0.1 Multi user. This approach is selected when assessing and comparing the environmental impact, the life cycle hotspots.
Functional unit: 1 kg of packaged fresh chicken with the expected shelf life corresponding to their respective packaging solution.

Figure 1. Product Environmental Footprint framework

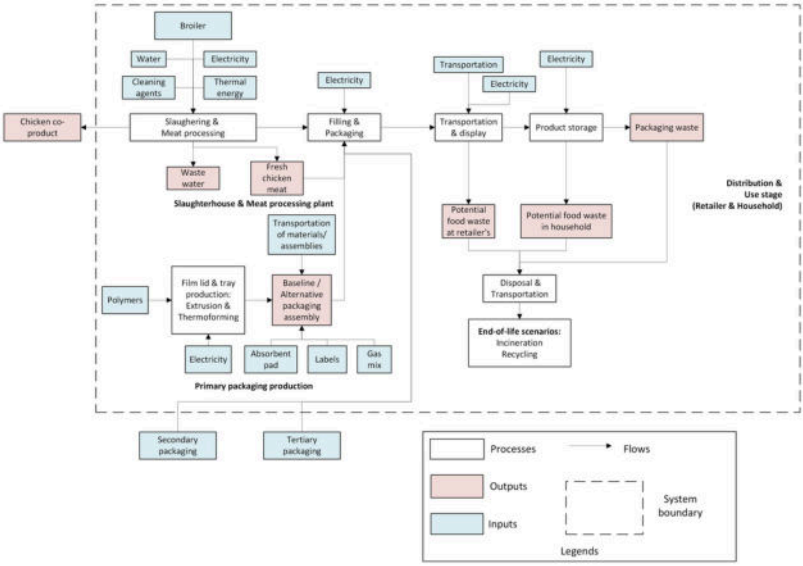

Figure 2. System boundary

Conclusion

- Chicken production dominates environmental impacts: Across all categories, broiler meat production was the most significant hotspot.
- Packaging trade-offs exist: Multi-material trays provided better barrier properties, reducing food waste but hindering recyclability. Mono-material designs improved recyclability but often shortened shelf life, increasing food waste impacts.
- Food waste influences overall life cycle results: In some cases, the benefits of improved recyclability were offset by the indirect impacts of increased food waste.
- End-of-life allocation choice: The potential gains from design-for-recyclability remain underrealized.
- Integrating the PEF methodology, although restricted, allows for improved comparability with PEF categories and policy alignment.

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Design and Analysis of Fat-based coatings used in the production of ice cream stick bars

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Summary

The rising cost of cocoa globally necessitates innovative and cost-effective solutions for ice cream coatings, without compromising product quality or consumer appeal. Compound coatings are created by strategically replacing the cocoa butter in the chocolate coatings with different fat systems. Methods were developed and established to characterize the performance and quality of the coating in different stages of production. Screening of fat systems with the analytical methods identified promising alternatives exhibiting characteristics comparable to cocoa butter for subsequent formulation and development of ice cream coatings. Analytical findings and sensory evaluations of the ice cream coatings suggest that strategic fat systems can provide cost-effective alternatives to cocoa butter in ice cream coatings, potentially enhancing consumer acceptance while maintaining desirable sensory properties.

CONFIDENTIAL TOPIC

The Role of Dynamic Shelf Life Labels in Consumers' Buying Decisions.

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Master Thesis tutors:
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Introduction

This study investigates consumer preferences and willingness to pay (WTP) for packaged fresh chicken breast trays, with particular emphasis on the role of expiration dates and dynamic shelf-life labels in shaping purchasing decisions. Fresh meat products, such as chicken, are highly perishable and strongly dependent on correct storage conditions. Traditionally, static labelling systems have been used to safeguard consumer health, with fixed "use by" or "best before" dates acting as indicators of freshness and safety. However, these labels are inherently limited. They are set using generalised safety margins and cannot capture variations in handling or temperature conditions across the supply chain, which means that products may be discarded prematurely while still suitable for consumption.
Dynamic shelf-life labels have recently emerged as a promising innovation to address this issue, as they provide real-time information on product freshness through a simple visual cue. Despite their potential, limited research has examined how such labels affect consumer preferences, value perception, and behaviour in retail contexts. By exploring these aspects, this study aims to provide novel insights into the decision-making process surrounding fresh chicken products.

Methodology

The study employed a discrete choice experiment (DCE) to evaluate consumer decision-making in relation to packaged fresh chicken breast trays. Three key product attributes were tested: price, time until expiration, and the presence or absence of a freshness indicator label. Consumers were also offered the option not to purchase any product (opt-out). This framework allowed for the estimation of trade-offs between attributes and the calculation of marginal willingness to pay. Data was collected through an online survey distributed to fresh chicken buyers in Lund, Sweden.

Given time and resource constraints, a convenience and snowball sampling strategy was used, resulting in a total of 111 valid responses. A conditional logit model was fitted to estimate consumer preferences at the aggregate level, and k-means clustering was applied to identify consumer segments with distinct preference patterns. Finally, WTP estimates were determined to establish the monetary value that consumers place on expiration date and labelling attributes.

Findings

The results of this study show that price and expiration dates are the most influential factors in consumer decision-making. For the full sample, preferences declined as products approached their expiration date, with a marked drop on the final day of shelf life.

Consumer segmentation resulted in four clusters with varying willingnes to buy products close to expiration (WTB) and willingness to freshness indicators (WTL). Cluster 1 (High-Mid) and Cluster 2 (High-High) showed moderate sensitivity, with willingness to pay (WTP) remaining relatively stable from days five to one before expiry but falling sharply on the last day. Cluster 3 (Mid-Mid) demonstrated a linear reduction of WTP between days five and one, and a significant drop on the last day.

By contrast, Cluster 4 (Low-Low) exhibited the strongest aversion to short shelf life; even small reductions significantly lowered WTP, which dropped below the market average on the last day, indicating that individuals in this group would require monetary compensation to purchase chicken expiring the same day. Figure 1 illustrates how perceived value shifts across shelf life for the total sample and each consumer segment.

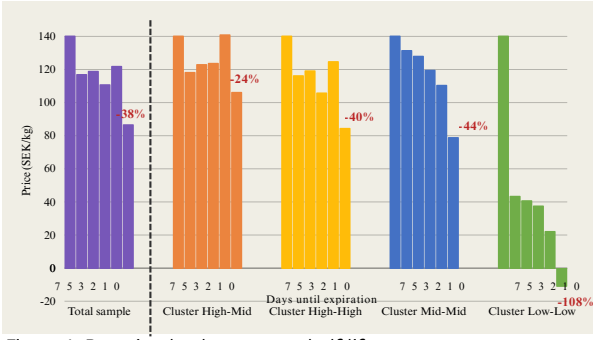

Figure 1. Perceived value across shelf life

In terms of the freshness indicator, there was varied effect among clusters. Cluster 2 (High-High) exhibited a positive WTP for the label, indicating that dynamic shelf-life cues helped retain 9% of the perceived value as the product approached expiration . By contrast, for Cluster 4 (Low-Low), including the label resulted in a further reduction of 23%, suggesting scepticism or mistrust toward such technology. This highlights that while dynamic labels may appeal to certain consumer groups, they may simultaneously reduce confidence in others if not designed and communicated effectively. The label did not have a statistically significant effect on Cluster 1 (High-Mid) and Cluster 3 (Mid-Mid)

The general behavioural results reinforced these findings. Most respondents reported regularly checking expiration dates in-store and showed strong reluctance to buy products close to expiry without incentives such as discounts. Post-expiration behaviours varied (Figure 2), with over half relying on sensory cues (smell and appearance) before discarding, while about a third discarded products immediately after expiry regardless of condition. These insights demonstrate that consumer trust in freshness indicators is critical for influencing purchasing behaviour and for encouraging value retention.

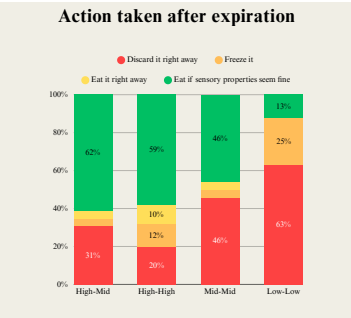

Figure 2. Behaviour after expiration date.

Conclusion

This study investigated how expiration dates and dynamic shelf-life labels affect consumer decision-making and WTP for fresh chicken. Overall, expiration dates remain the dominant factor in consumer choice, though dynamic shelf-life labels show potential to influence perceptions if effectively designed and communicated. For Innoscentia and similar companies, this highlights opportunities to reduce food losses by aligning labelling innovation with consumer trust-building strategies. While results provide valuable insights into early adopters' behaviours, broader representativeness is limited by the sampling approach. Future research should therefore target more diverse consumer groups to validate these findings across the wider population.

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Study the impact of protectants to increase shelf life in dry product

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The food industry has shown increasing interest in dry products due to their extended shelf life, improved handling, and consistent fermentation performance. Achieving these benefits requires a comprehensive understanding of the microbial and biochemical dynamics during fermentation. Factors such as acidification, enzymatic activity, moisture levels, and structural changes play a critical role in the success of drying techniques.

This study addresses the following scientific question: How does the use of protectants improve the shelf life of a dry product by increasing the glass transition temperature, while ensuring product stability and industrial applicability? To answer this, the research evaluates the role of protectant formulations in maintaining the viability, rehydration capacity, and overall performance of the dry product (F5).

The objective of this study was to evaluate the impact of different protectant formulations on the viability and storage stability of a dry product, with a focus on the glass transition temperature (Tg). Among the tested formulations, F5 demonstrated the highest protective efficacy.

Moisture sorption behavior was accurately described using the GAB model, which reflected strong water-solid interactions and enabled reliable prediction of equilibrium moisture content for storage optimization. The relationship between Tg, water activity (aw), and water content was investigated to assess the impact of moisture sorption on the physical stability of the F5 formulation compared to the Reference.

As aw increased, the Tg of the dry product declined, indicating moisture-induced destabilization. However, F5 consistently maintained higher Tg values across all aw levels, demonstrating enhanced structural stability and reduced sensitivity to water plasticization. Product humidity increased following a type III sorption isotherm, further confirming the moisture sensitivity of the dry product.

As a conclusion, the comparison between the REF and F5 underscores key formulation considerations. While the dry product requires strict aw control to preserve its glassy state at ambient temperatures, F5 maintains higher Tg values across a broad range of aw. This provides greater protection against moisture-induced destabilization and supports improved product stability.

CONFIDENTIAL TOPIC

Analysis of public financing of food in Île-de-France

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Profile in a nutshell:

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Context

Internship host: DRIAAF Île-de-France
• Regional and interdepartmental office of the Ministry of Agriculture and Food Sovereignty
• Under the authority of the Regional Prefect
• Contributes to the implementation and monitoring of rural development, land-use planning and sustainable development policies

MISAL (Interagency Food Taskforce)
• Created in 2019 by decree of the Prefect, coordinated by DRIAAF
• Aims to promote interagency cooperation for a systemic approach to food issues

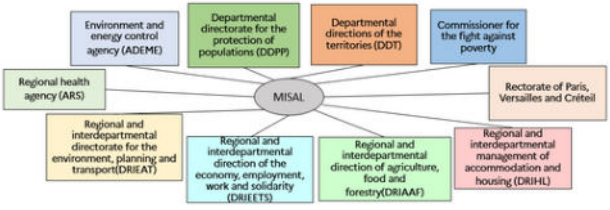
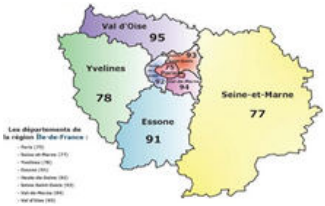


Figure 1. Membership of MISAL



Map 1. Departments of Île-de-France

Background and challenges

- Public funding is key in shaping food systems—but its impact depends on how it is distributed. Keynes (1936) saw public spending as a driver of development; Wagner (1883) saw it as a consequence. Today, public investment is shown to reduce poverty, malnutrition and food insecurity (Tapsoba and Brun, 2023).
- Yet in France, out of €53.6 billion in food-related public funding, less than 10% supports the ecological transition (I4CE, 2024).
- In a context of fragmented food policies, MISAL members fund numerous initiatives across various levels (regional and departmental) and topics (food insecurity, food waste, health).
- The absence of shared tools limits the capacity to identify who funds what, on which themes, and with what potential outcomes.
- A harmonised mapping of actions is thus essential to support evidence-based regional food governance.

Research question

How can we design a harmonised interagency database that enables a strategic, place-based and multi-stakeholder understanding of public funding for food systems in Île-de-France?

Methodology

Phase 1 – Scoping (February)	Phase 2 – Tool Development (March)	Phase 3 – Testing and validation (April)	Phase 4 – Collection (May)	Phase 5: Analysis and deliverables (June)
• Semi-structured interviews with institutional stakeholders (DRIAAF, ARS, etc.) • Co-development of a glossary to clarify and align terms as : o **Action:** what is the subject of an agreement. o **Food** (Loi d'avenir pour l'agriculture, l'alimentation et la forêt, 2014): "all actions that ensure that the population has access to safe, healthy, diversified food of good quality and in sufficient quantity" (including urban agriculture, supply chains, etc.).	• Preliminary Excel-based monitoring table • Collaboration with cartography and statistics departments • Data quality principles (atomic cells, dropdown menus, etc.)	• Testing with pilot datasets • Iterative adjustments	• Distribution of a filling-in guide (definitions of SNANC themes, types of action, audiences, etc.). • Support with filling in if necessary.	• Statistical analysis of data concerning the amounts committed or the number of actions (by funder, by theme, by type of action, by target audience, by territory). • Development of the finalized table and a inventory. • Glossary of terms • Excel spreadsheet for data collection • Automatically updated excel results analysis with linked graphs • Template for annual report

Results

- Inventory 2024 : €26.6 million, 448 actions
- Type of action: the most costly initiatives involve food aid (operations and purchases), followed by food chain monitoring systems and educational workshops. The largest number of initiatives involve awareness-raising, nutrition/health workshops and training
- Themes most supported (SNANC guidelines) : social justice (food aid), processing/distribution (food safety and food aid), health and food education.
- Target audiences : actions aimed at people in precarious situations predominate. Young people and the general public are also important targets for prevention initiatives.
- By funder : Differentiated strategies: some services fund few actions with high amounts, others disseminate numerous projects with low amounts.
- Regional distribution: the majority of funding is concentrated in priority social areas.

Discussion

- Two logics coexist: an intensive approach (high funding, targeted actions) and an extensive approach (multiplicity of actions with small amounts). This duality reflects the recommendations of the OECD (2024) for a resilient, place-based system.
- Thematic balance to be strengthened: actions relating to the environment, land use or employment remain marginal in line with the I4CE results (2024).
- Territorial inequalities : creation of departmental 'food identity maps' to contextualize the results of the inventory with territorial indicators.

Conclusion and perspectives

- An initial inter-departmental database, providing a cross-sectional view of food policies in the Paris Region.
- Areas for improvement : set up a permanent interdepartmental technical group; add impact and weighting metrics; distinguish in the analysis between incentive and regulatory actions.

Table 1. Example of food identity card

Essonne (91) food identity card

SNANC themes	Indicators	Departmental data	Ile-de-France average
Social justice	% population living in priority urban neighbourhoods		
	Poverty rate in %		
	Number of local solidarity contracts		
Health	Human development index		
	Number of local health contracts		
Food education	Number of schools (primary and secondary) involved in structured sustainable food education initiatives (positive food family challenge, etc.) and/or participating in the "milk and fruit at school" programme		
Environment	Percentage of agricultural land used for organic farming and in conversion		
	Concentration of pesticides in groundwater		
	Concentration of pesticides in surface water		
Fight against waste	Number of mass catering establishments that have introduced a system for measuring and/or combating food waste and/or combating food waste and indicating this on "ma cantine"		
Agricultural land	Percentage of land area classified according to land use (agricultural area)		
Mass catering/EGAlim	Number of canteens registered on "ma cantine"		
	Percentage of canteens meeting EGAlim targets		
Production	Average diversity of arable crops		
	Number of farms		
Transformation/Distribution			
Employment	Unemployment rate in %		
Other	Number of Territorial Food Projects (PAT)		
	Number of inhabitants		

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Improvement of the flavour profile of Philadelphia plant-based Cream Cheese and exploration and characterization of alternative vegan protein sources

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Introduction

In recent years, interest in plant-based dairy alternatives has increased due to rising consumer awareness of sustainability and the shift toward dairy-free diets [1],[3],[5]. Despite market growth, formulating plant-based spreads (PBS) remains challenging, particularly when replicating dairy-like properties with clean-label constraints. Fermentation, a traditional process widely applied in dairy, has been introduced to plant-based systems to enhance sensory and functional qualities. This thesis explores the impact of various starter cultures (SC) on improving dairy-associated sensory attributes, such as “creamy” and “buttery” notes, while reducing undesirable cereal flavors from oat-based matrices. Differences in composition and functionality of plant proteins (PP), presence of off-flavors from inherent volatile compounds [2] highlights the challenge and importance in selecting a suitable PP ingredient for PBS application.

Objectives

This research focuses on Plant-Based Spread (PBS), addressing key objectives:

- Develop a "dairy-like flavour" through fermentation by screening and prototyping plant-based spreads with different Starter Cultures (SC) and fermentation temperatures.
- Generate insights into understanding the impact of specific strain presence on fermentation speed, flavour development, as well as viscosity and firmness of the final product.
- Establish a protocol for Plant Protein (PP) evaluation.

Methodology

The Methodology was divided into two parts to meet the set objectives: first part covering SC evaluation and the second, exploring alternative PP for the PBS application. During both stages PBS bench-top production process was implemented (Figure 1) with changes in the ingredient or fermentation temperature depending on the screening stage.

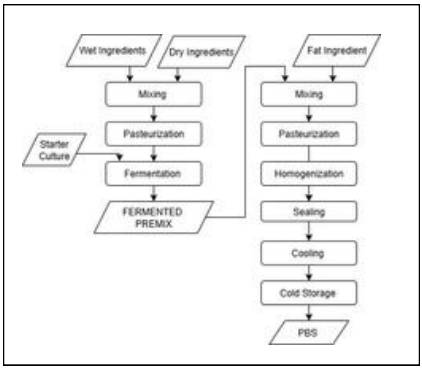

Figure 1. PBS bench-top production flow chart

Materials

During SC screening PBS samples were prepared with SC, suitable for plant and vegetable based fermented products. 12 SC were obtained from 4 different suppliers: A,B,C and D. Majority of SC used in the screening belonged to Thermophilic group with two exceptions: C.6 and D.1 being Mesophilic SC. For the second part of the research 8 PP were tested: (P.1-P.8) coming from:different plant sources and varyig in protein concentration.

Fermentation

Key process step, significant for the characteristics of the final product. Acidification was followed during both screenings: SC and PP. This step allowed to discriminate SC and PP with slower acidification time not allowing to reach target pH of 4,6 within 8 h of the fermentation in order to prevent microbial growth.

Viscosity

The viscosity measurement was conducted using Perten Rapid Visco Analyser 4500- and 4800 (RVA) with the measurement software TCW3. RVA is a cooking, stirring viscosimeter with ramped temperature and shear capability, it provides information on changes of viscosity (cP) of the sample over time (min). The measurement was performed at constant 4°C for 120 min and the rotating speed of the paddle was set at 80 rpm for premix samples and 80 rpm at 10 °C for 120 min for the PBS samples. Viscosity results were compared and then further used for the purpose of choosing the most promising cultures

Cold firmness

Measurement was performed on final formulations from both screenings. The measurement was performed with a TAXT2 Texture Analyser (Stable Micro Systems)(Figure 11) attached with a 45° glass conical test probe. All samples were tempered in a 10 °C fridge 24h before the measurement and the top layer of the sample was scraped off to ensure an even measurement surface with a standardized tool. During measurement the sample was penetrated at a speed of 2.00 mm/s for 10.0 mm with a trigger force of 3.0 g, and the maximum load (in gram) was noted. The measurement was preformed twice on opposite sides of the sample (Figure 2).

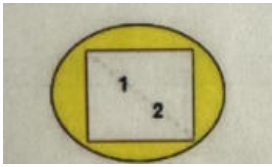

Figure 2. Cold Firmness Measurement Principle- Placement

Sensory Evaluation

For the purpose of SC Screening, sensory evaluation with experienced R&D colleagues was conducted on the fermented premix one day after preparation and 7 days after production for PBS samples. All participants completed a scoring sheet, and were asked to compare the samples to the reference using 3-point scale and 5-point (depending on the screening stage) Participants evaluated samples regarding following attributes: overall flavour, sourness, saltiness , cereal/malty flavour, creamy (cream/butter) flavour , sweetness and bitterness.

Results and Discussion

Fermentation

Fermentation was followed. During SC screening two Starter Cultures did not reach desired pH within set time and were excluded from further screening steps: C.6 and D.1 (Figure 3). Highlighting unsuitability of Mesophilic SC for the standard fermentation conditions. Following acidification of samples prepared with alternative PP, allowed to detect key attributes of PP ingredient impacting fermentation time. High concentration of protein was found unfavourable as lower fermentation yield was observed, possibly related to low sugar content, insufficient for the SC to ferment the sample: P.3 and P.4 (Figure 4). Additionally importance of soluble fibre content was highlighted. P.8 during processing formed a viscous mass, creating unfavourable conditions for the SC to ferment the batch.

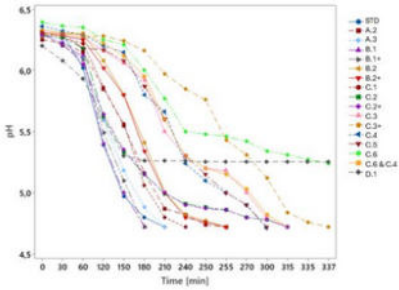

Figure 3. SC screening- fermentation curve

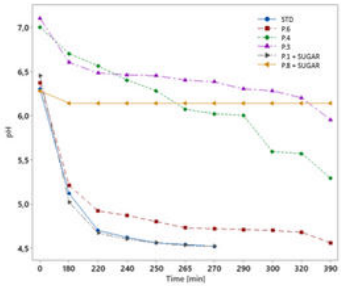

Figure 4. PP screening- fermentation curve

Viscosity

Viscosity of premixes fermented with following SC was measured (Figure 4). A.2. recorded the highest values, which could be explained by EPS production by the bacteria strain present in this SC. Measurement was conducted on PP Screening premix samples. Obtained results suggest that at the intermediate stage C.1 and C.6 have higher viscosity in comparison with the STD sample(Figure 5).

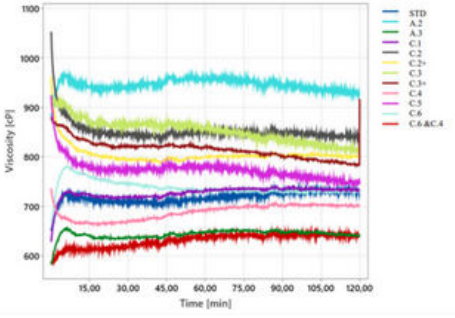

Figure 4. SC screening viscosity comparison at premix stage

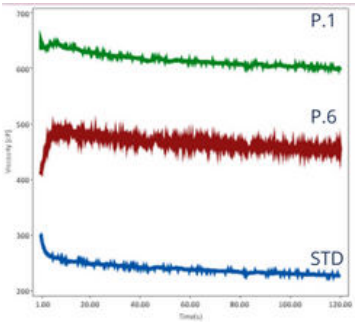

Figure 5. PP screening viscosity comparison at premix stage

Cold firmness

Firmness of the SC trial PBS samples was measured (Figure 6). No significant difference between the Cold Firmness values of the PBSs was recorded indicating that at current processing parameters Firmness of the PBS is not starter culture driven. Differences in viscosity between the premix samples were not transferred to the PBS stage as firmness values were not significantly different. nterestingly high viscosity at premix stage were not transfer to the final product form. As shown on (Figure 7) both alternative PP samples exhibited low firmness values, suggesting possible unsuitability of current processing parameters for the alternative PP matrix.

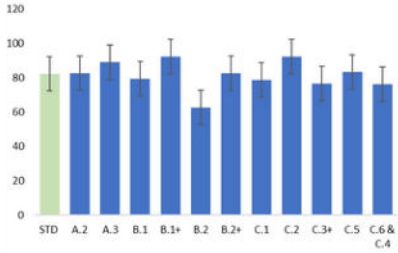

Figure 6. SC screening- Cold Firmness

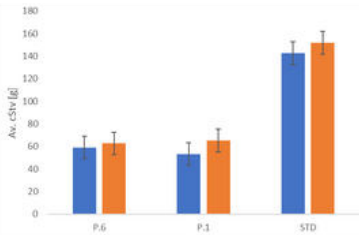

Figure 7. PP screening- Cold Firmness (Week 1-Blue, Week 3-Orange)

Sensory Evaluation

Evaluation conducted on Premix samples from the SC assessment allowed to discriminate Starter Cultures not driving the desired attributes and increasing the unwanted flavour profile: C.2+, C.3, C.4 and C.6. Highlighting at the same time SC enhancing desirable “creamy” attributes: C.3+ and A.3 and reducing unfavourable “cereal/malty” notes: A.3 and C.2. (Figure 8). As a result of internal sensory assessment and conducted measurements “most promising” SC were selected and tested at two different temperatures. Finally SC: C.2 at 37°C was selected as providing the best flavour profile to the PBS (Figure 9).

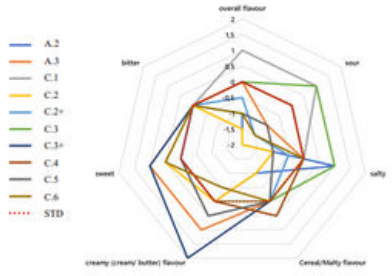

Figure 8. Sensory Assessment of SC Premix Samples

Figure 9. Final Sensory Assessment of PBS samples

PBSs formulated with P.1 and P.6 were evaluated during internal sensory assessment (Figure 10). Overall flavour, sourness and saltiness of the P.6 sample was lower in comparison with the STD sample, on contrary similar values of cereal, malty and bitter attribute were noted. Outstanding sweetness of the sample could be visible in
both collected ratings and comments. P.1 sample was characterised with lower creamy attribute, indicating low suitability for PBS application.

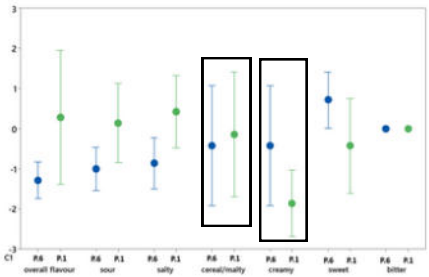

Figure 10. Final Sensory Assessment of PBS samples prepared with P.1 and P.6

Conclusion and Recommendation

Conducted measurements and collected sensory evaluation results allowed to distinguish SC: C.2 and A.2, that improved the sample overall profile. C.2 fermented at 37°C was chosen for future up scaling. PP screening highlighted importance of preliminary screening and drew attention to key characteristics of the PP ingredient : protein, sugar and soluble fiber level, and their limiting quantities making the PP ingredient not suitable for the PBS formulation. Over the screening a PP with favorable sensory profile and similar viscoelastic behavior to in comparison to the standard sample was discovered: P.6. However additional research is advised to possibly explore additional processing parameters, more suitable for this PP matrix. Combining both assessments, it would be advised to prepare PBS with P.6 PP and ferment using A.3 SC known for its “sour” notes enhancement which could possibly improve flavor profile of the sample.

CONFIDENTIAL TOPIC

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Experimental study of ice cream freezing

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Ice cream, a frozen dessert, can be defined as a food made from a pasteurized mix of dairy products (typically cream and milk), sweeteners and/or sugar, and stabilizers, to which air is incorporated during freezing. This process results in a smooth, creamy texture characterized by a complex matrix of ice crystals, air cells, and a continuous fat phase dispersed within a water-based serum phase.

The freezing unit operation is the principal site of microstructure generation for ice cream. In order to achieve a uniform product quality across various production sites while amplifying desirable product attributes, it is imperative to better understand the effect of process parameters and their interactions with product microstructure.

The scope of this thesis is the data collection and development of capabilities for Häagen-Dazs to set a foundational data set for upcoming projects on the modelling and inline measurement of unit operations like the freezer. The thesis explores the effect of processing conditions on the resultant product quality while simultaneously developing the analysis capabilities to model this unit operation.

CONFIDENTIAL TOPIC

Towards a Circular Future: A Roadmap for Sustainable Industrial Packaging

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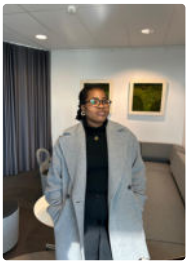

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Introduction

The European regulatory landscape is increasingly focused on promoting sustainability and circularity. The Corporate Sustainability Reporting Directive (CSRD) mandates corporate disclosure of environmental and social impacts, enhancing transparency and accountability (Karabeg, 2024). Under ESRS E5, packaging is addressed as part of resource use and circularity, requiring companies to report on their circular economy strategies.
Complementing this, the Packaging and Packaging Waste Regulation (PPWR) aims to reduce packaging waste and reinforce circular principles (European Commission, 2025).

Despite these developments, packaging sustainability has historically been undervalued in industrial supply chains—frequently seen as a functional necessity rather than a strategic lever for innovation (Hellström and Olsson, 2017). However, strategic approaches to packaging can offer significant benefits, including material efficiency, optimized logistics, and reduced waste (Pålsson, 2018a).

This thesis investigates Alfa Laval's current packaging practices across business units, identifying improvement areas and analyzing the impact of evolving sustainability regulations. Using the Packaging Innovation Scorecard (PIS), the study evaluates the company's packaging innovation capabilities and proposes a roadmap to support its transition toward more sustainable packaging solutions.

Methodology

A qualitative case study methodology was employed to investigate internal practices and barriers (Yin, 2014; Bryman, 2016). The analysis was guided by the Packaging Innovation Scorecard (PIS), a framework that assesses seven subprocesses critical for innovation maturity: Concept Generation, Packaging Development, Process Innovation, Technology Acquisition, Leadership, Systems and Tools, and Resourcing (Pålsson and Hellström, 2023).
The primary unit of analysis in this thesis is the packaging management system at Alfa Laval, a global manufacturer of industrial equipment. The study focuses on understanding how packaging is currently managed across different business units, what challenges exist in implementing sustainable packaging practices, and how innovation in packaging can be systematically improved. An overview of the research design is shown in Figure 1.

Figure 1. Research Design

Data collection

To comprehensively assess Alfa Laval's organizational maturity in packaging innovation, a multi-source qualitative data collection approach was employed. This included semi-structured interviews, on-site observations, and a review of internal documentation.
Triangulating these sources enabled a solid understanding of the company's internal structures, practices, and challenges related to sustainable packaging. Figure 2 summarizes the three primary sources of data and their contributions to the research. A detailed overview of the interviewed stakeholders, their functional roles, and relevance to the Packaging Innovation Scorecard (PIS) subprocesses is presented in Table 1.

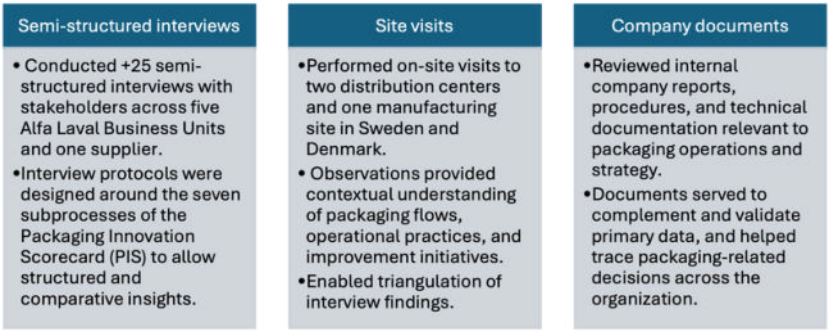

Figure 2. Data collection sources

Table 1. Summary of stakeholder areas and their role in packaging management

Stakeholder Area	Role
Sustainability	Provided insights into corporate environmental objectives, current practices, and alignment of packaging decisions with sustainability goals.
Product Development	Offered perspectives on how packaging integrates with product design, especially material selection and design constraints.
Sourcing/ Purchasing	Shared views on supplier selection, cost considerations, and how these align with sustainability efforts.
Packaging Projects	Contributed practical experience regarding implementation, project management, and common challenges in packaging development.
Packaging Supplier	Offered an external viewpoint on technological capabilities, collaboration processes, and alignment with Alfa Laval's goals.

Data analysis

Following data collection, all interviews were transcribed and analyzed alongside internal documents and site visit notes. The qualitative analysis followed the six-phase thematic process described by Byrne (2022) and Adu (2019), including data familiarization, coding, theme identification, and refinement.
NVivo software supported coding and pattern recognition. Findings were cross-referenced with the Packaging Innovation Scorecard (PIS) to address the research sub-questions.

Results and Discussion

Packaging decisions at Alfa Laval are shaped by a complex interplay of technical, logistical, organizational, economic, and sustainability-related factors. Rather than being driven by a single dominant concern, decisions often reflect trade-offs among competing priorities.

While product protection and cost-efficiency are consistent baseline concerns, other influencing factors include transport conditions, site-specific constraints, organizational decentralization, and emerging environmental objectives.

The absence of a unified decision-making framework or overarching packaging strategy leads to inconsistent prioritization across sites. For example, one factory may prioritize short lead times due to limited storage capacity, while another emphasizes material sustainability based on regional initiatives.

This variation stems from the company's decentralized model but highlights the need for strategic alignment. To structure these insights, the study identified five primary categories influencing packaging decisions: technical, logistical, organizational, sustainability, and cost factors.

Scorecard Evaluation

Building on thematic findings, the Packaging Innovation Scorecard (PIS) was used to evaluate Alfa Laval's innovation maturity across five business units (Figure 3).

The evaluation revealed notable disparities: while some units showed local strengths in areas like Concept Generation and Leadership, others struggled with core processes such as Resourcing and Technology Acquisition.

Three key capability gaps emerged across the organization:

- Lack of dedicated resources for packaging innovation
- Absence of integrated digital tools for packaging data and decision-making
- Minimal formal processes for scouting or adopting new packaging technologies

These gaps echo challenges identified in prior research (Hellström and Olsson, 2017) and emphasize the importance of packaging logistics as a cross-functional concern (Saghir, 2004).

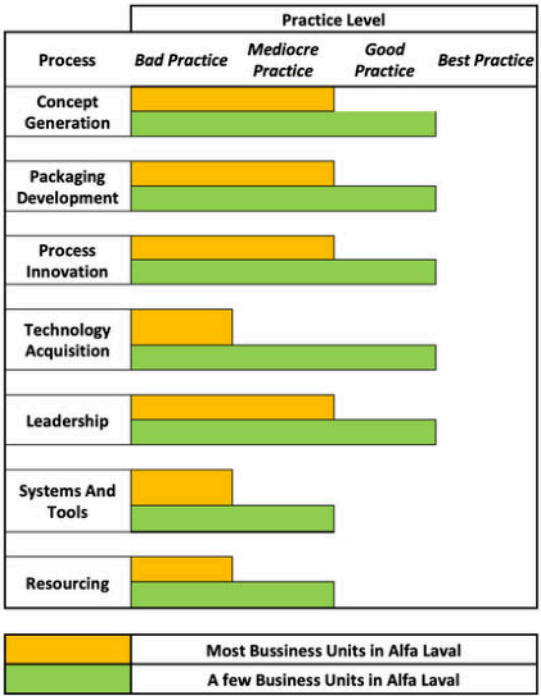

Figure 3. Summary of Scorecard Evaluation

EU Packaging regulation compliance

Alfa Laval is increasingly influenced by evolving EU regulations, including the Packaging and Packaging Waste Regulation (PPWR), the Corporate Sustainability Reporting Directive (CSRD), and Extended Producer Responsibility (EPR). These are shaping company decisions regarding packaging materials, waste management, and data reporting.

In response, various localized sustainability initiatives have emerged. These include waste-reduction efforts such as reusing incoming paper as filling material, standardizing packaging components, and implementing recycled plastic straps.
Some sites have introduced lighter cardboard pallets to replace wooden ones, while others aim to phase out plastic entirely. Although the overall approach remains fragmented due to Alfa Laval's decentralized structure, these initiatives reflect growing commitment within business units to sustainable packaging innovation.

Conclusion

This study reveals that packaging management at Alfa Laval is characterized by decentralization and significant variability across business units and sites. Packaging decisions are driven by a mix of technical, logistical, and organizational factors, with cost concerns often outweighing sustainability objectives.
Despite existing frameworks and sourcing strategies, the lack of formal ownership and dedicated roles limits consistent implementation and strategic alignment.
Internal barriers, such as fragmented responsibilities, limited packaging expertise, insufficient resources, and weak cross-site coordination, continue to constrain innovation and scalability of sustainable solutions.
Through an assessment of packaging innovation maturity, this study proposes a strategic roadmap focused on strengthening governance, competence development, supplier engagement, and data management. This roadmap (Table 2) offers a practical foundation for transitioning Alfa Laval toward a more coordinated, innovation-led, and sustainability-focused packaging strategy—offering broader insights for similar industrial organizations.

Table 2. Summary of Strategic Roadmap

Focus Area	Short Term (0-1 year)	Medium Term (1-3 years)	Long Term (3+ years)
Leadership and Governance	• Appoint Group-level Packaging Coordinator • Update sustainability procedure	• Assign BU-level Coordinators • Communicate packaging targets	• Monitor and review packaging strategies annually
Competence and Resourcing	• Identify skill gaps and training needs	• Launch packaging-focused training programs	• Establish external knowledge partnerships
Supplier Engagement	• Include innovation capability in supplier evaluations	• Implement supplier scorecards and feedback reviews	• Establish long-term collaboration agreements • Replicate solutions across sites
Design Ownership	• Evaluate ownership models (R&D vs supplier-led)	• Standardize handover procedures for supplier-led designs • Build in-house capabilities if needed	• Align design responsibilities with product development and site capabilities
Innovation and Scaling	• Document pilot initiativesDevelop tracking formats	• Launch Packaging Innovation Library • Host quarterly innovation forums	• Establish routines for scaling innovationsIntegrate continuous improvement
Data and Reporting	• Define packaging data structure and responsibilities	• Enhance data quality across ERP systems • Increase supplier data requirements	• Integrate packaging data into central reporting and decision-making

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Valorization of Agricultural By-products: Nanocellulose Barrier Films for Sustainable Food Packaging

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Introduction

The persistent reliance on petroleum-based polymers for food packaging has contributed significantly to environmental challenges. This thesis investigated the valorization of lignocellulosic agricultural by-products, such as corn-cob, artichoke, coffee husks, and grape pomace, as sources for high-performance nanomaterials. The study focused on fabricating multilayer films composed of polylactide (PLA), chitosan tie-layer, and nanocellulose extracted from agro-industrial residues to develop sustainable alternatives to conventional plastic barriers.

Methodology & Objectives

The study systematically evaluated bio-based multilayer films by optimizing preparation protocols for stable cellulose nanofiber (CNF) and cellulose nanocrystal (CNC) suspensions from agricultural waste streams, then characterizing their barrier properties and transport mechanisms.

Films were constructed using a three-layer architecture: corona-treated PLA film as the hydrophobic core, chitosan as a biodegradable tie-layer forming electrostatic bonds between PLA and nanocellulose, and multiple nanocellulose layers deposited via bar-coating.

Barrier performance was evaluated using:

- *Dynamic Vapor Sorption (DVS):* Measured water vapor uptake and diffusion coefficients
- *Long-term Back-Face Measurement:* Monitored water vapor and oxygen transport over extended periods under controlled environmental conditions to quantify oxygen barrier performance under dynamic humidity and elucidate molecular transport mechanisms.

CONFIDENTIAL TOPIC

Optimization and validation of a pilot-scale protocol for assessing the technological suitability of wheat flours in croissant production

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The laminated bakery category, especially croissants, presents unique technical challenges that require highly functional wheat flours. Conventional analytical tools, such as the farinograph, alveograph, and extensograph, are commonly used for flour assessment but fall short in predicting flour performance under the complex, large-strain conditions of croissant production. Inconsistent product outcomes, high production costs, and the increasing variability in flour properties, underlines the need for application-specific evaluation tools.

The aim of this study was to develop and optimize a standardized, pilot-scale protocol to assess the technological performance of wheat flours in croissant production. The protocol was designed to closely replicate industrial processing steps, including mixing, lamination, fermentation, and baking, and to integrate structural and rheological measurements relevant to flour functionality. Two industrial types of wheat flours, were tested over multiple production days to evaluate both repeatability and robustness.

This research fills a critical gap in both academic and industrial settings by providing a product-specific protocol framework that links flour rheology and end-product quality under realistic production conditions. The methodology can offer R&D and quality assurance teams a valuable tool to screen flours for croissant applications, reduce dependency on trial-and-error, and contributes to establishing more predictive and standardized flour assessment practices within the bakery industry.

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