FIPDes

Food Innovation & Product Design

FIPDes Day 2019
International talents in Food Innovation and Product

Students' Book of Executive Summaries

Congratulations to the FIPDes Cohort 7 !

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Contemplation in our VUCA* world

When I was asked to write a piece for the FIPDes Book of Executive Summaries, I was deeply touched but also a bit overwhelmed by this responsibility. I have been giving the matter some thought, and here is what I would like to share with you all before you move on to your new "post-FIPDes" lives.

I would first like to remind you of what you had in mind a couple of years ago.

When questioned about their reasons for choosing this particular Master's degree, FIPDes students often underline their desire to acquire top level scientific knowledge and develop skills in various fields (Food Science, Food Technology, Innovation, Marketing, to name a few).

They then often mention language skills. FIPDes students can all speak English in addition to their mother tongue at the beginning of the program, and some are proficient in other languages as well. They generally hope this experience will give them the opportunity to learn French and maybe Italian or Swedish, depending on where they choose to spend the third semester.

They quite naturally wish this degree will give them better options when looking for a job later on and lead to better career opportunities.

Travelling across Europe is also quite high on their bucket list. They know that they will be living in at least two different European countries, France and Ireland, possibly three. They are aware that the Old Continent is relatively small and that even short breaks can give them the opportunity to discover new cities, regions or countries.

Most of these expectations, if not all of them, are generally met.

But the motivation for choosing this particular program often reflects a more personal agenda: students often wish to gain autonomy and independence, become more adaptable and develop problem-solving skills. The vast majority happen to be curious and genuinely interested in other cultures and are keen to discover how their own culture is perceived in other parts of the world.

I am wondering however if you realized when enrolling for this Masters' degree that you were embarking on a soul-searching voyage. Going far away from home to study and live for two years with such a diverse group of peers, taught and accompanied by multicultural teams of academics and support staff, moving to a different European country every semester, is a once-in-a-lifetime opportunity to experience and compare a broad variety of ways of thinking, behaving, doing things, communicating with others, reacting to situations and incidents.

As you have tried to make some sense of it all, observing others, comparing habits and customs, but also coming to terms with your own perceptions and emotions, you first

and foremost have ended up learning a great deal about yourselves, your own cultural codes, references and values, your own identity. And the more you have reflected about all this, the more you have tried to figure out what was going on, the more complex, the more nuanced human nature and human relationships have started to appear to you. One more reason not to fall into the trap of stereotypes and generalisations…

Going through the various stages of adaptation, quite possibly overcoming some degree of culture shock, you have become aware of how cultural differences combined with personality impact who we are, what we do and how we do it. You have found ways which have helped you not only to survive in very different environments, but also to negotiate compromises which were satisfactory enough for you to be able to acquire knowledge and skills and to work successfully in multicultural teams on projects which meant a great deal to you.

You certainly have become more flexible and more creative, but also more perceptive, more attentive, more patient, more humble. These are precious life skills which will enable you to build bridges between people and groups. This is why, after this unique two-year experience, you probably are better equipped than most to deal with complex situations and navigate the troubled waters of our VUCA* environment. What could be more valuable in today's world, in which everything seems so uncertain and changeable?

I have had the opportunity to travel around Canada this summer. One day, as I was hiking in a national park in Eastern Quebec, I came across a sign describing the many daily chores of the farmers who used to live in that area in the early 1900s. To my surprise, *Contemplation* was on the list.

So here is one more little piece of advice to you: in our crazy 21st century world, when everything apparently has to be faster than ever, try to remember to regularly press *Pause*. Take the time to sit down and contemplate. Just as you have learned to stop and suspend judgement when applying *Flexible Thinking* to avoid hasty misleading conclusions when interacting with people. Try to sometimes stop rushing to stay the course. Remember to be true to yourselves, to others, and enjoy the moment.

Thank you all for choosing FIPDes and granting us your trust.

Thanks to you all the world may be a better place for us all.

**VUCA= Volatility Uncertainty Complexity and Ambiguity*

Ghislaine TAMISIER,
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Fractionation of proteins on size, using centrifugation and membrane filtration

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Profile in a nutshell:

- Master of Science in Food Innovation and Product Design with specialization in Food Design and Engineering
- Bachelor in Food Science and Human Nutrition

Interests:
New experiences, travelling, using food for medical purposes

Master Thesis hosing lab:
Danone Nutricia Research, Utrecht, Netherlands

Master Thesis tutors:
Dr Anna VAN DINTHER
Dr Stephanie ROUX

Lately efforts have been put on separating proteins of similar origin, on size and on investigating their properties. In the present study, centrifugation and membrane filtration methods were used to fractionate these proteins on size. The physicochemical properties of the fractions obtained from the above methods were investigated. A significant conclusion of this study was that centrifugation was able to separate the protein particles in a satisfactory range of particle sizes. Furthermore, the bigger the protein size in the medium, the lower the viscosity of the medium. The smaller sizes, on the other hand, had higher protein on dry matter levels. The main conclusion is fractionated proteins on size did indeed possess different properties, on viscosity, heat stability and protein and mineral content. Thus, some of the fractions obtained, are interesting for application to advanced medical nutrition products.

Confidential Topic

Exploring the product development process of a dairy based UHT drink

A public-private partnership targeting the Base of Pyramid market in Zambia

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GUATEMALA

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Profile in a nutshell:

- MSc. In Food Innovation & Product Design
- BSc. Engineering in Food Science
- Working experience of 2 years in R&D and QC of nutritional products

Interests:

Contributing in the development of nutritional products that create a positive impact in society, travelling and knowing different cultures.

Master Thesis hosting lab:

Global Alliance for Improved Nutrition (GAIN)

Master Thesis tutor:

Märit BECKEMAN

Karla Marie BATINGAN PAREDES

Introduction

One of the Sustainable Development Goals (SDGs) aims to end all forms of hunger and malnutrition by 2030, making sure all people – especially children and the more vulnerable – have access to enough and nutritious food all year round. Several organizations around the world have been working for many years in tackling hunger and malnutrition. (Sustainable Development Goals Fund, no date)

Currently, the Global Alliance for Improved Nutrition (GAIN-which is an NGO-) is working in partnership with a multinational dairy ingredient supplier, a multinational packaging company, a multinational micronutrient supplier, a dairy processing company in Zambia and the SUN Business Network to co-create a dairy based UHT drink for low income consumers. The product will support the launch and promotion of the Zambian Good Food Logo. This one intends to help consumer choose healthier. The product is expected to be nutritious, affordable, safe and compliant with the national regulations, tasty, aspirational, accessible, convenient and produced locally.

Better availability and accessibility to food is key to target food and nutrition deficiencies. This is something that can be improved with the private sector engagement, and producers, consumers and entrepreneurs at the base of pyramid (BoP). The term BoP refers to the people that ear less than 8 USD per day. The private sector can help by optimizing the production of raw materials and food that include small-scale

local producers. This could help with income growth and in some cases, increase in food in local markets. The private sector al-

so intervenes to reach low income food consumers by producing, processing, distributing and marketing food and food products that benefits the accessibility and utilization of food. (Chevrollier et al, 2012)

This thesis is intended to explore the product development process within the co-creation approach of the public-private partnership in the project.

Research objectives

To get the understanding on the product development process up to the time of the thesis period (May 2019) and the role of the different partners in this process, the following research question was defined as the central focus of this thesis research.

What was the product development process of a dairy-based aseptic drink targeting the BoP of Zambian consumers within the framework of a public-private partnership?

In order to support the understanding of the product development process within this kind of partnership the following questions were raised:

- What were the steps of the product development process of the dairy based UHT drink for BoP consumers in Zambia?
- How did the different partners of the public-private partnership contribute to the product development so far?
- What were the main challenges and strengths of this kind of partnership for the product development process?
- How did the potential consumers in Zambia evaluate the product prototype?

Methodology

An exploratory case-study research approach was selected for this master thesis with qualitative data gathering. The main methods for collecting the data were through documentation, semi-structured interviews to the different partners involved in the project, observations and focus groups. The iterative steps by Yin (2009) were followed along the process which were planning, designing, preparing, collecting analyzing and sharing.

For this master thesis, data triangulation was used in order to construct validity. In order to analyze the information, a thematic approach was used. This helped in identifying and analyzing patterns in the data as stated by Braun & Clarke (2006). The interviews were transcribed, some of the sentences were edited to improve the readability of the phrases but without changing the sense of what the interviewee said. Then, the interviews and notes were gathered and coded. According to Vaughn & Turner (2016), this is useful in qualitative research when meaningful themes need to be identified within the collected data.

Results and discussions

The work done during this thesis allowed the researcher to explore the product development of a dairy-based product under a public-private partnership approach where the different partners helped in the co-creation of the solution considered as of the writing of this document (May 2019). To address the research questions for this project, the different steps for the product development of the dairy-based drink were identified and are presented using the first three steps of the framework proposed by Castillo, Diehl & Brezet (2012). The steps of the product development were the following:

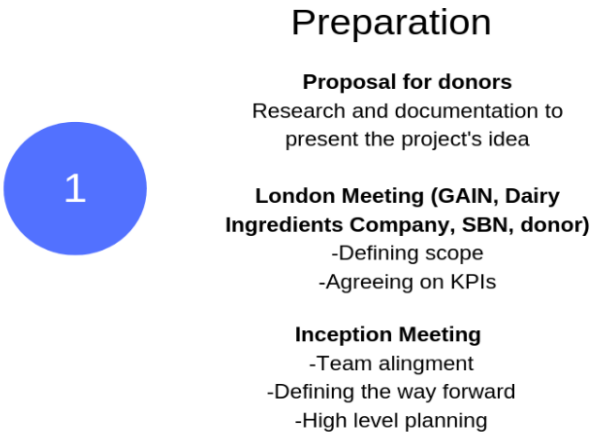

Figure 1. Preparation phase in product development process

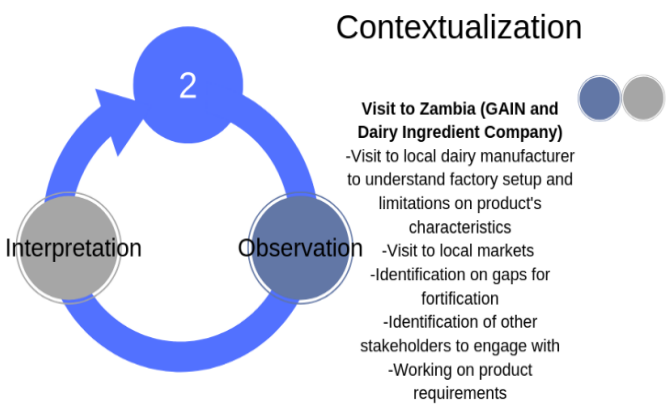

Figure 2. Contextualization phase in product development process

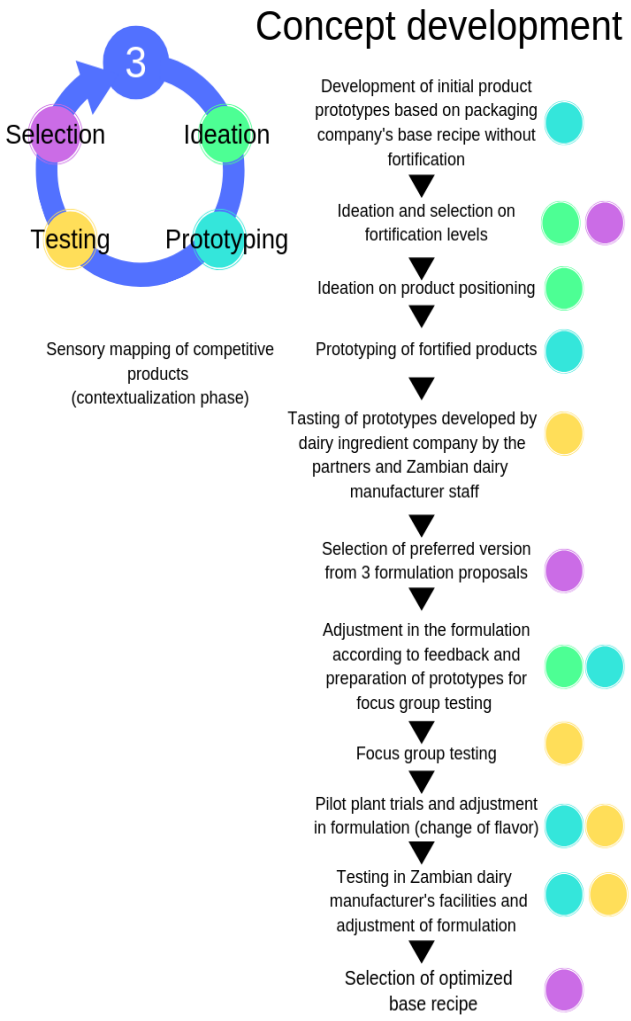

Figure 3.**Concept development phase in product development process**

Developing nutritional products for the Base of Pyramid has great potential in targeting nutritional deficiencies, although it can be challenging. As stated by Cordaro (2013), a single company would not be able to overcome all the barriers and obstacles to introduce nutritional products in developing countries. This highlights the importance of creating partnerships and for this project was as from public-private partnership approach.

It was found that the private sector contributed with their technical capabilities, expertise on the product's characteristics and access to in kind resources. The NGO had a central role in the nutritional design of the product and helping to build the local company's capacity. The local partners helped understand the local context and gave access to their networks. The main strengths in the partnership were the trust and transparency between the organizations, the synergetic expertise, and helping the local company to build capacity. The main challenges were related to the project timeline, bureaucracy, communication, and challenges with the initial criteria set for the product. Finally, the focus groups showed that the people found the product to be too thin, acid, and not sweet enough. The packaging shape was found to be more attractive to kids than for adults. The improvement suggestions were implemented, and a final base recipe has been developed which is to be tested with different flavors to have the final developed product.

Conclusion

The focus of this study was to explore the product development process a dairy- based UHT drink that was co-created within the approach of a public-private partnership. The product development was successfully mapped under the framework proposed by Castillo, Diehl & Brezet (2012) and the contributions from the different partners were identified. Also, the product prototype was tested in Zambia through focus groups and the learnings from this stage of the product development process were presented. The feedback from the market was addressed by the partners with further trials and testing. A

final base recipe was obtained which will be tested with different flavors by a flavoring company which will help in the co-development of the final solution to present in August 2019.

Recommendations for future projects

The BoP literature highlights the importance of getting a deep understanding of the local context and consumers habits, eating patterns and cultural aspects that can effectively guide product development. Especially during the initial phase, it would be important for the product developer to spend as much time as possible (which will also depend on the available resources) "immersing" into the local context and working with the consumer to understand and design nutritional solutions that can be acceptable. Also, getting the consumer's feedback as soon as possible is important to loop back to the solution's improvements.

Another key finding was the importance on the local partner's capabilities. Authors like Codaro (2013) propose using scorecards to evaluate the production capacity of the solution to implement which can help guide the selection of the partner, the solution of the product to develop and the resources needed to build the capacity and do a specific product.

Finally, as stated by Tennyson (2011), it is common that in public-private partnerships some of the members leave the project (for whichever reason), but it is important to have a plan to ensure the survival of the partnership and very importantly the information flow. Having a project onboarding plan can help maintain the information flow as well as the interest and engagement from the partners to facilitate the information flow.

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Development of Nutrient Rich Probiotic Beverage Based on Fermented Quinoa

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Profile in a nutshell:

- M. Sc. in Food Innovation and Product Design (Specialized in: Healthy Food Design)
- B.Sc. in Food science and Nutrition (Specialized in: Human Nutrition and Dietetics)
- Work Experiences as: Food Researcher, Social media marketing manager, Nutritionist and radio broadcasting

Interests:

New food product development, Communication, social networking and travelling

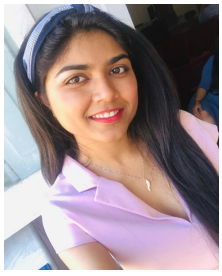
Master Thesis hosting lab:

Lund University (Lund, Sweden)

Master Thesis tutor :

Prof. Gianluigi MAURIELLO (UNINA)

Dr. Claudia LAZARTE (Lund University)



Introduction

Fermented probiotic foods and beverages are gaining huge popularity because of its known health benefits (Misihairabgwi, & Cheikhyoussef, 2017). It is forecasted that annual growth rate (CAGR) of fermented food products will incline by 7.2% during the period of 2018-2023 (Byakika *et al.*, 2019). Moreover, 74% of functional and probiotic foods are dairy based (Salmerón, 2017) where increasing vegan, lactose and gluten intolerant population has highlighted the need for non-dairy and gluten free products. Therefore, plant-based beverages are becoming trendy in this segment (Das *et al.*, 2019).

Quinoa is a super food with macro and micronutrients, but it possesses nutrient inhibitory compound called phytate (0.5 to 2g/100 g) which inhibits the bioavailability of important minerals in the gut (Lazarte *et al.*, 2015). Therefore, lactic acid fermentation was used in this project to enhance the nutrient profile of quinoa by the action of endogenous phytases and microbial phytases.

Research objectives

The project aims to develop an instant-beverage based on fermented quinoa taking into account two main characteristics:

a) to reduce phytate content, which will in turn improve zinc, iron and calcium bioavailability in the final product.

b) to investigate the viability of lactic acid bacteria in the final product.

Methodology

Fermentation Type 1: Milled quinoa sifted with 500 µm sieve was roasted in termaks incubator at determined temperature and time (confidential). 500 grams of this roasted milled quinoa (in replicates) was then mixed with 1 liter sterilized water and 1 capsule of Probi Mage *Lactobacillus plantarum* 299v®. The samples were mixed thoroughly in air seal containers. Then, the samples were allowed to ferment in Termaks incubator at 37˚C until pH decreases below 4.6. pH and lactic acid content were measured at 0, 3, 6 and 9 hours in both replicated samples.

The final fermented samples were packed in zip lock bags (1 cm thickness) and were frozen at -20˚C and -80 ˚C for freeze drying.

Fermentation Type 2: 650 g of raw milled quinoa was mixed with 1300 ml of sterilized water in replicates. One capsule of *Lactobacillus plantarum* 299v® was inoculated in both replicated samples and was allowed to ferment for 6 hours (1st fermentation). Lactic acid content and pH was measured at 0, 3 and 6 hours. After this time, the samples were dried at 60˚C for 18 hours in termaks incubator. The dried samples were then crushed and milled in laboratory scale mill (Laboratory Mill 120, Perten Instruments AB, Sweden) with 500 µm sieve. The milled quinoa samples were then roasted at a confidential temperature and time and was weighed as 500 g (each replicate) for 2nd fermentation. The processed samples were then mixed well with 1 liter of water (1:2 m/V) and 1 capsule of Probi Mage *Lactobacillus plantarum* 299v®.

Beverage Formulation

Fruits used with flavor combination:

- Mangoes and peaches
- Pineapple and orange
- Raspberries and blueberries

INGREDIENTS	
Fruits	*84-86%*
Pectin	*0.5%*
Erythritol (Sweetner)	*13-15%*

Steps

Following steps were followed for the preparation of all the recipes mentioned above:

- All ingredients were blended in CombiMax 600 food processor.
- Pasteurized at 80˚C for 1 minute.
- The samples were frozen at 80˚C for freeze drying.

The process was same for all the recipes mentioned above.

*5%, 10% and 15% of both fermented freeze dried quinoa was added to freeze dried fruity mixes (with pectin) of each flavor to select the best recipe accepted by consumers (through sensory analysis). Final amount of fruit powder mixed in quinoa is kept confidential.

Results and Discussions

Protein Analysis

The protein content reported for quinoa in literature ranges between 13-20% (Sezgin & Sanlier, 2019). The results observed from *Chenopodium* quinoa shows no significant differences ($p>0.05$) in protein content

Protein content (g/100 g) in raw and fermented quinoa samples.

Samples	Mean ± SD
Raw Milled Quinoa	14.26 ± 0.01[a]
Fermentation Type 1	13.97 ± 0.14[a]
Fermentation Type 2	14.33 ± 0.00[a]

Values with different letters are significantly different ($p<0.05$)

before and after fermentation averaging approximately 14% for all the samples.

Phytate Analysis

Fermentation Type 1

Sample	Phytate content	Phytate reduction (%)
Raw Milled Quinoa	8.882 ± 0.00	
Roasted Quinoa	7.16 ± 0.00	13 ± 0.4
Final Sample	3.392 ± 0.00	61.8 ± 0.00

Fermentation Type 2

Sample	Phytate content	Phytate reduction (%)
Raw Milled Quinoa	8.882 ± 0.00	
step 1; 6 hour fermentation	3.533 ± 0.00	60.2 ± 0.00
Final sample	3.160 ± 0.00	64.4 ± 0.00

Phytate content and reduction percentage in fermented samples Mean ± SD where $p>0.05$ (analyzed by Tukey test).

The results are statistically analyzed using mean and SD with further one tail paired t-test comparison for phytate reduction in the final product of both fermentation processes. Phytate reduction is not significantly different from each other ($p>0.05$). The results for phytate analysis illustrates 61.8% and 64.4% reduction in phytate content in 1st and 2nd type of fermentation respectively. Higher phytate reduction was observed in raw milled quinoa as compared to roasted quinoa because of dual effect of endogenous phytates and microbial acitivity. Where phytates was killed during roasting of quinoa.

Mineral Molar Ratio

The recommended phytate: minerals molar ratio for adequate bioavailability of zinc, iron and calcium are; Phytate: Zinc (Phy:Zn) < 15 whereas Phytate: Iron (Phy:Fe) < 1 and Phytate: Calcium (Phy:Ca) < 0.24

Samples	*Molar Ratio*		
	Phy:Zn	***Phy:Fe***	***Phy:Ca***
Raw Quinoa	*19.56 ± 0.15*	*13.47 ± 0.10*	*1.44 ± 0.01*
Fermentation type 1	*8.12 ± 0.3*	*5.57 ± 0.2*	*0.58 ± 0.02*
Fermentation type 2	*7.52 ± 0.01*	*5.17 ± 0.00*	*0.54 ± 0.00*

respectively.

Higher mineral bioavailbility was observed in Zn followed by Fe and Ca.

Microbiology

The higher viability of *Lactobacillus plantarum* in 9 hours' fermentation of both processes proves to be efficient at a temperature of 37° C where quinoa proved to be a rich nutrient medium for the growth of the microbes.

Statistical results obtained by comparing fermentation type 1 and fermentation type 2 freeze dried samples at -20°C and -80°C are significantly different ($p<0.05$). Moreover, statistical comparison between freeze dried samples from fermentation 1 showed significant differences at -20°C and -80°C ($p<0.05$). However, comparing the lactobacillus count from fermentation 2 samples frozen at -20°C and -80°C showed no significant difference ($p>0.05$).

Higher viability was obtained at -80°C as compared to samples frozen at -20°C .The main loss of viability at -20°C more than -80° C or in general are mainly because of macromolecule denaturation induced by water removal (higher in -20°C sample) and higher osmolarity because of higher

concentration of internal solute (Polo *et al.*, 2017).

Sensory Evaluation

9 scale hedonic test was used to assess most preferred flavor, type of fermentation (among both) and quantity of fermented quinoa in final beverage by using the attributes as color, aroma, taste, mouth feel, after taste and overall acceptability. Pineapple with orange with a 5% concentration of fermentation type 1 quinoa was prefered over all other samples including the control sample (Commercial swedish blueberries beverage).

Conclusion

Fermentation indicated 61-65% reduction in the phytate content of quinoa where phytate was more quickly degraded in raw milled quinoa as compared to roasted quinoa.

37˚C proved to be efficient temperature for microbial growth and phytate reduction in 9 hours of fermentation. Moreover, Higher viability of *Lactobacillus plantarum299v*® was achieved by freeze drying the samples frozen at -80˚C as compared to -20˚C. Addition to this, with high *lactobacillus growth*, final product can be claimed as “contain live and active culture” with few more analysis. Pineapple and orange flavor with 5% quinoa scored higher than the control commercial product.

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Extending the shelf-life of fruits and vegetables in retail stores — Assessment of an innovative controlled atmosphere solution

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Profile in a nutshell:

- Junior Packaging Developer in Nestle Purina EMENA (since June 2019)
- Msc in Food Innovation and Product Design with specialization in packaging and logistics at Lund University (2017-2019)
- Msc in Food Science at AgroParisTech Life Sciences University in Paris (2014-2019)
- Erasmus exchange in Design for Sustainability at Wageningen University (2016)

Interests:
Passionate about the challenges currently facing the packaging industry and how to create viable and sustainable solutions for the future.

Master Thesis hosting lab:
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Master Thesis tutor :
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Introduction

More than 50% of the fruits and vegetables (F&V) global production goes to waste at different stages of the supply chain, among which 5 to 10% occurs at the retail stage (FAO, 2011).

F&V waste is directly linked to freshness and visual quality, which are the most important criteria for consumers when choosing a product (Oliver Wyman, 2014). A poor quality of the products can be explained by temperature abuse, non-optimal storage conditions and mishandling. Currently, products in retails are stored at a unique temperature with no control over other environmental parameters like relative humidity or gas composition, which influences greatly F&V quality.

F&V waste in retail stores linked to consumer dissatisfaction has led to an increased interest in new preservation solutions of fresh produce. While some solutions for individual products are being developed, no solution currently exists to improve storage conditions of fresh F&V in bulk.

In this study, the potential on extending shelf-life of F&V of controlled atmosphere (CA) combined with optimal temperature and relative humidity (RH) for short-term storage periods was assessed using an innovative prototype developed by Air Liquide.

Research objectives

- Assess the impact of the prototype on F&V quality and shelf-life compared to

the current situation in retail stores. Shelf-life will be assessed via quantitative and qualitative methods including consumer acceptability.

- Determine the financial viability and environmental impact of the prototype based on its daily gas consumption and food waste avoided.

Methodology

Seven types of F&V were stored at 4°C and optimal RH in normal atmosphere conditions and in CA under the prototype for 3 to 7 days.

Shelf-life determination

The impact of different storage conditions on the quality of F&V was assessed by both qualitative visual evaluation, based on grading scales determined using visual quality attributes such as color, browning, firmness, shriveling and wilting (Nunes & Emond, 2007; Lill, 1980), and quantitative methods, such as weight loss and texture analysis evolution.

Shelf-life extension was determined by taking into account consumer acceptability related to purchase intent, and linking it to the visual evaluation results (Matar *et al.,* 2018).

Financial viability and environmental impact assessment

Average daily consumption of gas by the prototype during every experiment was monitored for th different preservation environments.

Next to this, costs in-use and environmental impacts of daily gas consumption were estimated based on Air Liquide L50 gas cylinders prices, and four environmental indicators: global warming potential (GWP), damages to human health (HH), damages to ecosystem diversity (ED) and damages to resource availability (RA).

On the other hand, F&V prices were averaged based on prices found online for 5 main retailers in France in May 2019, and enviromental impact of the production of several F&V was assessed based on EcoInvent 3.4 database.

For each product considered, the quantities of product (in kg) that would be necessary to save to compensate the cost or environmental impact of daily gas consumption were determined. These quantities were then translated into % of prototype's volume capacity for each F&V, to give an idea of the share of products stored under the prototype that would have to be saved.

Results and discussions

Shelf-life determination

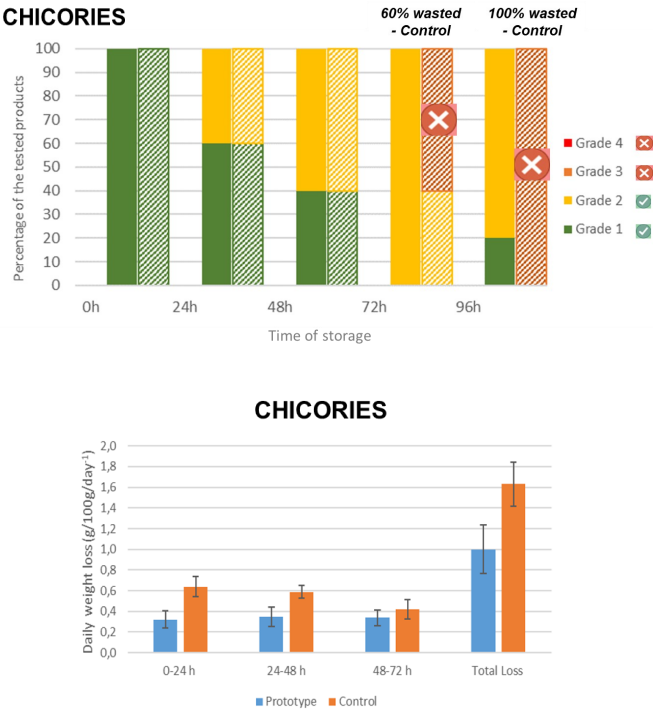

Figure 1— Visual quality assessment and weight loss evolution for chicories

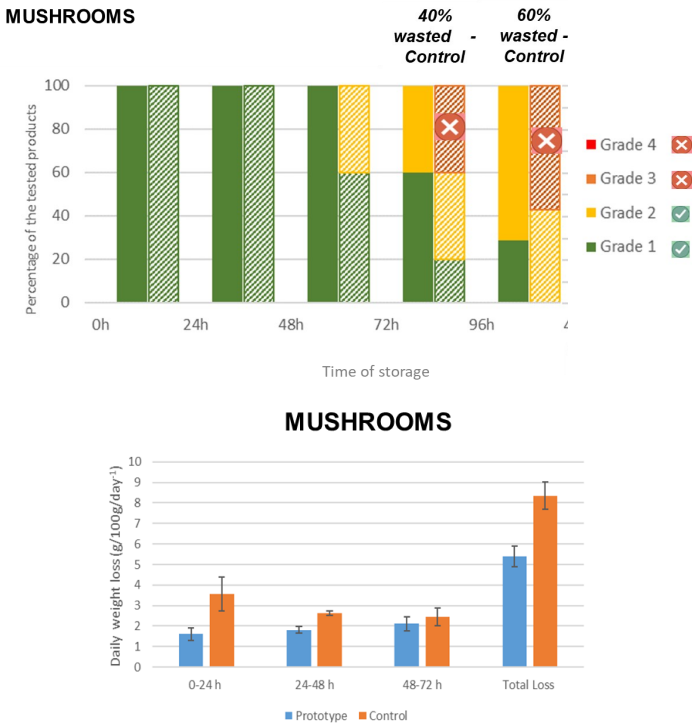

Figure 2— Visual quality assessment and weight loss evolution for mushrooms

CA storage for short periods of time had a positive effect on quality for leafy greens and mushrooms, allowing to extend shelf-life after 72h of cold storage for chicories and mushrooms by saving up to 100% of the products for chicories after 96h of cold storage. The differences in visual quality between batches could be explained by higher respiration rate for control samples, leading to a more important weight loss causing increased browning and higher deterioration (Nunes & Emond, 2007).

For strawberries, CA also had a positive effect on quality, with a better firmness of the prototype samples indicating a slower ripening under CA storage conditions, which was confirmed by the visual quality evaluation.

Financial viability and environmental impact assessment

In the experimental settings of the study, CA storage using the prototype was financially viable only for organic chicories and potentially strawberries. These results were totally

Fruits & Vegetables	*% that can be saved by the prototype after 3 days of storage (PART 2)*	*% of prototype's volume capacity to be saved after 3 days*
Mushrooms (Champignons de Paris)	40 %	163,5 % ⊗
Organic mushrooms (Champignons de Paris)	40 %	51,6 % ⊗
Chicory (France)	60 %	110,7 % ⊗
Organic chicory (France)	60 %	27,6 % ✓
Strawberries Gariguette	/	15,6 % ✓
Organic strawberries	/	11,7 % ✓
Strawberries Ciflorette	/	16,8 % ✓

Figure 3— Quantity of F&V to be saved per day to compensate financially the daily gas consumption

dependent on the size and gas consumption of the prototype, and are subject to change at the industrial scale with different sizes and different airtightness solutions.

In order to have an overall positive impact on all four impact categories considered, different minimal amounts must be saved daily for strawberries, asparagus and lettuce,

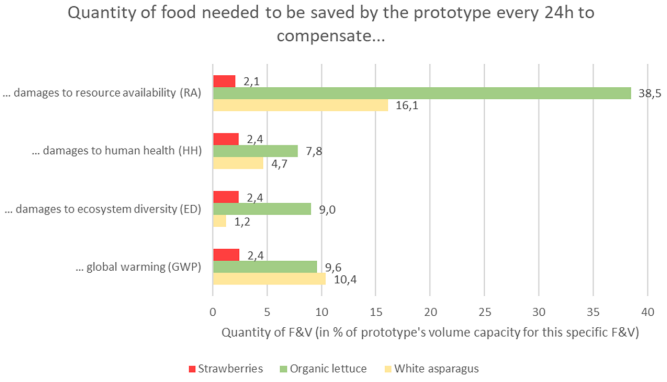

Figure 4— Food waste to be avoided per day for different F&V to compensate the environmental impacts of the prototype's daily gas consumption

respectively 2,4% of the prototype capacity, 16,1% and 38,5%. For strawberries, the quantity to be saved seemed achievable (15% for 72h of storage) and could potentially be reached if CA storage was done in optimal RH conditions.

For asparagus and salad, for which no shelf-life extension potential was identified, the quantities to be saved were more important, and unreachable for lettuce after 72h of sto-

rage, with more than 100% of the quantity stored under the prototype that should be saved to achieve a positive environmental impact.

Environmental impact on mushrooms and chicories were not performed due to a lack of data concerning these products in the Ecoinvent 3.4 database.

Conclusion

This study confirmed that CA storage combined with optimal temperature and humidity conditions had a positive impact on the quality of leafy greens and berries for short-term storage periods. The prototype was able to extend the shelf-life of chicories, mushrooms and potentially strawberries after 3 days of storage, by delaying browning and reducing weight losses resulting in slower deterioration.

With its current gas consumption, the prototype was only financially viable for F&V with high-added value, like berries or organic products, and its environmental impact potentially positive for strawberries and negative for lettuce and asparagus when considering all four environmental indicators described earlier.

Further prototype development will focus on reducing gas consumption by improving airtightness .

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Developing Dog Biscuits from Industrial by-product

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Introduction

The most common and least preferred way to dispose of the solid waste from craft breweries is through landfill, composting and lastly through industrial uses (Environmental Protection Agency, 2019). In 2019 craft breweries are paying up to 16000€ to dispose their solid waste and at the same time Sweden has been described as a "Dog paradise" having more than 780,000 registered dogs in 2012; according to a study, the dog owners treat their pets as a family member (National Veterinary Institute SVA 2018, Stier 2010 and passport 2018).

Research objectives

Solely purpose, to up-cycle the by-product from craft breweries. In 2018 forecast there will be an increase of 6.6% in sales for dog food (passport, 2018).

The objectives of the thesis are to:

1. Utilise as much wet spent grain as possible to formulate a recipe for canine consumption (dog biscuit)
2. Explore the formulations of dog biscuit from wet spent grain and compare them with the commercial dog treats in physical and microbiological level.

Materials and Methods

The material that was used, wet spent grain (brewer's by-product), egg, oil, different kind of flours. Following the new product development process by Earle 2017, the figure 1 illustrates the overall designing procedure of making a dog biscuit.

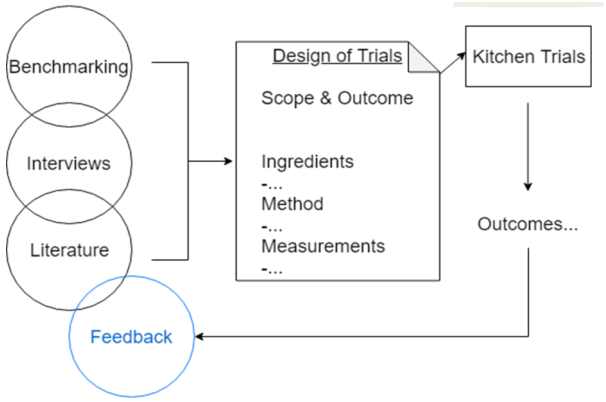

Figure 1. Design process of dog biscuit

The baking process of biscuit making was conducted and measurements of water activity, moisture content, color and texture were taken for quality control. Through primary consumer approach, the product was viewed and feedback from dog owners was recorded.

Findings

Four trials were conducted to get to know the behavior of wet spent grain and get an initial feeling. To begin with, analogies of different portions of wet spent grain were viewed and a working formulation occurred when utilizing 50% of wet spent grain with rice flour. Continuing, different ingredients were studied and incorporated in the recipe such as egg, oil for creation a moldable and structural dough. Later on, experimenting with different types of flours and various formulations on texture and color was studied and the findings were compared with 3 commercial dog treats. Through recipe repetition, the unexpected occurred. The findings of color and texture were not similar among the trials.

Discussion

The levels of wet spent grain that was incorporated in a working dog biscuit recipe reach 54% the percentage. Compared to Petrović study, the creation of human biscuit from wet spent grain reaches the incorporation of 50% (Petrović, 2017). Through the trials in the kitchen, the initial feeling of how the wet spent grain behaves with other ingredients (egg, flour, oil) had a positive attitude towards creating some working formulations. Also, the comparison with commercial dog treats regarding texture and color has promising results. From quality assurance perspective, the levels of water activity and moisture content were within the limits of dry pet food legislation (European Pet Food Industry Federation (FEDIAF), 2018 and 82/475/EEC). Initial consumer approach was promising even though challenging. Dog owners showed awareness and positive attitude towards sustainable dog biscuits.

Conclusion

The maximum content of wet spent grain that can be incorporated in a recipe was identified. Consumer gave initial feedback that needs to be taken into consideration. Through the new development process, the outcome of reaching acceptable product prototypes concurred. However, due to time limitation the design process of creating and launching a final product prototype could have been possible.

Further research

Possible next steps, creation of a business strategy for supporting the product. Continuation of consumer investigation for identifying the trigger ingredients. In-depth research of product development process.

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Scientific evaluation of probiotics and prebiotics for product innovation

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Science exploring the relationship between the gut microbiome and mental health is emerging, and the market of probiotics is also increasing and expanding. The objective of this master thesis is to help identify the external opportunities in prebiotics and probiotics in global for food, via the selection and scientific evaluation of the potential strains and substances.

Clinical studies studying probiotics and prebiotics effects on mental wellbeings, such as stress, anxiety and mood, were systematically retrieved and reviewed. Results show that a significant number of studies did not meet the quality or relevant criteria for analysis. And only a limited number of prebiotics or prebiotics reach a convincing level of evidence. However, external communication opportunities were also limited by the freedom to operate.

It was also observed that in the competitive market, companies were operating in different scientific standards and policies.

More research and intervention studies with larger sample size and adequate statistical design, are essential for the future development and communication of prebiotics and probiotic in foods. Science and fact-based communication on a product is as much important as product design and technology in the whole process of food innovation.

Confidential topic

Design of infant milk formula: focus on the factors affecting heat stability

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Introduction

The infant milk industry is constantly developing new products to satisfy its consumers' evolving needs and preferences. For this purpose, great research efforts are done on the development of new ingredients, formulas and also optimization. One of the ongoing challenges is regarding the heat-stability of the high total-solids wet-phase stage, prior to pasteurization and spray drying. A lack of stability in this key phase would lead to manufacturing failure. Therefore, it is key to better understand the impact of the different parameters affecting heat-stability, so that future products can be designed appropriately.

Research objectives

The aim of this thesis will be to clarify the key parameters affecting the heat-stability of the wet-phase to better design Infant Milk Formulas for future product developments.

To this purpose the following intermediate objectives will be achieved:

1) To identify the effect on the time taken for coagulation ($T_{max.grad}$) and the viscosity after heating (V_{heat}) of a sample wet-phase mix, by changes in its pH, calcium content, calcium salt and casein:whey ratio in its composition.
2) To find any correlations between these variables, and to identify the most relevant for the creation of a predictive regression model.

Methodology

Samples of a reference wet-mix recipe were prepared in lab-scale and standardized at 50-51 total solids. The samples were then treated according to the tested parameters. For the pH-experiments, they were standardized at pH from 6.6 to 7.2 in 0.1 steps with the use of a 1M alkaline solution. For the calcium-experiments, they were fortified with different calcium salts: calcium carbonate, calcium hydrogen phosphate and tricalcium phosphate. Finally, for the casein: whey ratio experiments, new recipes were formulated to obtain ratios of 60:40, 70:30 and 80:20, while maintaining the total solids and total protein content.

The samples were then analyzed with pressure cell rheology, which permitted to measure their viscosity throughout a heat-treatment similar to those applied in the industry. The output data was plotted in a viscosity-time graphs for each of the experiments and was reviewed for patterns and anomalies. A suitable range of time for calculating the V_{heat} was determined by observation. The $T_{max.grad}$ was determined by calculating the gradient within the data points, and registering the time at which the maximum gradient was observed.

The viscosity-time profiles for the different experiments followed a pattern: The samples undergo an initial thinning at the beginning of the heating until a sudden raise in viscosity occurs. Afterwards there is a long period of a stable high viscosity. When the cooling started, the viscosity increased again.

Considering this pattern, the desired measurements were calculated for each sample tested:

V_{heat} = Viscosity after heating, which is the average of all values between t=350s to t=500s

$T_{max.grad}$ = The time at which the maximum gradient was reported.

The pattern and way to calculate the values can be appreciated in **Figure 1**.

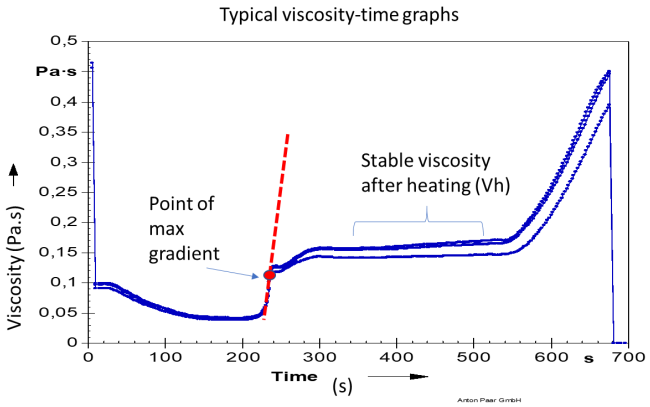

Figure 1 - Viscosity-time graph showing selected measurements

Results and discussions

All the results for $T_{max.grad}$ were tested for significant differences (paired t-tests) within their experiments. No significant difference ($p>0.05$ in all cases) was found. Thus, the $T_{max.grad}$ values are independent to: changes in pH from 6.6 to 7.2, changes in calcium addition between 0 mg to 600 mg, differences in calcium sources (calcium carbonate, calcium hydrogen phosphate and tricalcium phosphate) and changes in casein:whey ratio from 60% casein to 80% casein.

This is in disagreement with the literature. This measurement is derived from Heat-coagulation time analysis, an established method to test heat-stability. All of the tested factors (pH, calcium amount and C:W ratio) have shown to significantly affect heat-stability. It is likely that this result is due to the high total solids % in the samples prepared, and so this derived method was not well suited to this matrix. In his research, Singh (2004) arrived at the conclusion that Heat Coagulation Time was not an appropriate method way to measure the heat stability of high total solids samples, but attributed this to the method's subjectivity of the end-point. This subjectivity was not present in the measurement of the $T_{max.grad}$, which is why this value was initially considered.

In regards to the V_{heat}, an increase in viscosi-

ty from pH 6.6 to 6.9, followed by a decrease from pH 6.9 to 7.2 were found. A peak is formed at pH 6.9, and so this is the least heat-stable pH. These statements are supported by a statistically significant results ($p<0.05$) in the V_{heat}, and a by a strong positve correlation (0.90) and a negative correlation (-0.68) respectively.

These results are in line with those from *Singh (2004)* and *Dumpler and Kulozik (2015)* showing that milk has a heat-stability peak occuring at its natural pH of 6.7. *Singh (2004)* also showed that concentrated milk had its heat-stability peak at pH =6.6, which is identical to that found in this research.

In regards to the calcium experiments, both the addition of calcium carbonate and calcium hydrogen phosphate increased the V_{heat} values slightly but not in an statistically significant way ($p>0.05$). They both showed to be positively correlated with the V_{heat} .

The addition of tricalcium phosphate, however, showed no clear pattern. Its addition did not change V_{heat} in a significant way either ($p>0.05$) but there was no correlation whatsoever (0.22). This means that tricalcium phosphate has no significant effect on the heat-stability on the samples tested.

The addition of 600mg of calcium was strongly correlated (0.87) with an increase in V_{heat}, and the results were statistically different ($p= 0.0001$). This shows that the addition of calcium to a sample will increase its V_{heat} and therefore, reduce its heat-stability.

These results are in line with what was expected from literature. Addition of calcium to the mixture is expected to lower the heat-stability as shown by *Jeurnink and De Kruif (1995).* However, by the use of insoluble calcium sources such as calcium carbonate, calcium hydrogen phosphate and tricalcium phospahte this destabilizing effect is expected to be small or negligeable, as proposed by *Omoarukhe et al. (2010).* In each of the calcium experiments carried in this research there was a decrease in heat-stability with the addition of the calcium sources. Nontheless, when each calcium sources was tested independently, none of them brought a statistically significant change in the heat-stability indicator V_{heat}.

In regards to the recipe's casein:whey ratio, increasing the casein had a strong negative correlation with the V_{heat} (correlation test = -0.93), and the values were shown to be significantly different ($p=0.04$). This shows that increasing the percentage of casein in the sample decreases its V_{heat} and so, increases its heat-stability.

This result is in agreement with *Taterka and Castillo (2018),* who found that coagulation and increase in viscosity were caused predominantly by the action of whey. Therefore, it follows that recipes with more whey would produce a higher viscosity and therefore have a lower heat-stability.

Conclusion

There were no significant differences in $T_{max.grad}$ throughout the different experiments, showing that this measurement is not a valid way to assess the heat-stability of high TS samples tested in the present study. On the other hand, V_{heat} , was able to reflect well on the heat-stability and it was selected as the best indicator for the high total solids samples.

The parameters with the best established impact on heat-stability produced both a significant difference in the V_{heat} and proved a correlation. These were pH 6.6-6.9, pH 6.9-7.2, the addition of 600mg of calcium and the casein:whey ratio. Regarding heat-stability the data showed that:

- As pH values increase from 6.6 to 6.9, the V_{heat} values increase and heat-stability decreases.
- As pH values increase from 6.9 to 7.2, the V_{heat} values decrease and heat-stability increases.
- When a 600mg dose of calcium is add-

ed to the recipe, the V_{heat} values increase and heat-stability decreases.

- As the ratio of casein increases in the recipe, the V_{heat} values decrease and heat-stability increases.

Very interesting data were obtained from the experiment involving the addition of tricalcium phosphate. They show that addition of 600mg of calcium (the regulatory maximum) from tricalcium phosphate has no effect on the heat-stability and could become the calcium salt of choice for high-protein and high coagulation-risk recipes. If it is confirmed by future experiments it would be a very valuable result. Additional research on other sensory attributes would be needed as well.

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Development of plant protein-based nutritional formulations

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Introduction

Research conducted over the past 20 years has demonstrated that there is a clear relationship between environmental influences in early life and adult health (Barker, 2004). Differences in infant nutrition have been found to affect growth, development and the long-term function in humans (Robinson and Fall, 2012). Proteins are important for the maintenance of cellular function and for ensuring normal health and growth and are also used as an alternative source of energy when it becomes necessary. Protein requirements for infants and young children generally increases as they grow (Abeshu *et al.*, 2016).

With an increase in population (projected population of 9.5 billion by 2050), the de-

Figure 1. 10 key trends in Food, Nutrition and Health for 2018. Source: New Business Nutrition

mand for food is expected to rise by 59-98% and currently, there is an increasing number of flexitarians, vegetarians and vegans implying huge variations in the type of food demanded by consumers (Elferink and Schierhorn, 2016).

Figure 1 summarizes the 10 key trends among consumers with respect to Food, Nutrition and Health for 2018. The research shows that in 2018, consumers were found to be drawing more towards plant-based foods for a number of diverse reasons. Richter *et al.*, (2015) also noted that there has been an evolution in how consumers perceive plant proteins, which are currently regarded as a healthy alternative for meeting one's protein requirements. These choices made by adults indirectly affect children as food choices for infants/toddlers may be based on the dietary patterns/ choices of parents. Therefore, there is also an opportunity within the infant and young child food market for more plant-based products.

Single plant protein sources may not contain all of the essential amino acids in adequate amounts (Henchion *et al.*, 2017). Mixing of plant proteins is a useful strategy to obtain a higher level of nutritional quality (Young and Pellett, 1994). A variety of plant protein sources with complementary amino acid profiles, for example, blending of a soy protein which has high amounts of lysine with a cereal which would have higher amounts of sulphur containing amino acids would provide a better and more complete nutritional profile than the single sources. Thus, blending of protein sources may improve the nutritional properties when developing products using plant proteins (Henchion *et al.*, 2017).

Research objectives

1) To characterize and compare selected plant-based proteins based on buffer capacity, protein solubility, scanning electron microscopy images and amino acid profile

2) To design, prototype and develop nutritional formulations from plant-based protein with optimal amino acid profile, sensory characteristics, processability and shelf stability.

Methodology

The plant proteins selected for this study are outlined in Table 1.

Table 1: Protein content of plant proteins and algae powders

SOURCE	% PROTEIN
Cereal	81
Brew by-product	89
Legume 1	65
Legume 2	79
Tuber	90
Vegetable	60
Algae 1	55
Algae 2	60
Sativa plant	55
Commercial product (legume + cereal)	82

Ingredient analysis

The initial pH and amount of acid/ time needed to acidify to pH 2 was determined for all proteins. Protein solubility was also measured (Dumas method) and Scanning Electron Microscopy images obtained using the JEOL scanning electron microscope (JSM-5600).

Recipe and product development

Recipes were first designed using a formulation software and those recipes that were able to meet all nutritional requirements were further optimized and prototyped. Based on a sensory assessment, products with acceptable characteristics were produced at a pilot plant scale and stored at 25˚ C.

Statistical Analysis

Statistical analysis of all data obtained was performed using IBM SPSS STATISTICS version 19. Mean values were compared using one way ANOVA at a confidence interval of 95%. Post Hoc analysis was done using Tukey's B.

Results and discussions

The initial pH of the selected plant-based proteins ranged from pH 3.24 to 8.30. The tuber protein isolate had the lowest pH of 3.24.

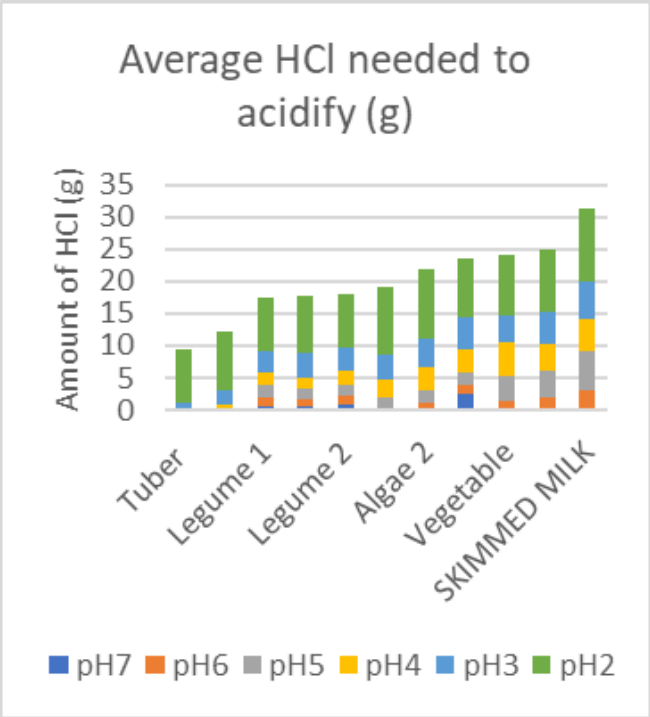

Figure 2: Buffer capacity of ingredients (soy and skimmed milk as reference samples)

Buffering capacity of food refers to the capacity to resist changes in pH and this influences the ability of such foods to be acidified or alkalinized (Kim *et al.*, 2018).

The results obtained show that generally, the buffering capacity of the plant-based samples were significantly lower than that of skimmed milk. The results obtained are comparable to that obtained from a study conducted by Aldabbas *et al.*, (2010) in which they measured the buffer capacity of five legumes and other foods such as peanuts, carob and raw cow's milk. As seen in this study, they also found that the buffer capacity of the legumes and all plant-based samples were lower than that of cow's milk. The differences between samples were mainly attributed to differences in protein content, amino acids such as aspartic and glutamic acid and phosphorus (Aldabbas *et al.*, 2010).

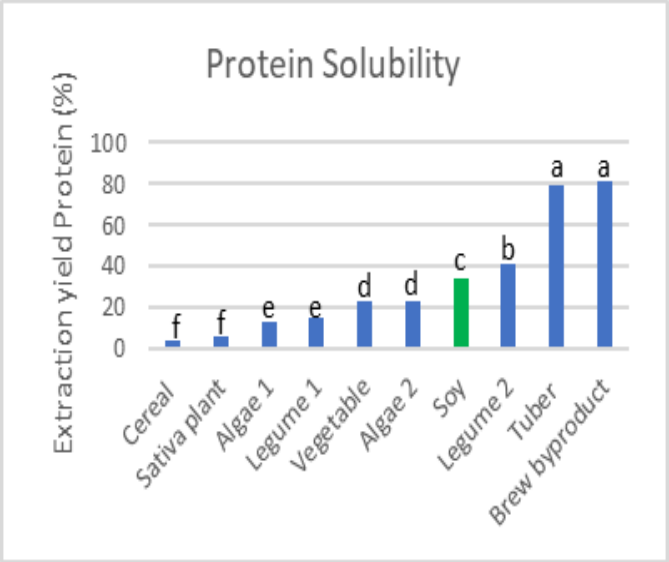

Figure 3: Protein solubility of plant proteins at 60˚C

The protein solubility at 60˚C was assessed and results obtained for the various plant proteins and algae under review show that the solubility of the samples ranged from 3.96% to 80.88%. The tuber protein and brew by-product were the most soluble with values of 79.62% and 80.88% and there was no significant difference between the two samples ($p>0.05$). Cereal protein isolate and sativa plant recorded the lowest solubility values.

On comparison of the amino acid profile of the selected ingredients, it was found that while some of the plant proteins contain all the essential amino acids, some are deficient in one or more amino acids, and when used in the development of a young child formula (YCF) nutritional formulation, it will be necessary to fortify the products with free amino acids. Also, these results support the idea to create blends of the various protein sources

by combining the different ingredients in order to attain a composition similar to dairy as proposed by Gorissen *et al*. (2018).

Table 2: Finalized recipes designed using plant-based protein blends

Base protein source	Supplementary protein source
Legume 2	Cereal
	Brew by-product
	Legume 1
	Tuber
	Sativa plant
	Algae 1
Cereal	Brew by-product
	Tuber
	Algae 1
	Algae 2
Brew by-product	Legume 1
	Tuber
	Vegetable
	Algae 1
Tuber	Algae 1

Figure 4: Photographs of some plant-based YCF prototypes from the pilot plant production

Overall, all of the plant proteins selected for this study were processable. An initial sensory evaluation of the fresh products showed that all products had a creamy taste, which is a desirable feature. Products which did not contain algae had a neutral smell, those containing algae had a "green" or strong vegetable smell and taste while those containing tuber protein isolate also had a distinct earthy/mushroom flavor.

After pilot plant production, the prototypes were stored at 25˚C and observed weekly for emulsion stability. Prototypes containing legume 2 and either cereal, brew by-product, legume 1, vegetable or sativa plant and the commercial product remained stable throughout storage for up to 4 weeks. After one week however, all products containing tuber protein isolate, algae 1 and algae 2 were found to have separated. When plant proteins are employed in food applications, processing parameters during ingredient production may also have an influence on the functionality of the ingredient. Researchers have found that thermal treatment, pH and ionic strength of a protein may affect functional properties such as emulsification and solubility (Pćksa *et al*., 2009).

Conclusion

Plant-based proteins provide a promising and sustainable alternative protein source to animal based ones. Different plant proteins however vary in their nutritional and physicochemical properties. This study showed that the various sources assessed differ in their protein and amino acid content, buffer capacity and protein solubility. The findings suggest that in order to obtain adequate nutritional benefits from these plant protein when used in nutritional formulations, creating blends is a good approach since different sources complement each other.

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Performance of frozen meal packaging system in the cold supply chain

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Packaging helps to protect the product and safety handover the product from producer to end user. The sustainable packaging would reduce the overall cost and environmental impact, increase the value of the packed product in the whole system. Two types of packaging, i.e. carton frozen meal packaging system and plastic frozen meal packaging system were selected and analysed the performance of the packaging under four areas such as product waste, logistics, value adding, packaging material. The supply chain was mapped from producer level to consumer level. The plastic packaging system performed better with producers and the carton packaging system performed better with all other supply chain actors, i.e. distributors, retailers and consumers. The packaging features such as product protection and production efficiency were given the highest importance by the producer. Volume and weight efficiency, convenience and packaging waste were given the highest importance by other supply chain actors. The convenience and packaging waste were given the highest importance by consumers. Further, the top 5 important packaging features were identified for the supply chain actors and for consumers, and found that the product protection, circular economy and convenience are most important features for the whole supply chain.

Confidential topic

Towards Paper Insulation Packaging: Evaluation of Thermal and Logistics Performance

A Case Study at HelloFresh

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Introduction

There's a global push for reducing the amount of plastic used in the world and companies are trying to find alternative materials to use. Paper is one of the first ones that comes to mind, however it comes with a number of disadvantages for which it can't be a one to one replacement for plastic. Paper is sensitive to moisture, can be easily ripped off and is not the most suitable gas barrier. This work evaluates a Paper-Based Cool Pouch (CP) prototype that can be a promising alternative to the currently implemented PET and PLA CP. The main advantage of this paper-based CP is that it achieves sufficient thermal insulation, is made primarily out of recycled newspaper insulation, which can be disposed in the paper household waste and is biodegradable by nature.

Methodology

The pouches were evaluated and compared in its thermal performance using an ice melt test. They were also evaluated using an infrared camera. Additionally, they were evaluated using a packaging performance methodology which analyses the performance of

the packaging in the supply chain. This method helps evaluate packaging in a holistic perspective by identifying the relevant stakeholders that interact with the CP. It scores the performance of the CP using packaging-specific features.

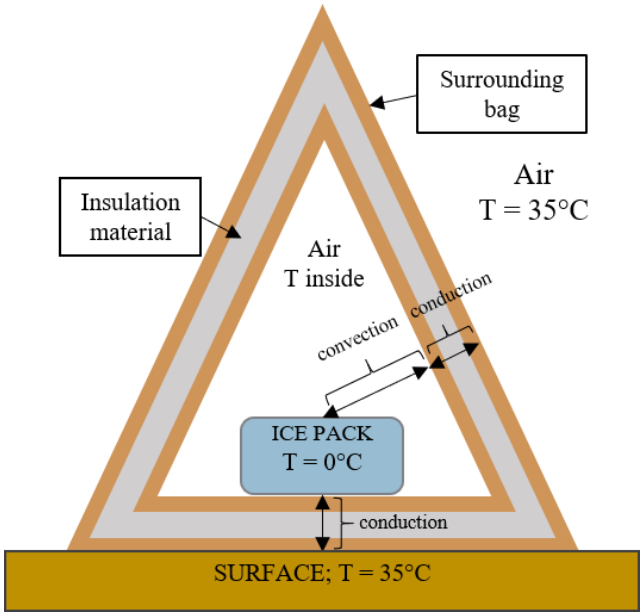

Figure 1. Simplified diagram of convection and conduction mechanism inside the Paper CP

Results and discussion

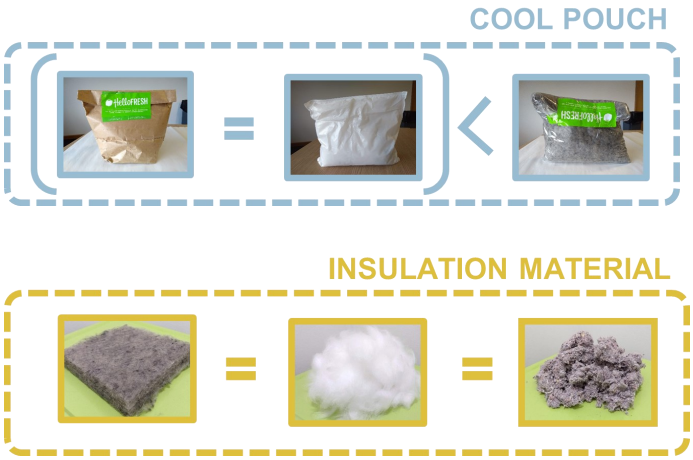

Figure 2. Main results comparing the performance of the cool pouches and the insulation materials. From left to right: PET, PLA and Cellulose.

The results indicate that recycled newspaper insulation is equally insulating as PET and PLA insulation. The Paper CP is equally insulating as the PLA CP, but slightly less insulating than the PET CP. The key features that affect insulation in these CPs were the thermal conductivity of the material, thickness, compressibility and homogeneous distribution of the insulation material.

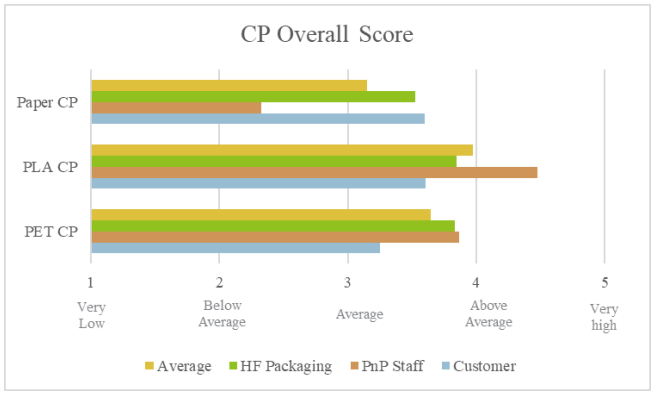

Figure 3. Overall score of each CP (Paper, PLA and PET CP) for each stakeholder

Conclusion

All three pouches performed above average in the packaging scorecard, which indicates that all three serve its purpose and are acceptable to use. However, PLA had a notorious advantage due to its production efficiency, which was not as good for the Paper and PET CPs. This is due to the zipper mechanism that facilitates opening and closing of the PLA CP. The Paper CP had a notorious good score in packaging waste because it's highly recyclable, biodegradable and packaging licensing fees are lower for paper materials than plastic. The only stakeholders that interact with the CP are the HelloFresh packaging decision makers, PnP Staff of the distribution center, and Customers. All three should be considered when evaluating and purchasing CPs. In conclusion the Paper CP is a promising alternative to PET and PLA pouches. It achieves sufficient thermal insulation and has considerably better recyclability than the others. Further development of this project should evaluate its manufacturability and consider dimension adjustments to improve its apportionment in the HelloFresh Box.

Study on analytical techniques for monitoring protein behavior in milk system during heat treatment

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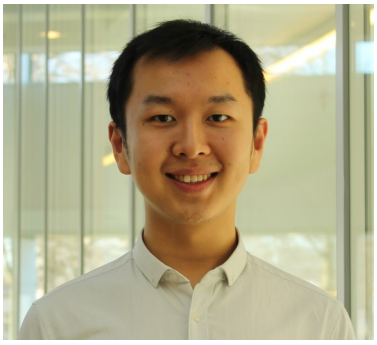

Heat stability evaluation methods of infant milk formula are developed as the tool for optimization of the recipes and identifying the least sensitive recipe by following the protein denaturation caused during heating. NanoDSF (Nano Differential Scanning Fluorimetry) is a novel technology which uses fluorescence as signals to measure the protein unfolding during heating which is the key reason for fouling. This study evaluated the potential of NanoDSF as a novel approach for heat stability. The single ingredients and full recipe of infant milk formula were analyzed and compared with reference method. Heat stability parameters from NanoDSF technology were identified and verified in this study.

Confidential topic

Effect of Unit Operations on Food Particles – Evaluated by image analysis and correlated with mechanical tests

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Introduction

The global economy is increasingly competitive. Consumers generally pay attention to the safety and conformity aspects of the food products that they buy and consume, but their potential expectations with respect to quality involves different factors. As a food packaging solutions provider, Tetra Pak aims to provide their expertise and knowledge about processing of food products with particles that could maintain the best possible product quality. The knowledge about particle and processing relationship is then vital.

Research objectives

The objectives of the study are:

- To set up parameters for mechanical tests method to measure particle strength that can be used to predict the extent of change in size and shape due to the agitation, passing through wing rotor pump and restriction pipe
- To measure the change in particle size and shape by image analysis method
- To test whether the obtained measured values from mechanical tests and image analysis methods are correlated
- To compare the developed image analysis method with the existing sieving analysis

This study is more into exploring the relationship between particle strength and change in particle morphology due to processing such as agitation, passing through wing rotor pump and restriction pipe.

Methodology

In this study, the predominant external force considered is axial stress, or vertical stress. There are 4 phases in deformation: elastic phase, bio-yield point, ultimate strength and rupture. Some of the indicators of particle strength are the texture profile parameters and bio-yield stress. Texture profile parameters are maximum stress, modulus, cohesiveness, and chewiness.

These were measured by double compression test, while bio-yield stress was determined using single compression and puncture test, in two probes, 2 mm and 5 mm. These mechanical tests were done using texturometer.

Thirteen samples of fruits and vegetable particles were analyzed for the mechanical properties, and three representative samples, thawed diced carrots, thawed chopped mangoes and canned diced potatoes were subjected to three processing operations. With the set parameters, these are agitation, pumping and passing through restriction rig. Sample particles were collected, and morphological properties (size and shape) were analyzed. Size was indicated by circular equivalent (CE) diameter, while shape was indicated by circularity, elongation and convexity parameters. These are measured using two apparatus: Digi-Eye for image capturing and Morphologi 4-ID for image analysis.

Results and discussion

The study concludes the following:

1. Particle strength can be measured in three different ways. In this study, this property was measured using double compression at the elastic limit and compression and puncture up to the bio-yield point; however, the results have different trend. These results were sought to be correlated to the results of the morphological analysis.
2. Even the pilot scale experiment conditions were intended to be harsher than in the real food processing conditions, the mango and carrot particles did not break significantly based on image analysis. Correlation of the results of mechanical test and image analysis cannot be done because not all the particles tested (2 out of 3) did not significantly break.

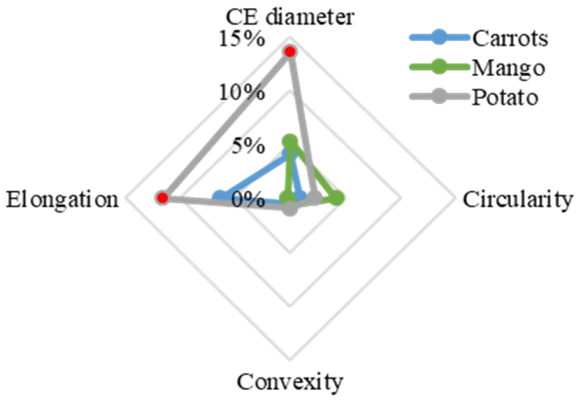

Figure 1. Change in size and shape of different test particles due to agitation, passing through pump and restriction pipe.

3. No conclusion can be derived on the comparison of the three particles tested. Based on the availability of the raw material, thawed mangoes were treated with the different test conditions from the other particles.

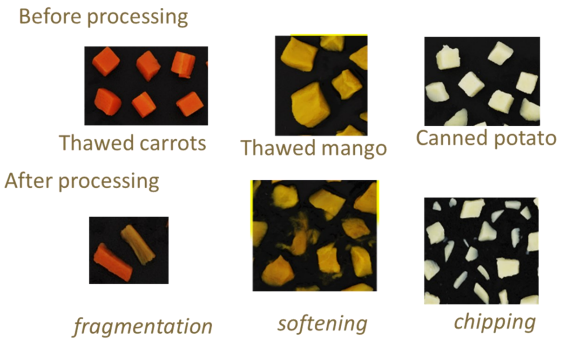

Figure 2. Different mechanisms of breakage of the test particles.

4.For more rapid measurement of particle breakage, the existing sieving analysis is still recommended. However, this method is limited to mass and volume-based particle size distribution. For cases that good quality images of particles are desired, image analysis

is suggested to be done. Aside from particle size distribution, shape parameters can be obtained that are helpful on understanding mechanism of breakage.

The following are recommendations based on the results and findings of the study:

1. The use of apparatus for mechanical tests that could measure smaller forces is recommended.
2. Apply the same study using other types of particles in order to have more points in the correlation.
3. Other forms of particle breakage like shearing and measurement of stress from fluid can also be examined for correlation studies.
4. For modelling studies, food sample model (e.g. standardized cubic gel particles) could be used in the test instead of using real food sample in order to avoid variation within the sample.
5. In order to investigate the effect of restriction rig, the possible future work that could be done are to provide harsher treatment such as using smaller restriction rig, to increase the fluid flow rate.
6. Perform the same study and focusing on other unit operations. If possible, one-unit operation at a time is recommended to avoid interference of the effects of other operation to the particles.

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The impact of minerals on yogurt structure and organoleptic properties

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Yogurt is a very popular acid induced milk gel due to its nutritional and sensory properties. In yogurt, although the mineral fraction is small (0.5-0.8%), it appears to be quite complex, dynamic and in strong interaction with the protein fraction and/or other fractions. Therefore, the mineral fraction can have a sinigificant impact on the structure and organoleptic properties of yogurt. Understanding in depth its effect could be very favorable for dairy industries due to the constant need of improvement of final yogurt properties such as viscosity and firmness.

In the current study, the impact of minerals on the structure and organoleptic properties of a specific stirred yoghurt model were investigated. Soluble mineral content and insoluble mineral content were reduced and specific components were compensated to the same level of the control. All the modifications in mineral and/or other component content were related to final characteritics of yogurt: viscosity, firmness, water binding capacity, pH, acidity and sensory characteristics.

Confidential topic

Effect of flavoring and coloring agents on stability of a nutritionally dense product

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The study focused on the oral nutritional supplement Compact Energy Chocolate, developed by Nutricia. This variant from the range Compact Energy is more viscous than all the others and this feature has been attributed to its flavoring and coloring agents. Therefore, the aim of this study was to determine which is/are the component(s) having a negative impact on the viscosity and heat-stability of the product and how this impact could be easily balanced.

The flavoring and coloring agents were individually studied. Analysis of the particle size distribution and viscosity of the samples demonstrated that the problematical components were the cocoa powder and the dye, caramel powder. The effect of the former has been attributed to the particles it adds to the product, whereas the effect of the latter has been related to its low pH.

On another note, the effect of citrate addition was investigated and no significant effect on the heat-stability was observed over 2-month shelf life.

In conclusion, this thesis has provided new insights in the impact of cocoa and caramel powders, used as flavoring and coloring agents in the product Compact Energy Chocolate. The practical relevance for Nutricia was described, demonstrating that it is possible to decrease the product viscosity through a pH adjustment. Finally, it has been shown that a chocolate variant can be added to the seven flavors in the Compact Energy Rejuvenated range.

Confidential topic

Understanding product build up at packaging material surface to address food waste

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Introduction

One of the reasons for wasted yoghurt at consumer level is due to difficulty in getting all the yoghurt out from the packaging material (William et al, 2012). Around 10% of fermented milk product stick on the inner surface of the packaging material (Hansson, Andersson & Skepö, 2012). Product build up is residual amount of product layer (yoghurt) on the packaging material surface. It is attributed to the adhesion of the product to the packaging material. In emulsions such as yoghurt, fat, protein and hydrocolloid stabilizers are thought to adsorb to the packaging material surface. Rheological properties are also considered to have some impact on the sticking phenomenon (Hansson et al., 2012). It is often difficult to establish the effect of a single ingredient and property independently because yoghurt is presented as a complex system. Further the rheological property of yoghurt is dynamic and changes with time and shear history of the product.

Research objectives

This thesis focuses to address food waste by getting an understanding of macroscopic product build-up on the inside of the packaging material.

Therefore, the objectives of the thesis are to:

1) Develop a tool box to address the link between the physicochemical product analysis could be used to predict product build up.
2) Understand the microstructure of yoghurt and how it affects the phenomenon of product build up.
3) Understand the microstructure of yoghurt and how it affects the phenomenon of product build up.

Hypothesis

The intrinsic property of yoghurt affects the quantity and morphology of product build up on packaging material. This hypothesis covers the following points:

1) The product build up can be quantified by gravimetric method.
2) Yield stress and other texture parameters could be used to predict the product build up.
3) Distribution of fat and protein could influence the product build up on the polymer surface.

This hypothesis is tested by comparing influences of intrinsic properties on build up in different yoghurts (low and high fat natural yoghurt, low and high fat vanilla yoghurt).

Materials

Four different stirred yoghurt types were used in this study. The yoghurts were purchased from supermarkets in Lund and Malmö in Sweden and then kept in cold storage room at 5˚C prior to the experiment. The yoghurt types used were vanilla yoghurt (0.5% and 2.5% fat content) and natural yoghurt (0.5% and 3% fat content).

Packaging material samples and thin polyethylene films were provided by Tetra Pak Packaging Solutions AB. Packaging material used in this study was Tetra Brik Aseptic. The other materials used were Rhodamine B ([9-(2-carboxyphenyl)-6-diethylamino-3-xanthenylidene]-diethylammonium chloride) as fluorescent probe and were prepared by dilution with Acetone. The dye solutions were kept at 4℃ in the bottle glass wrapped with aluminum foil.

Methods

Quantification of product build up by Gravimetric Dip Test method

The thickness of product build-up on the inside of packaging material surface was evaluated by gravimetric force measurement using Instron Tensile Tester (Instron 5565) with 100N load, which was calibrated to 2N. The force exerted by the remaining weight of yoghurt is measured as function of hanging time after packaging material was pulled out from yoghurt container. The force then calculated into weight per area to quantify product build up. Total of six packaging material samples were used in this study. The prepared packaging material with the food contact surface exposed on both sides was incubated for 10 minutes in the sample before being pulled up and left hanging for 5 minutes to record the weight. In addition, the thickness of product build-up on packaging material was also measured using Laser Scanner (Scan control 2950-100 by Micro-epsilon).

Yield stress measurement by Linear Shear Stress Ramp test

Linear shear stress ramp method was used to measure yield stress on a controlled stress rheometer by applying increasing stress into yoghurt samples from 1 to 10 Pa for 20 minutes at 23˚C with sampling interval 20 (Sun and Gunasekaran, 2009; TA Instruments, n.d; Malvern Instruments, 2015). The yield stress was measured using Rheometer (Malvern Kinexus Rheometer) with a bob geometry (C25 SC0053SS, diameter = 250mm) and a conical cylinder (PC250086AL, diameter = 250mm). Yoghurt samples were kept in a refrigerator for 1h then shaken 2 times at an angle of 90° and stirred once prior to pouring in the conical cylinder. Yield stress was measured using tangent method (Malvern Instruments, 2015). The measurement was carried out in triplicate and the data were presented in averaged value.

Texture Profile Analysis

The cohesiveness and firmness of yoghurt samples were measured in Texture Analyzer TA-XT2i (Stable Micro Systems, UK) using cylinder probe (d = 35mm) with back extrusion method. The test was carried out at 1 mm/s speed for pre-testing, during testing and post-testing (Joon & et al, 2017). The probe was held for 10 s inside the container (d = 57mm) containing 50g of yoghurt and immersed at distance of 10mm. All the measurements were carried out in triplicate and the data were presented in averaged value.

Fluorescence microscope

Yoghurt samples were diluted with whey to the ratio 1:10. Rhodamine B (excitation and emission wavelengths of 543 and 625 nm, respectively) was used to stain the yoghurt samples. Delaminated polyethylene film was folded with the food contact side exposed on the outside and mounted on the glass slide. A piece of folded polyethylene film was mounted on the glass slide with cover glass and few drops of specimen were added through the space between cover glass and slide. Then, the prepared glass slide was observed under TRITC filter. The microscope analysis was performed using Nikon Eclipse Ti-U with x 20 magnification objective with suitable filters and dilution to obtain a clear image.

Susceptibility to Syneresis

The drainage method whereby 200 g of yoghurt was placed on a funnel containing an ordinary coffee filter paper was kept undisturbed for 2hr at 5°C in a refrigerator (method adapted from Hassan et al, 1996). The amount of whey expelled was weighed at the end of 2 hours.

Results and Discussion

Quantification of product build up

Both high fat yoghurts (vanilla 2.5% and natural 3%) had significant greater build-up than the low fat yoghurts (vanilla 0.5% and natural 0.5%) ($P < 0.05$) as per a T-test. During the gravimetric dip test, it was observed that formation of canal occurred on the film of build-up on the packaging material. The canal formation could be correlated to syneresis. The susceptibility to syneresis (STS) in natural yoghurts are higher and these are more prone to canal formation as observed in picture compared in vanilla yoghurt.

Thickness of product build up measured by Laser Scanner

The thickness of product build-up was 1-1.5mm for vanilla 0.5%, vanilla 2.5%, and natural 3%. Meanwhile, natural 0.5% had the lowest thickness value, which was less than 1mm. It was observed that the thickness of product build-up decreased over 5 minutes in all yoghurt types. The results were comparable to the thickness obtained from gravimetric dip test and rheometer. However, the method is limited because the method cannot be performed on the same sample to quantify build up in gravimetric dip test because of test conditions.

Yield stress measurements

The yield stress values obtained from the rotational rheometer showed a clear difference in the yield stress between the vanilla and natural yoghurt. Presence of stabilizer in the vanilla sample might be a contributing factor. However, small differences are observed between the yoghurt with high and low fat content both for the vanilla and natural yoghurts. Yield stress values obtained for texture analysis were four times higher than the values from rheometer. Because of limitation due to geometrical factors the results from texture analysis would not be considered for this work.

Texture Analysis

The result obtained from texture analysis showed that the firmness and cohesiveness values of different types of yoghurt does not seem very different from each other. This might possibly be due to processing parameters to keep the eating quality of the yoghurt similar irrespective of fat content.

Comparison of experimental and theoretical build up

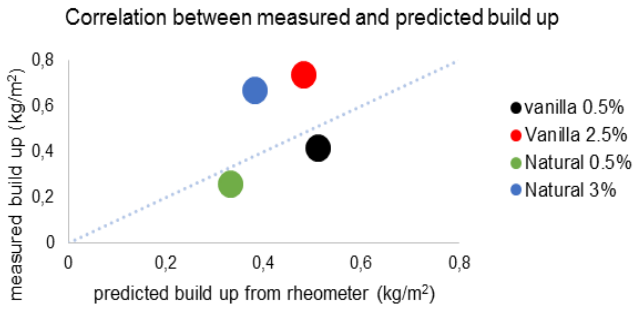

Figure 1: Comparison between measured and predicted product build up in kg/m²

The measurement from the gravimetric dip test and the rheometric test shows the same order of magnitude and agrees reasonably. The predicted build up value from yield stress in the low fat yoghurt are closer to the measured value of build up. Hence, yield stress does not fully explains the build up in the high fat yoghurt suggesting that there is an additional factor responsible for the product build up in the high fat systems.

Characterization of Fat and Protein Distribution in Yoghurt using Fluorescence Microscope

Visualization of fat and protein component separately was not achieved by the fluorescence microscope. This is attributed to the smaller size of the fat globule in comparison to the aggregated protein network and also because in the emulsion fat globule is entrapped within the protein network (Skytte et al, 2015). However, aggregated floc of protein network along the packaging material was seen and also presence of swollen starch globules were detected in the vanilla yoghurt. The thickness of build-up was approximated to be < 0.3mm which gives reasonable agreement with the thickness value from gravimetric and rheometric measurement considering the fact that the samples in the fluorescence microscope were diluted.

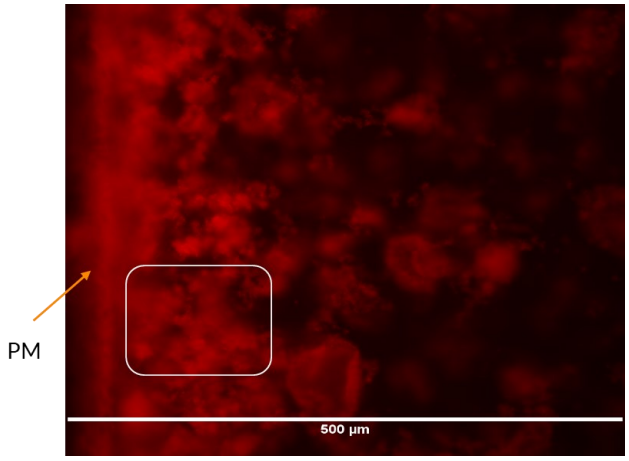

Figure 2: Representative of yoghurt microstructure obtained from Fluorescence Microscope. Encircled in white is aggregated protein flocs, in yellow starch globules.

Conclusion and Future recommendations

Gravimetric dip test and laser measurement were the two methods used quantify experimental build up. The gravimetric dip test gave reproducible results making it a viable method while further improvements needs to be done on the laser measurement such as measurement on more than one position and better data handling process to obtain robust results. Fat content of the yoghurt does seem to have significant influence on the build up. The prediction model using yield stress value fully explains build up in low fat yoghurt while it only gives a partial explanation for the high fat yoghurt. Clear distinction between fat and protein component was not seen in the fluorescence microscope. It

was observed that there was not much difference in the microscopic images of the different yoghurt. More work on yoghurt with obvious difference might give noticeable difference. Nonetheless, it would be interesting to study in the future the build up of other food products in the same category or on other packaging material surfaces using the proposed methods.

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Assessment of Methods Suitable for Characterization of Gastric Clot

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Introduction

According to World Health Organization (WHO), only 36% of infants between 0 - 6 months were exclusively breastfed from 2007 to 2014. Human milk (HM) is the gold standard for infant's healthy development, due to various reasons. However, unavailability of HM or in rare occasions insufficient amounts, requires complementary breast milk substitutes. This led to the development of Infant formula (IF). IF is mostly produced from cow's milk (CM). However, next to other macronutrients CM proteins are different to HM proteins in composition, structure and therefore nutritional efficacy. Despite numerous adaptions done in CM protein content and composition in IFs, formulas still differ from HM. Today, there are numerous initiatives focused in protein innovations to close the gap between HM and IF.

Project Scope

Proteins under gastric conditions form clots. Clot formations are expected to play a big role in determining the rate of gastric emptying (GE). HM forms different clots than IF. This research is focused in assessing methods to characterize the clot formations.

Research objectives

- To establish reliable methods to assess protein clots using in-house methodology
- To characterize novel protein formulation clots' using identified methods

Project Summary

Suitable qualitative and a quantitative methods were identified complementing each other in characterizing gastric clots. Various IF formulations were assessed for gastric clots structure and quantity.

Confidential topic

Effect of Unit Operations on Food Particles – Evaluated by image analysis and correlated with mechanical tests

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***Jan Roland Guerreri MOLINA carried out a join thesis with Nuti* HUTASIGNH.**

Please refer to page 40.

Aroma Encapsulation for Delayed Release by Fluidized-Bed Agglomeration and Coating

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Aroma compounds are highly volatile and sensitive molecules. Encapsulation can provide an effective barrier to avoid aroma volatilization, limit degradation, improve handling and control their release.

Fluidized-bed encapsulation has been widely studied and applied in the pharmaceutical industry as the preferred process for delayed release of drugs. Though, the coating material has the major influence on the functional properties of the encapsulate.

The aim of this study was to encapsulate a sprayed-dried aroma for delayed release by a two-step fluidized-bed granulation and coating technique. The experimental approach focused on identifying suitable operating conditions at laboratory and pilot-scale and assessing different binder and coating materials by their tensile strength, elongation at break, elastic modulus and water solubility.

Confidential Topic

Development of drum dried fruit ingredients by joint optimization of recipes and operating parameters

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Clean label foods are an increasing trend since the 2000s and the concept is related to the replacement of additives used in food formulation for natural ingredients, with no chemicals or e-numbers. Drying processes use additives to overcome possible technological problems and to increase the quality of the final product.

The main objective of this work is to screen the functionality of different ingredients, mixes of ingredients and process parameters in the drum drying operation to achieve a clean label dried fruit product with similar properties to those currently produced.

The strategy used for this work was to test different process parameters and group of ingredients in the formulation to understand what are the properties they bring to the final product. Tests were performed using Apple Puree as raw material and ingredients that showed the best results regarding the chosen reference were tested using Strawberry Puree as raw material.

Some of the measured properties in the premixes (slurry before drying) showed a relation with the process feasibility and to the obtaining a good dried product. Plus, change in steam pressure/temperature and in drum speed also leaded to different final properties.

The findings of this project will be of great value to the development of clean label dried ingredients by the company.

Confidential Topic

Understanding product build up at packaging material surface to address food waste

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Please refer to page 46.

Validation of physico-chemical methods to assess the heat stability of liquid infant milk formula

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Introduction

Infant Milk Formula (IMF) is very sensitive to heat treatment (Cattaneo et al., 2009). Heat treatments are applied to kill pathogenic micro-organisms and extend shelf life (Singh, 2004). When milk is heated at high temperature, it tends to gel or coagulate or increase in viscosity. This causes fouling in the processing line. Hence, effective methods of heat stability for concentrated milk system is needed (Ritota et al., 2017). Protein conformational changes are the major factors that affect the heat stability of IMF which are the result of physical and chemical factors. These factors include internal factors or recipe composition (total dry matter content, whey to casein ratio, lactose, minerals in free ionic form, nativity of raw materials, calcium ion activity, pH) and external factors or process conditions (time-temperature profile, pre-heating conditions, sterilization, flow rate) (On-Nom et al., 2012; Wolz and Kulozik, 2015). Several methods quantify heat stability. Oil bath is the most commonly and widely used method which measures the Heat Coagulation Time (HCT) for concentrated milk products. Other methods include Pressure Cell Rheometer (PCR), Particle Size Distribution (PSD), Microscopy and Ethanol/Alcohol test.

Research objectives

The aim of the study was to compare, evaluate, select and initiate the process of validation for the most suitable method of heat stability measurement for effective product development and profit of the organization.

Methodology

Sample Preparation:

A model recipe containing 1.32% of total protein and about 12% of dry matter was reconstituted in the pilot plant facilities of Danone. In accordance with standard IMF, the casein: whey ratio was set to 40:60. The model system included whey protein concentrates, skim milk, sunflower oil, lactose and water. All the ingredients were first weighed, reconstituted and homogenized using the Pony homogenizer from GEA Niro Soavi. The pH was set using 2mol/l HCl and 2mol/l NaoH. Optionally calcium chloride was added to modify calcium ion activity.

Methods Applied:

Oil Bath:

Oil bath Thermal M (Julabo) was used to measure HCT using a standard protocol at a temperature of 140˚C. DURAN® culture tube (ISO thread, 16 x 150 mm) was filled with 15ml of samples. The samples were submerged in oil bath. Furthermore, foaming and sedimentation were prevented. Directly after placing the tubes in oil bath, the timer was started. Tubes were turned upside down every 30second to assess the coagulation and ensure homogeneity of the sample. HCT was defined as soon as the coagulation was observed. The maximum observation time was limited to 20 mins. The higher the HCT, the more heat stable the recipes were considered.

Pressure Cell Rheometer:

Heat induced coagulation and aggregation of protein is expected to result in an increase of viscosity. An Anton Paar© MCR102 Rheometer was used to measure the change in viscosity using starch pedal geometry at a high temperature profile of 140˚C for 5mins (140˚C matches the UHT conditions) with a shear rate of 1000 1/s.

Particle Size Distribution:

Particle size analysis was performed by light scattering techniques using Malvern Mastersizer 3000 with a large volume automatic wet dispersion unit. First, the recipes were heated for 4 mins and 7 mins in oil-bath at 140˚C and cooled in an ice cold water bath (to stop the aggregation reaction). These recipes were then compared with the d50 values of the particle size of the reference recipe (non-heat treated).

Microscopy:

Transmitted light microscopy (Zeiss Axioskop-2 laser microscope) was used to visualize the protein aggregation. Samples were heated at 4mins and 7mins and compared with the non-heated references. All the samples were diluted in a ratio 1:10 to enhance quality of the images. Images were acquired using the Axio-Vision Imaging System under magnification 100X.

Ethanol test:

Ethanol test was done using ethanol concentrations of 60%, 70%, 80%, and 90%. An equal amount of ethanol solution (5ml each) and milk sample (5ml) was taken in a petri-dish and mixed well. The result was noted after letting it stand at room temperature for 1 min. Visible precipitates was noted as positive test and samples not having any precipitates were confirmed as negative. Recipes which could pass 70% (v/v) ethanol were taken as stable as experimented by Horne and Muir (1990) and mentioned by Chavez et al. (2004).

Statistical Analysis:

Statistical Analysis was performed only for the PCR measurements. For experiments that were replicated 2 times, t-test was performed by using the statistical package in Excel. The viscosity data obtained at different pH values and also at different calcium concentration were analyzed as area under the curves of each experimental condition and values compared for statistical difference by t-test. A significance level of $p < 0.05$ was set in every analysis.

Results and discussions

Oil bath method:

Influence of pH:

Fig.1 shows the HCT results. The data overall indicate good heat stability of IMF. The recipes with pH 6.6, 6.8 and 7.0 have good heat stability as HCT is above 5mins (above 5mins taken as reference to good heat stability) whereas the recipe at low pH 6.4 shows coagulation at t=4 mins (less heat stable) when compared to the other recipes. This result is well aligned with the literature studies which clearly shows that the heat stability increases with increasing pH values (Dumpler 2017; Singh, 2004).

Note: It is to take into account that the calcium addition described in the results in all the experimentations are on the top of calcium that comes from skim milk and whey protein (values not shown in the report).

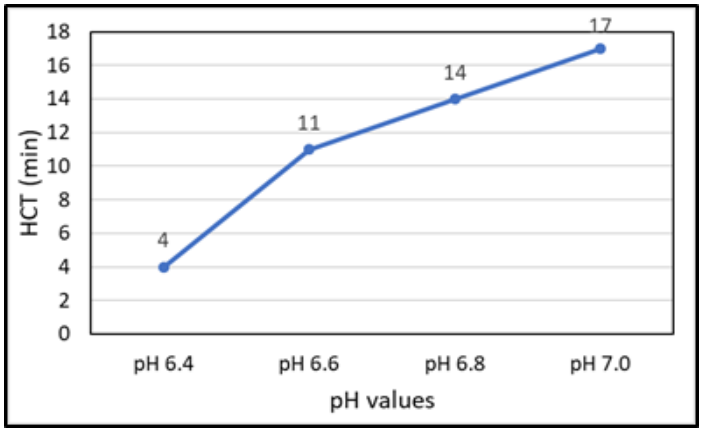

Figure 1: HCT Results: Influence of pH

Influence of calcium chloride addition:

Fig.2 shows clear difference between two recipes. All concentrations of added calcium showed maximum heat stability at pH 7.0 whereas the lowest heat stability was at pH 6.4. From these results, it can concluded that calcium is one of the major factor causing heat instability (Omoarukhe et al., 2010). It was easy to detect heat stable and heat unstable samples using oil-bath method of heat stability measurement.

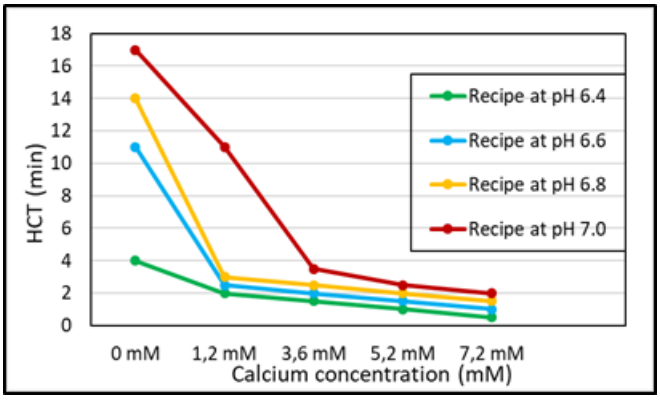

Figure 2: HCT Results: Influence of different calcium concentration at pH 6.4, 6.6, 6.8, 7.0

Pressure Cell Rheometer:

The way to interpret the result using PCR is by comparing the relative viscosity increase from the lowest viscosity point until the viscosity plateau. The higher the difference, the less stable the recipe is.

Influence of pH:

Fig.3 shows no clear differentiation between different recipes in contrast to expectations. No relative viscosity increase from the lowest viscosity point until the viscosity plateau is observed and hence all the recipes seem to be heat stable according to the result obtained.

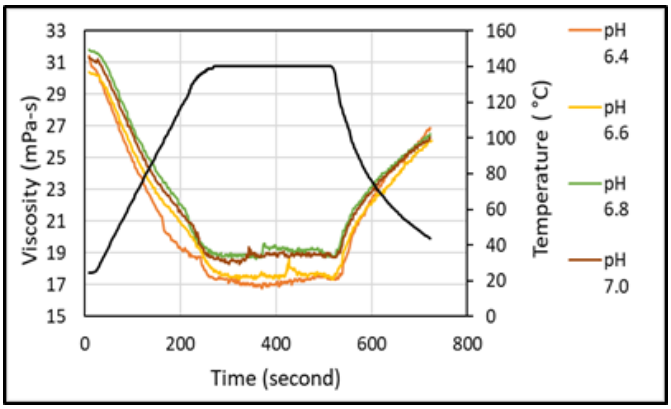

Figure 3: Viscosity profile at different pH values

When this result is compared with oil bath method, it can be seen that recipe at pH 6.4 is heat unstable and recipe at pH 7.0 is very heat stable. Except for the recipe at pH 6.4, all the recipes show very high heat stability which is true with the results of the PCR as

same time and temperature profile was used for both methods.

The analysis of variance revealed no significant differences between the viscosity values observed with different samples maintained at different pH ($F(3,4) = 1.07$, $p = 0.457$)).

Influence of calcium chloride addition:

Fig.4 shows that, the recipe with no added calcium seems to be the unstable recipe as the relative viscosity increase from the lowest viscosity point until the viscosity plateau is clearly observed. All other recipes also show a very small change in the viscosity values before or after entering the temperature zone of 140˚C. These results are not as expected. The change in the viscosity value is so small that, except for the recipe with 0mM calcium, all the other recipes look stable which is not in agreement with the results from the oil bath method.

A possible explanation can be the sensitivity of

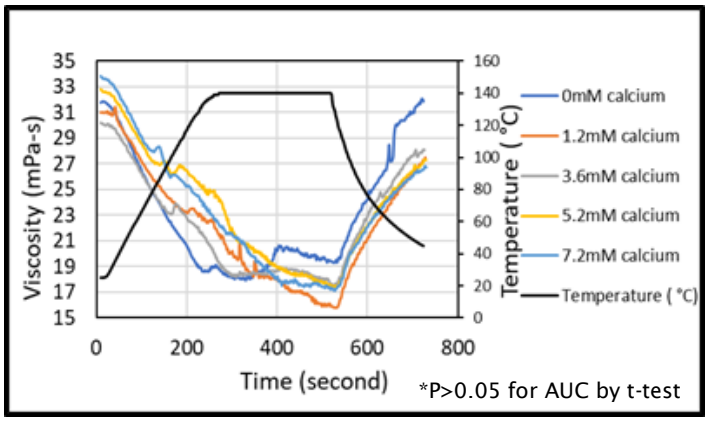

Figure 4: Viscosity profile under the influence of different calcium concentration at pH 6.4

the device which is not sufficient to measure the difference between different recipes.

The analysis of variance revealed no significant differences between the viscosity values observed with different samples with different calcium concentration maintained at pH 6.4 ($F(4,5) = 1.72$, $p = 0.281$)).

From all the measurements performed using PCR, it can be concluded that, it does not seem possible to measure heat stability of liquid IMF. Therefore, no further experiments were carried out using this methodology.

Particle Size Distribution:

Influence of pH :

Particle size done at 0min, 4mins and 7mins of the heated samples showed interesting results. The particle size was continuously decreasing over heat treatment instead of increasing (results not shown). Even the particle size at 4mins was comparatively higher to the one at 7mins. These experiments contradict with literature studies, which confirms that the casein micelle size was significantly affected by the change in pH conditions during heating. According to literature, when pH was low, the size of casein micelle increased in the beginning steps of heating and it plateaued on an extended period of heating (Anema and Li, 2003). The possible reason behind the results obtained here could be casein micelle dissociation phenomena (Dumpler, 2017). It can be assumed that probably the size of the casein molecules in the recipes were bigger which is breaking down to smaller particles on heat treatment and thus, lower particle size with higher heat treatment.

Influence of calcium chloride addition:

All the recipes with $CaCl_2$ addition coagulated at early stages of heating because of which particle size measurements were not possible. From PSD measurements done, it can be concluded that, this is not a suitable method to be used for comparison of heat stability between two recipes. The result wasn't obtained as expected so this method was not used further.

Microscopy:

The results obtained from the microscopic measurement showed that the particles were dense and more aggregated for all recipes at t=0min whereas when these samples were heated at 4mins and 7mins, the particles were more dispersed instead of aggregating

and thus comply with the results obtained from the particle size measurement (results not shown).

Ethanol test:

Influence of pH:

Ethanol test result showed that the recipes with pH 6.6, pH 6.8 and pH 7.0 were negative to ethanol concentration of 60%, 70%, 80% and 90% meaning the recipes are stable and when taken for further processing might not coagulate. Ethanol test was positive only at the lowest pH 6.4 at 80% and 90%. The results obtained were in agreement with the literature studies which shows that the ethanol test is sensitive to pH (Horne and Parker, 1980). According to scientific studies, the test is negative for high pH values and positive for low pH values (Horne and Muir, 1990; Horne and Parker, 1980).

Influence of calcium chloride addition:

Even at very small concentrations of calcium, the test of samples at pH 6.4 was positive. This result is in agreement with literature studies which prove the strong role of calcium to ethanol stability (Davies and White, 1958; Horne and Parker, 1981 a, b; Horne and Muir, 1990). Similarly, when the different concentrations of calcium were used at pH 6.6, the recipes at all concentrations of calcium showed positive result with the increasing concentration of ethanol solution except for 1.2Mm with 60% ethanol. When there was no added calcium, this recipe showed negative test for 60%, 70% and 80% of ethanol whereas it was positive with 90% ethanol solution.

The result obtained with added calcium at pH 6.8 showed positive result too at all the concentration of ethanol except for the recipe with no added calcium. Moreover, the results were negative for all the concentration of ethanol when no calcium was added and even when only 1.2mM calcium was added for recipe at pH 7.0. Hence, positive results were observed with increasing calcium and increasing ethanol%. It can be thus concluded that, the result obtained using this method can be helpful in roughly deciding the heat stability of the recipes as a quick and easy method with a limitation that this method does not give any information on the kinetics of aggregation.

Conclusion

From the study, it was found that the oil bath and ethanol test methods are the most suitable methods for heat stability measurement especially for the recipes with low total solid content. The results were quite clear and the differentiation between two recipes was vivid.

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Development of innovative plant based dairy alternatives

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Master Thesis hosting lab:

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Master Thesis tutor:

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Project Synopsis

The plant based dairy alternative market is expected to rise to $7.4 billion by 2027 with a CAGR of 4.9% from 2017– 2027. This is attributed to growing flexitarian and reducitarian consumer preferences of vegan, vegetarian, dairy free and low sugar/fat claims (‘Vegan Yoghurt Markets’, n.d.).

There exists a ’blue ocean’ for a simply better non-dairy offering due to dissatisfaction with the bad after taste, vegetal off flavors and watery/ lumpy/ non homogeneous texture of current market products. *Great taste* and *indulgent texture* were the two key drivers identified for this mainstream affordable concept, nutritionally on par with its dairy substitute.

This scientific study evaluated and optimized the use of different ingredient sources and their concentration as well as processing conditions to develop the next generation plant based dairy alternative.

References

Vegan Yogurt Market to Be Worth $7.4 Billion by 2027. (n.d.). Retrieved June 25, 2019, from https://vegnews.com/2018/4/vegan-yogurt-market-to-be-worth-74-billion-by-2027

Confidential topic

Applicability of bio-based polymer packaging in the meal kit context

A case study with HelloFresh

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Profile in a nutshell:

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Introduction

Plastic – a ubiquitously utilized material of modern lifestyle. It offers the perfect combination of unequalled functional properties, low cost and broad applicability. Yet, the environmental impacts of plastic production and waste are slowly becoming too big to repair. As an alternative, bio-based plastics are increasingly penetrating the market, promising reduction of resource depletion by decoupling the production from fossil feedstocks (European Bioplastics e.V., 2019; Guidotti et al., 2017) . Besides, compostability is a catching asset, leaving consumers to believe that a material will simply biodegrade in nature.

Research objectives

Up until now, the applicability of bio-plastics has rarely touched upon the field of food packaging, due to limited barrier and mechanical properties (Vilarinho et al., 2018) . The meal kit industry follows a just-in-time (JIT) procurement strategy and might therefore offer a more beneficial context for bio-based packaging.

The aim of this thesis was to study

- *The extent to which bio-**based packaging films** are applicable for food packaging in the **meal kit industry context***

and

- *In how far the application of bio-based materials contributes to a more **sustainable packaging approach***

The study was conducted in cooperation with ***HelloFresh*** as an exemplary large-scale meal kit provider. The applicability was investigated for 3 product categories: Bakery products (BAK), fresh herbs (HERB) and ground spices (SPI).

Methodology

The study was conducted as a case study, split into three analysis parts.

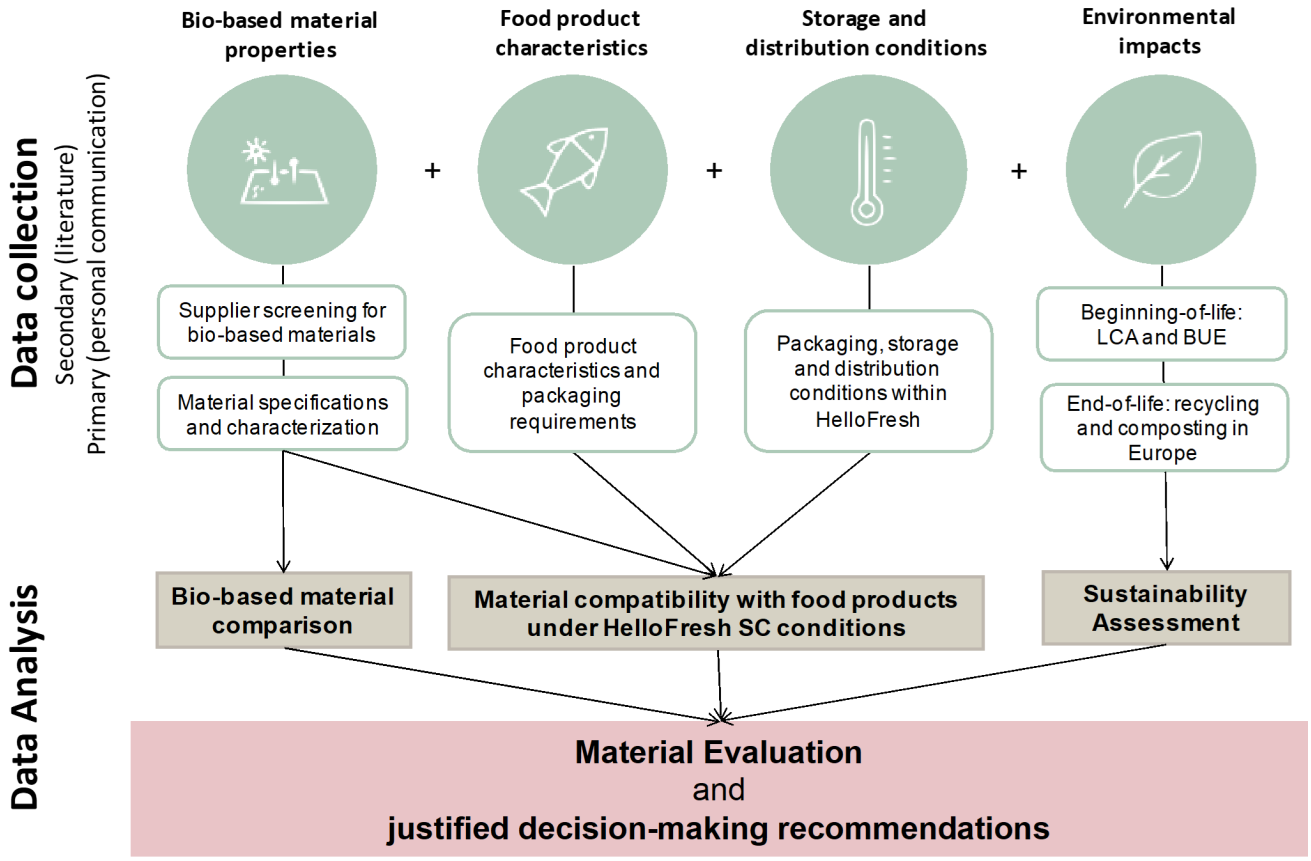


Figure 1. Schematic study approach

A selection of 6 material types (starch-based, cellulose based, polylactic acid (PLA), polyhydroxy alkanoates (PHA), bio-based polyethylene (BioPE) and bio-based polybutylene succinate (BioPBS) were compared in terms of bio-based content, level of compostability, recyclability, industrial availability and transparency. Barrier properties (oxygen transmission rate (OTR) and water vapor transmission rate (WVTR)) were compared to conventional plastics. Furthermore, the shelf-life determining factors of the food products were identified, as well as the product specific storage and distribution conditions within HelloFresh. Based on that, packaging requirements were determined. The requirements were then aligned with the bio-based material barrier properties to identify potential material candidates. Moreover, the *Norner* barrier calculator tool was used to simulate the shelf life performance of the product-packaging systems, taking the supply chain conditions and packaging sizes into consideration. Currently applied packaging materials at HelloFresh were used as reference materials for this simulation. The environmental assessment was split into two parts: the beginning-of-life (BoL) phase and the end-of-life (EoL) phase. The BoL was evaluated by means of the global warming potential (GWP) and cumulative energy demand (CED) as well as the biomass utilization efficiency (BUE). In terms of EoL assessment, post-consumer plastic packaging waste recycling was compared to the likelihood effec-

tive compostability by evaluating insights about composting plant operations in Germany, France, the Netherlands and the UK.

Eventually, overall material preference recommendations were determined.

Results and discussions

The study proved that most currently available bio-based films exert overall weaker barrier properties compared to conventional plastics. Following the product characterization, BAK and HERB products theoretically benefit from weaker barrier properties offered by bio-based materials, especially lower water vapor barriers, providing naturally occurring anti-mist properties. SPI on the other hand require both high gas and water vapor barriers.

Nevertheless, the study revealed limited applicability of bio-based films at current shelf life conditions at HelloFresh. Logistical challenges and procurement strategies do not allow just-in-time delivery for all product categories, thus the required shelf lives for the considered products were found to be 30 days for BAK, 8-10 days for HERB and 12-18 months for SPI.

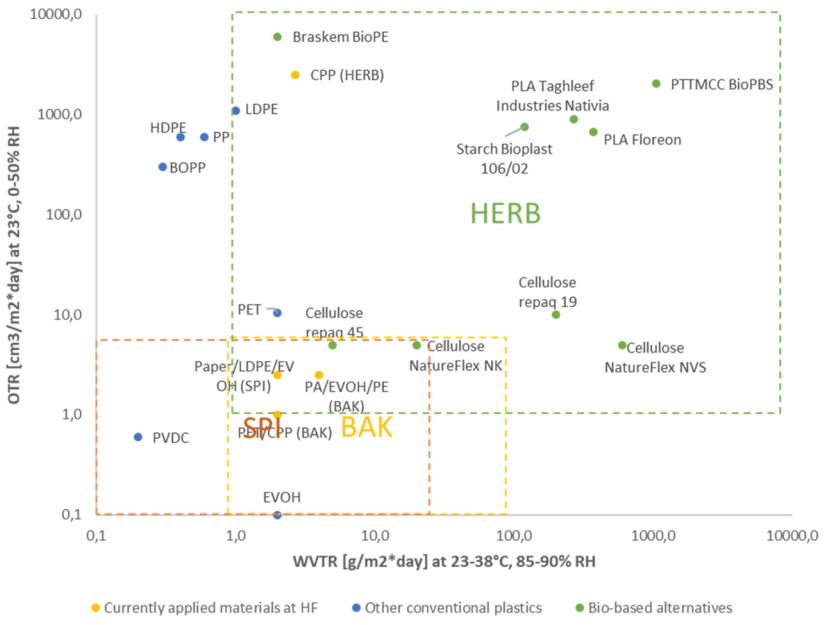


Figure 2. Results of Material-Product compatibility. (OTR = Oxygen transmission rate, WVTR= water vapor transmission rate)

To avoid the risk of food waste, it is of high priority to provide adequate product protection in order to reach the required shelf life. Therefore, the following material candidates were identified: HERB category is predicted to be compatible with all considered materials, except BioPBS and PHA, while the compatibility for BAK and SPI is limited to two identified high-barrier cellulose-based films. Additionally, BioPE is expected to be applicable for BAK, provided that BAK products are stored at frozen conditions for the majority of the supply chain duration. Practical shelf life tests need to be conducted to verify the predictions.

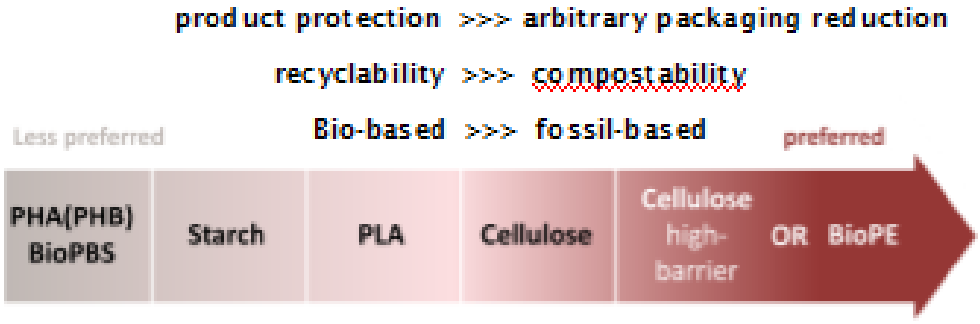
With regards to the environmental assessment, the BoL analysis has shown that most bio-based polymers outperform fossil-based counterparts in terms of GWP and CED. Starch-based and cellulose-based polymers proved to be most efficient in terms of biomass utilization amongst their bio-based competitors.

However, the outlooks for EoL options for bio-based materials, are rather disillusioning. Most bio-based packaging materials are intended to be disposed in industrial or home composting facilities, except for BioPE which is considered as a drop-in material that can be recycled in existing recycling streams. Yet, the study proved that compostable plastics, despite carrying the compostability certifications, are rarely compatible with composting facilities in Germany, the Netherlands, France and the UK at current stage. Effective composting is hence an unlikely scenario, resulting in the materials being sent to landfill or incineration. Similarly, recycling is not an option, since compostable materials require designated recycling streams, which have not been

implemented in Europe's waste infrastructure yet.

Considering the small likelihood of compostability, recyclability in existing recycling streams turns out to be a preferred material feature. Yet, the probability of effective recycling is reduced once considering a packaging *film* which is likely to be *contaminated with food residues*. The choice of material and hence the choice of EoL is thus dependent on the product to be packaged. BioPE is preferred as a recyclable option. However, if excessive food contamination residues avert recycling, cellulose-based films are recommended as a compostable alternative.

Conclusion



Future Research Recommendations

Investigations on bio-based material applicability for further food products is recommended, especially for products with low chances of recyclability, such as meat and dairy.

Further, opportunities for recyclable and/or recycled materials should be investigated. Concerning the meal kit industry, it is also recommended to explore potential optimization of the secondary packaging, e.g. improving volume and weight efficiency or the potential of implementing a packaging return system.

No "one-fits-all" sustainable solution

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Function is priority

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Study on the effect of whey protein aggregates in a dairy system

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Whey Protein isolate (WP) is mainly composed of β-lactoglobulin and α-lactalbumin and is a highly valued by-product of cheese production since it is capable to confer functional properties, such as emulsifying and foaming properties as well as texturing properties. Under certain conditions of pH, temperature, mineral and protein content, WP forms aggregates in aqueous solution with different sizes and shapes, such as fibrils, microgels, and fractals.

In view of the relevance of whey protein aggregates (WPA) for food applications, the objective of this work was to study the effect of replacing different fractions of micellar casein (MC) by WPA on gelation in the presence of chelating salts in order to describe the importance of the two protein components on the gel stiffness and the microstructure.

The insights of this study aided to better understand the interactions between MC and WP and showed the potential of WPA as texturizers in a food matrix.

Confidential topic

Study of the Impact of Formulation on the Fermentation of a Naturally Sparkling Beverage

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Mr. François COLOMBAN

Recent literature has reported the importance of fermentation on the bioavailability of nutraceuticals present in traditional herbal medicine. Therefore, there is an opportunity to develop functional fermented foods and beverages from this kind of plant-based ingredients. Additionally, the fermentation process itself is generally recognized as healthy, and it also creates interesting and desirable organoleptic properties. The aim of this work is to study the effects of herbal extracts on the fermentation dynamics and the above-mentioned desirable properties.

The study of parameters such as the temperature of fermentation, concentration in sugar, the type of sugar and yeast extract content has allowed the better understanding of the fermentation dynamics of sweet aqueous solutions, using a standardized mixed culture of yeasts and bacteria. The replacement of these plant extracts realized by decoction of raw materials with industrial standardized powdered extracts was also investigated. The result of each fermentation was characterized by acidification kinetics, yeast and bacteria colony count, sugars consumption and composition, production of organic acid, and production of ethanol.

A principal component analysis allowed to discriminate initial parameters with significant impact on the results of the fermentation: the addition of yeast extract and the temperature of fermentation. The concentration and the type of sugar, as well as the concentration in yeast extract did not have a significant impact on the fermentation's descriptors. On the other hand, the addition of the yeast extract had a positive impact on the velocity of the acidification, the yeast development, and therefore increased the sugar

consumption and the final ethanol content. Samples fermented at temperature above the optimal of the strains also showed a faster acidification, potentially due to the modification of the metabolism of the microorganisms.

The herbal extracts did not show detrimental effects on the fermentation, some of them even exhibited boosting properties, due to the nutrients extracted during the decoction. Positive effects were reported on bacterial growth, yeast growth, and the production of their respective fermentation products.

The powdered industrial plant extracts exhibited results that were similar for some medicinal plants but could also be significantly different, in terms of sugar consumption or bacteria/yeast ratio. Shelf life studies also demonstrated a better conservation of the microbial population in the industrial extracts in comparison to the ones obtained by decoction. The impact of extraction methods, the additives content and the suppliers still need be screened in order to select the optimal standardized extracts in the perspective of the product's development and upscaling.

Confidential topic

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