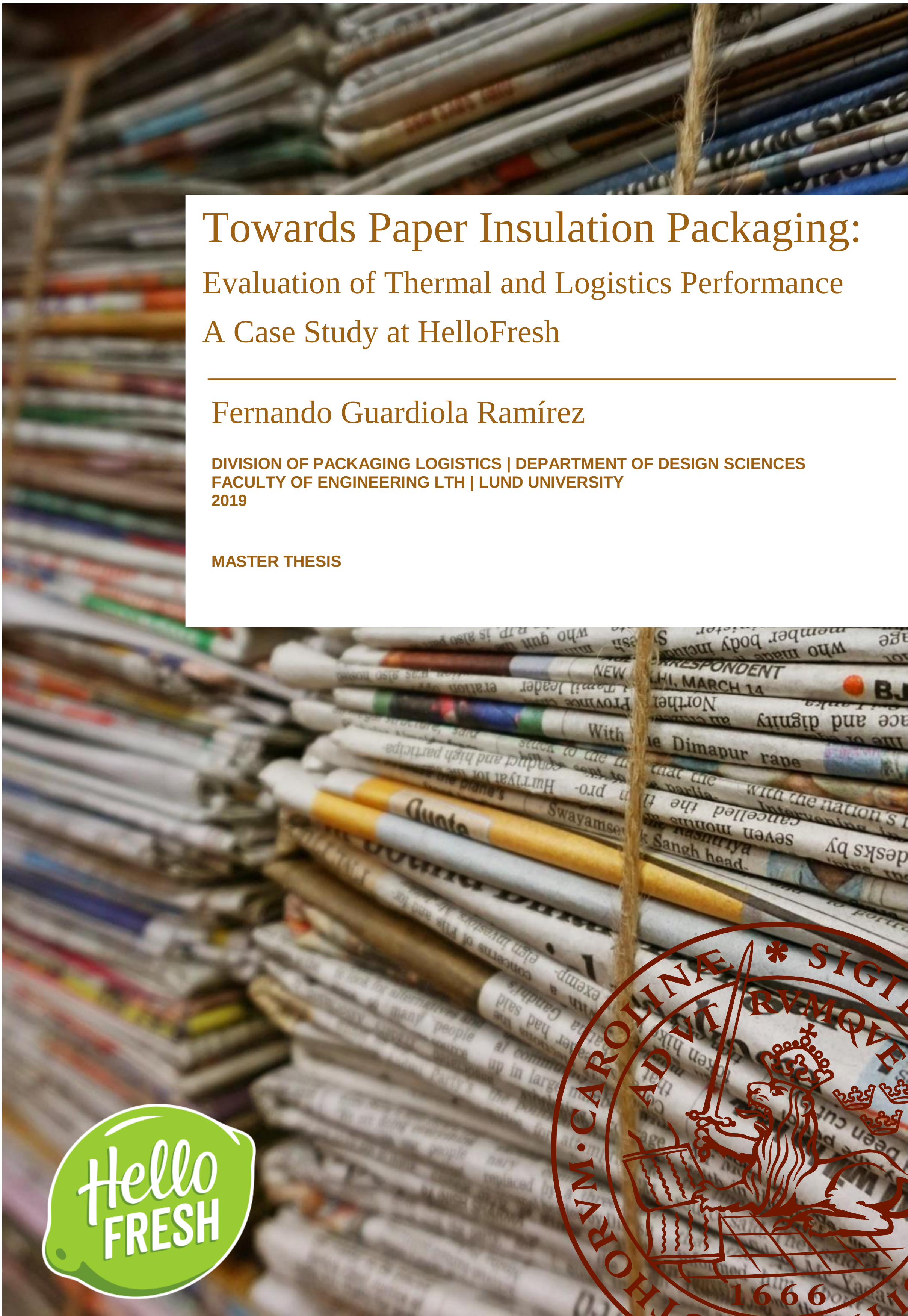

Towards Paper Insulation Packaging:

Evaluation of Thermal and Logistics Performance

A Case Study at HelloFresh

Fernando Guardiola Ramírez

DIVISION OF PACKAGING LOGISTICS | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY

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MASTER THESIS

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Abstract

The most common thermally insulated packaging used today is plastic-based and customer behavior towards plastic materials has changed rapidly in recent years. The Meal Kit Industry has a particular need for insulated packaging/cool pouch (CP) and is looking to shift from plastic materials to more paper-based ones. Unfortunately, paper-based insulated packaging hasn't been completely developed in the market and the options available face challenges such as ensuring sufficient insulation, affordability and product/packaging compatibility. For this work, a paper-based CP (Paper CP) insulated with cellulose insulation fiber (CIF) was developed and is evaluated against the polyethylene terephthalate (PET) and polylactic acid (PLA) CPs used by HelloFresh, the industrial partner. Three methods were used for this evaluation. First an ice melt test was used to evaluate thermal insulation performance. Second, an infrared thermography test was used to identify and analyze features that influence the thermal performance. Third, a packaging performance test was used to evaluate and compare the CPs in the supply chain for three main actors: Pick and pack staff (PnP Staff), HelloFresh packaging decision makers and Customers. Results indicate that the CIF is equally effective as PET and PLA as an insulation material. However, when comparing the whole CP, the PET CP is significantly better than Paper CP and PLA CP. The last two showed the same insulation performance. Thermal conductivity, compressibility, thickness and homogeneous distribution of the insulation material were identified as key features that affect the thermal performance of the Paper CP. Paper CP performed overall "below average" for the PnP Staff of HelloFresh and slightly "above average" for HelloFresh Packaging. The main features that lowered this score were apportionment, production efficiency and material handling.

Keywords: thermal insulation packaging; paper-based; ice melt test; thermography; packaging scorecard; meal kit industry

Executive summary

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.

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.

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. 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.

Acknowledgments

There are events in life that feel particularly special. Your first kiss …your first Nintendo console… your first dog… the last episode of Game of Thrones (I hope, since I've been waiting to finish the thesis to watch it) the moment Harry received his letter of admission to Hogwarts… The last one pretty much describes how I felt when I knew I was going to start FIPDes, a 2-year adventure that has changed my life and with this last section of my thesis it comes to an end. I can´t help but acknowledge all the people that have been meaningful to me during this journey.

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To all my FIPDes "Mastermates" Oh my … this was a crazy mix of people… what a journey… ups … downs … fortunately more ups than downs. Looking back now, I wouldn´t change it for nothing, I treasure your souls as they are and all the memories we´ve created together. You guys have a friend for life.

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To my lovely family, for staying strong and making me who I am.

God, thank you for guiding me and protecting me in this crazy and fun world you've created.

Berlin, May 2019

Fernando Guardiola Ramírez

Table of contents

List of Figures

List of Tables

List of acronyms and abbreviations

CP	Cool pouch
CIF	Cellulose insulation fiber
PET	Polyethylene terephthalate
PLA	Polylactic acid
3PL	Third party logistics
PnP	Pick and pack

XVII

1 Introduction

This chapter introduces the outline of the whole work and also describes the theoretical background behind this study as well as the interest of HelloFresh in this project. Afterwards the overall goal and research questions are stated. Finally, delimitations of the work are stated.

1.1 Report Outline

This report begins with an introduction to the academic and industrial background of the project as well as stating the overall goal and research questions for it. Afterwards, the theoretical framework is showed for the reader to understand the concepts that are mentioned in further chapters. The methodology, results, discussion and conclusion chapters are presented afterwards followed by an appendix for additional information relevant for the study.

1.2 Background

In the early 90´s the internet as we know it today was introduced (Tian & Stewart, 2008), and with it, many services started to integrate such as banking, newspapers and groceries, just to mention some. One of the pioneers in integrating to the internet was Peapod, the first e-grocery delivery service, established in 1989 (Peapod, 2019), since then the e-grocery has evolved into different categories; one of those is the Meal Kit category, pioneered by Linas Matkasse in Sweden in 2008. They deliver pre-portioned groceries with corresponding recipe cards that arrive weekly through the mail (Konrad, 2015). After them, many other Meal Kit and e-grocery businesses have been launched.

When delivering goods, each of them has its own features, which define the needs of their packaging and transportation mechanism. The challenge lies in that some categories of food need to comply to very strict food safety requirements. For example, in Germany, minced meet needs to maintain a temperature of no more than +2°C in its core during production and transportation (Deutsches-TiefkuhlInstitut, 2012). A wrong management of cold chain could potentially lead to food poisoning.

This can occur when the cold chain is disrupted during delivery. Since many Food Box companies and third-party logistic companies (3PL) don´t use refrigerated trucks, they rely on the use of thermally insulated packaging which is used to maintain the chilled ingredients at the refrigerated temperature during delivery (Rodrigue, Comtois, & Slack, 2017).

The most common thermally insulated packaging used today is plastic-based. For example, expanded polystyrene has been widely used as an insulation material since 1937 (EPSA, 2014) and is widely used in the food and pharmaceutical industry to deliver temperature sensitive products (Burgess, 1999). The increasing popularity of the Meal Kit Industry has pushed to the industry to develop new insulated packaging solutions, going from rigid packaging like expanded polystyrene, to flexible packaging (cool pouches) such as bubble wrap and sheep wool. Bredehoft (2016) has done a broad study of the insulation materials used in the Meal Kit Industry and shows that plastic and sheep wool solutions are the most commonly used. Customer behavior towards plastic materials has changed rapidly in recent years. Environmental awareness, social pressure and positive attitude towards banning plastic bags are some of the factors driving this behavioral change. (Arı & Yılmaz, 2017). At least 127 countries have adopted legislation to regulate plastic bags and single use plastic (Excell, 2019), which has pushed Meal Kit companies to consider other insulated packaging materials, being the most popular one paper, since it’s a biodegradable and recyclable material (Thompson, 2017). Unfortunately paper based insulated packaging hasn’t been completely developed in the market and the options available face challenges such as ensuring sufficient thermal insulation, affordability and product/packaging compatibility (HelloFresh H. o., 2019). There is a need to understand and develop paper-based insulation packaging solutions to provide alternatives to the current plastic-based ones.

1.3 Case Study

HelloFresh is the global leader in the Meal Kit Industry. The product they offer is a box containing the necessary ingredients to cook the recipes they offer. In the German market the box is delivered with third party logistics companies (3PL). The box includes ingredients that need to be maintained at < 2°C, therefore a cool pouch (CP) is used to maintain the products at this temperature. Polyethylene terephthalate (PET) is the main insulation material used for the CP today as well as a polylactic acid (PLA) CP, which are shown in Figure 1(a) and (c). HelloFresh is committed to find a more sustainable packaging alternative. Therefore, they are looking for a paper-based (or from an equivalent material) chilled compartment solution, which can be fully recycled with the paper waste at the home of their customers in Germany, Austria, Switzerland and the United Kingdom. HelloFresh has collaborated with Lund University in the course MTTN40 of Packaging Development and Technology in autumn 2018, by challenging a group of students to propose a Paper CP. A prototype was developed (Figure 1b), and cellulose insulation fiber (CIF) was proposed as a potential paper-recyclable insulation material

(a) (b) (c)

Figure 1. (a) PET CP currently used by HelloFresh, (b) Paper CP, (c) PLA CP.

1.4 Goal and Research Questions

The Paper CP has only been developed as a prototype, but it is unknown if it is able to achieve the necessary insulation required by HelloFresh, which leads to establish research question (RQ) 1.

RQ1. How is the thermal insulation performance of the paper CP (Paper CP) compared to HelloFresh's current CP?

Additionally, new packaging development can be a complex task if the characteristics of the product and packaging are not well understood. The CP has particular features that need to be identified and understood in order to ensure its thermal performance and establish quality parameters. This leads to RQ2.

RQ2. Which CP features should be adjusted in order to improve the thermal insulation of the Paper CP and which are the critical limits of these features?

Packaging plays an important role in safeguarding and adding value to its content, but it also plays an important role in the supply chain. When narrowing only in packaging specific features, many details of its role during the supply chain can be missed. Therefore, a holistic approach in evaluating packaging and its interaction with its stakeholders can help understand better the packaging system and identify improvements to be made. This leads to RQ3.

RQ3. How does the Paper CP perform in comparison to HelloFresh's current CP made out of PET and PLA; specifically, for the stakeholders that interact with the CP in the supply chain.

1.5 Delimitations

This work focuses on testing the insulation performance of the Paper CP using CIF and compared them with HelloFresh already implemented PET CP and PLA CP. It does not discuss the use of other insulation materials nor analyses the requirements of phase change materials (ice or gel packs). Although HelloFresh is an international company, the work focuses mainly in HelloFresh Germany. The tests and some interviews are performed in the United Kingdom due to the geographical location of the packaging laboratory of HelloFresh. The logistics of both Germany and the United Kingdom are similar therefore, the results can be applicable to both countries. Acquisition of samples was a challenging task that took a considerable amount of time, therefore the tests performed were made progressively as the insulation materials were acquired. The time available to perform the thermal chamber experiments was limited to 1 week and the infrared camera was only available for 1 day to perform all the necessary experiments, hence repetition of experiments at a different time was not an option.

2 Theoretical Framework

This chapter is used to explain concepts that are if importance to understand the methodologies used and the results of the next chapters. First, the packaging system of this work is explained, followed by an explanation of parameters relevant for evaluation of thermal insulation, afterwards CIF is described thoroughly followed by an overview of waste management of paper with emphasis on CIF. Finally, an explanation of packaging performance methodologies is described.

2.1 Packaging System

Packaging is defined by Hellström & Olsson (2017) as *the science, art and technology of protecting and adding value to products*. It can have numerous functions but in general, seven are highlighted for food packaging: protection, containment, preservation, apportionment, unitization, convenience and communication of the product (Hellström & Olsson, 2017; Livingstone & Sparks, 1994; Paine & of Packaging, 1981; Robertson, 1990). Descriptions of each feature are summarized in Table 1.

A packaging system is composed of three levels of packaging: primary secondary and tertiary. Primary is the one that has direct contact with the product, secondary has a number of primary packaging and tertiary has a number secondary packaging (Pålsson, 2018). However, packaging systems can be more complicated depending on the business model.

HelloFresh manages thousands of ingredients to compose all their recipes, which can make understanding the packaging system very complicated (Legal, 2019). Therefore, it’s necessary to establish: the system boundaries, the product and the packaging levels. Hellström & Olsson (2017) describe common terminology used to define the packaging system and is used as inspiration define the one of this work in the following sections. Figure 2 shows an overview of the packaging system established for this work.

Table 1. Descriptions of packaging functions and its application to the chilled ingredients (Hellström & Olsson, 2017).

Function	Description
Protection	Involves protecting the product from external hazards and vice-versa. For the case of chilled ingredients, thermal insulation to maintain temperature requirements is of high importance.
Containment	The function refers to securely hold the content and protect the surroundings. Chilled ingredients must be kept inside the CP.
Preservation	Refers to maintain the quality of the product by avoiding biological or chemical deterioration. This is ensured by proper maintenance of the temperature inside the CP.
Apportionment	Refers to appropriate size and volume to ensure a manageable use of the product. The CP should ensure that all the chilled ingredients fit inside.
Unitization	Refers to consolidate the product into units. The CP is managed as a unit before its placed in the Box, however, after the chilled ingredients are placed inside, the Box is the unit that is handled.
Convenience	Refers to making the product and the packaging easy and convenient to use. For the case of the CP convenience from the PnP Staff is easy material handling and for customers, easy opening, emptying and disposal.
Communication	The packaging is an information carrier, could be flow information for logistic purposes or product information for identification and selling the product to the customer. Disposal information is of relevance to the customers.

2.1.1.1 The product

Mainly meat and dairy products are the products placed in the CP. The product for this work will be defined as *chilled ingredients*.

2.1.1.2 Primary packaging

The primary packaging is product specific, depending on the ingredient, e.g. a PET container for Crème Fresh or high-density polyethylene (HDPE) vacuum packaging for meat.

2.1.1.3 Group Packaging

The product is then placed into a group packaging that encloses all the chilled ingredients for a particular recipe. The group packaging is usually a HDPE plastic bag closed with a paper label.

2.1.1.4 Returnable Transport Packaging

A reusable and returnable plastic crate is used as transit packaging when moving the GP from the kitting area to the assembly area.

2.1.1.5 Consumer Packaging

The corrugated box is considered the consumer packaging of HelloFresh because it’s the one that the consumer interacts with when it’s delivered. Production in HelloFresh begins when the Box is erected in the assembly line.

2.1.1.6 Cool Pouch

The CP is placed inside the Box right after it is erected, then the GP is placed inside the CP and a paper label is placed to seal it.

2.1.1.7 Tertiary packaging

The rest of the recipes are placed inside the Box, then the pallet is sealed and assembled in a Euro-pallet. Stretch film is used to wrap the pallet.

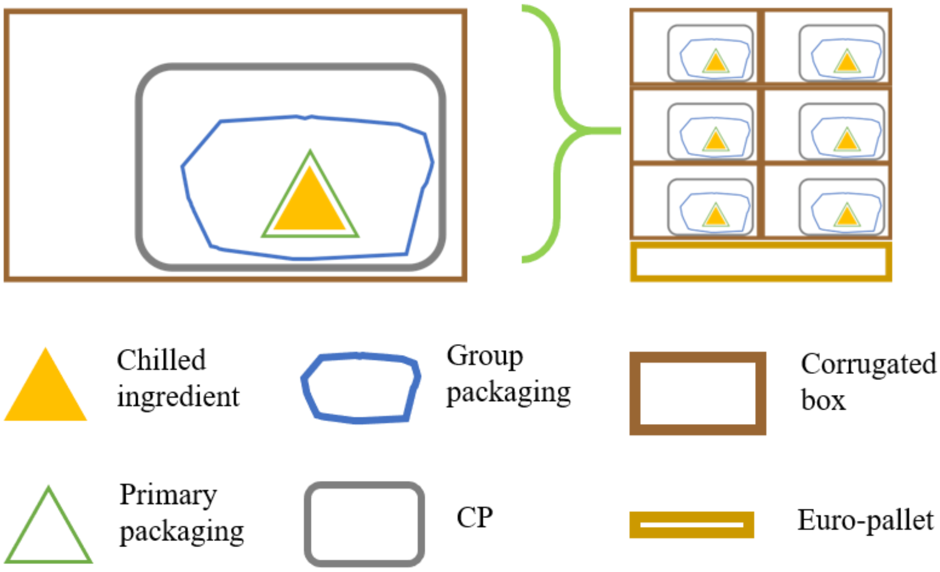

Figure 2. Packaging system established for this work.

2.2 Evaluation parameters

2.2.1 **Thermal parameters**

There are several parameters that are used to evaluate the thermal insulation of a material and is important to define them and understand them to avoid confusion and use the correct parameters that play a role in the insulation performance of the CP. Most of the research regarding thermal insulation comes from the building industry, hence the constant reference to publications of this area. Packaging can be thought as a small-scale representation of a house or a building and the same thermal concepts and principles apply for thermal insulation in the construction industry and in the packaging industry.

The most common property used in insulation materials is the thermal conductivity (λ), expressed in Watt (W) per meter (m) Kelvin (K) ($Wm^{-1}K^{-1}$). The usual goal is to achieve a thermal conductivity as low as possible. Another parameter that is commonly used and gives a more accurate indicator of insulation is the thermal resistance (m^2K/W), which is commonly known as the R-value and is shown in Equation 1. Thermal transmittance is the reciprocal of the R-value and is usually known as U-value (W/m^2K).

Equation 1.

$$\lambda_{tot} = \lambda_{solid} + \lambda_{gas} + \lambda_{rad} + \lambda_{conv} + \lambda_{coupling} + \lambda_{leak}$$

Where λ_{tot} is the overall thermal conductivity, λ_{solid} is the solid state thermal conductivity, λ_{gas} is the gas thermal conductivity, λ_{rad} is the radiation thermal conductivity, λ_{conv} is the convection thermal conductivity, $\lambda_{coupling}$ is the thermal conductivity term that accounts for second order effects between the various thermal conductivities in Equation 1 and is usually neglected due to its low contribution, and λ_{leak} is the leakage thermal conductivity. The last one considers leaks of air and moisture due to pressure differences and is important to consider it when the material is not fully sealed and allows exchange of gases; λ_{solid} is linked to the energy exchange between atoms due to vibrations; λ_{gas} is linked to the energy transfer due to the collision of molecules; λ_{rad} is linked to the emittance of radiation in the infrared wavelengths from the material surface; λ_{conv} comes from the heat transfer of convection mechanism due to the thermal mass transport, e.g. when wind transport air with different temperatures through a medium (Petter Jelle, 2011).

2.2.2 **Compressive Young's modulus**

The compressive Young's modulus is a mechanical property of a material that indicate its stiffness. It indicates how easily a material can be bended or stretched. This parameter is also known as the Modulus of Elasticity and consists on the relationship between a stress and strain. When an incremental stress is applied to a material, a deformation will appear after reaching a certain stress (Stoebe, 2000). This parameter is important in packaging because one of the parameters that affect the insulation of a material is its thickness. If the material is compressed and a significant change in thickness appears, the heat that is transferred can also increase. Compression happens due to the weight of the ingredients that are placed inside the CP.

2.3 CIF

2.3.1 **Cellulose definition**

The most abundant biopolymer on earth is cellulose. It's recognized for being renewable and biodegradable. Molecularly it's a linear polysaccharide (β (1-4) linked to D-glucose units) and is generally found as a structural component of cell walls in plants and algae or as a biofilm secretion of some bacteria species. Van CP Waals and hydrogen bonding between the polymer chains promote parallel stacking and subsequent formation of fibrils, which range in diameter from 5-50 nm (Illera, Mesa, Gomez, & Maury, 2018)

2.3.2 **History of cellulose as thermal insulation**

Thermal insulation has a very wide spectrum of applications. Anything that needs to be protected from losing or gaining heat can use insulation materials. Some of the first applications of insulation materials have been in the building industry.

Cellulose insulation has been used since the beginning of mankind when cavemen used wooden walls to protect themselves from the cold however using cellulose as an insulation material by itself is dated to Thomas Jefferson's time in the 18^{th} century, when he added insulation between walls for his design of Monticello. He used balsa wood or sawdust encapsulated in paper packages. Therefore today, balsa insulation can be found in old historical houses (ECIA, 2019).

In the 1920s in Scandinavia cellulose insulation was commercially prepared from forestry by-products. They were applied as core insulation for half-timbered housing and sometimes also implemented in attics. This material is widely popular nowadays due to its ease of implementation. (Bozsaky, 2010). Also, in 1919 Canada used cellulose fiber for housing insulation (Siddiqui, 1989).

In the 1930s the steel mills industry looked at "rock metal slag", one of their by-products and used it to create rockwool, one of the most popular insulation materials. The same happened with silica, which was used to create fiberglass insulation. The process to manufacture both is similar; rock or silica is melted into liquid state to then fiberize it, consequently creating rockwool and fiberglass. The paper mill industry also payed attention to the by-products of the industry to create value. One of the applications was to use recycled paper as a sound deadener material for the building industry. At the time, the technology was not mature enough to create insulation material out of cellulose, so fiberglass became the most popular option in the 1940s (ECIA, 2019).

The energy crisis of the 1970s led an increase in the demand of house insulation, which reached an all-time high and triggered the interest in using CIF. Although

CIF was only a small share of the market, the manufacturers were committed to refine the material, its processing and manufacturing technology, and applications techniques (ECIA, 2019).

In the 1990s the scientific community of building materials interested in energy efficiency building, which led to scientific studies about the properties of CIF (Zaborniak, 1989).

Table 2 Average component proportions of newsprint and office paper. (Lopez Hurtado, et al. 2016)

Component	Office paper	Newsprint
Cellulose %	67.4	48.3
Hemicellulose %	13	18.1
Lignin %	0.93	22.1
Extractives %	0.7	1.6
Proteins %	0.31	0.44
Ash %	11.6	2

2.3.3 **CIF composition**

CIF is made from ground paper fibers. The consistency of this material is similar to that of wool, this is due to the production process. Usually boric acid (H_3BO_3) and borax ((sodium borates, $Na_2B_4O_7 \cdot 10H_2O$ or $Na_2[B_4O_5(OH)_4] \cdot 8H_2O$) are added in the process to give fire retardant and antifungal properties (Petter Jelle, 2011). The ground paper fibers are usually sourced from unsold or recovered papers. Newsprint (the paper used to make newspaper) is generally manufactured by mechanical pulp, whereas chemical pulp is use for a wider variety of papers, such as “office paper”. Both can be incorporated in the process. Newsprint is composed of a mix of cellulose, hemicellulose and lignin. Table 2 shows the average component proportions of newsprint and office paper. Chemical pulp removes part of the lignin whereas mechanical pulp doesn’t. Mineral and organic additives are added into paper pulp in order to improve properties such as opacity, moisture retention and strength. Some of the additives are for example mineral and organic additives such as kaolins, china clay or cationic starch. The inks used in paper are usually derived from inorganic carbons and the chromatic inks come from organic pigments (Lopez Hurtado, Rouilly, Raynaud, & Vandenbossche, 2016).

2.3.4 **Production process**

Cellulose insulation can be presented in two forms. One is a prefabricated panel, and the second one is loose fibers. Prefabricated panels use a binder made out of polyester or a similar material, whereas the loose fibers are made only from unsold newspaper and are sold in bulk and manually applied on housing. The process of manufacturing loose fibers consists of the following stages shown in Figure 3.

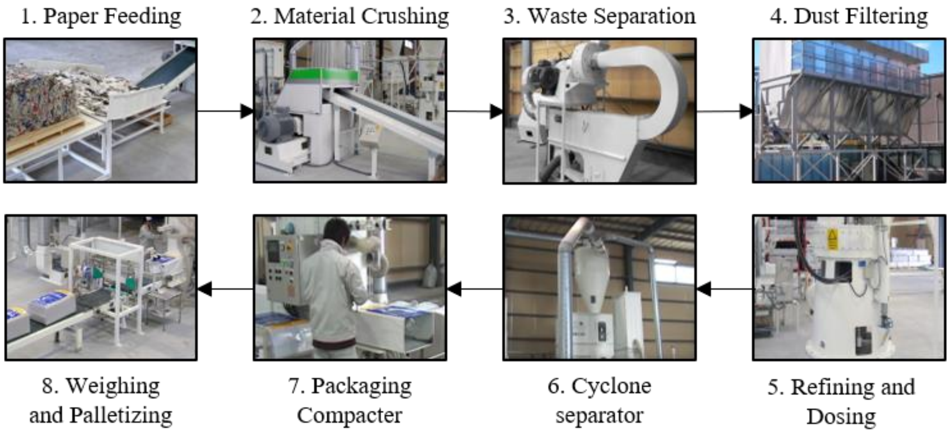

Figure 3. Production process of CIF. Adapted with permission from (Makron 2019)

The first stage is paper feeding, where the raw material is fed into a pre-handling table and afterwards it's moved to the conveyor for the next steps. Defending on the scale of the line impurities are separated manually (small capacity lines) or the raw material comes previously purified and baled (high capacity lines) to put in directly into the paper feeder (Makron, 2019).

The second stage is material crushing. Here, the raw material is moved through the conveyer belt into a hammer mill or shredder, where it is transformed into small pieces between 2 and 4 cm in diameter.

The third stage is waste separation. Here, metal and heavy particles are separated. This is done by using cyclone separator, where a high-speed rotating air flow carries the less dense particles to the top and the high dense particles aren't able to follow the air flow and are collected in the bottom of the machine (Kucukal, 2015).

The fourth stage is dust filtering, where air and dust is removed with dust filters. An air flow between 8,000 to 15,000 m^3/h is processed through the dust filtering equipment (Makron, 2019).

The fifth stage is refining, where the material is fiberized. High pressure air is used to reduce the paper into low-density cotton like flakes. At this stage chemical dosing is also done. As mentioned before boric acid and borax are usually applied to cellulose fiber to protect against mold and fire. The dosing is very accurate, and the equipment can be adjusted to deliver from 20 to 240 kg of boric acid per hour (Makron, 2019).

In the sixth stage the fines that are generated in the refining stage are removed using a cyclone separator just like in stage three. The cyclone separator has a packing reservoir where the flakes are stored.

In the seventh stage the flakes are filled in bags and then mechanically compacted. In the eighth and last step, the packages are weighed, palletized and shipped to the clients.

2.3.5 Thermal conductivity of cellulose fiber insulation

The thermal conductivity of CIF can vary with mass density, temperature and moisture content. For example, the thermal conductivity of CIF may increase from 40mW/(mK) to 66 mW/(mK) with an increase in moisture from 0vol% to 5vol%, respectively (Petter Jelle, 2011).

As a point of reference, Table 3, shows the thermal conductivity of a range of materials commonly used in the building and packaging industry.

Table 3. Thermal conductivity of thermal insulation materials used in the building industry. (Adapted from: Illera, Mesa, Gomez, & Maury, 2018)

Material	Thermal Conductivity ($W \cdot m^{-1} \cdot K^{-1}$)
Expanded polystyrene	0.030–0.040
Polyurethane	0.020–0.030
Fiberglass	0.033–0.044
Mineral wool	0.030–0.040
CIF	0.040–0.060

2.3.6 Risks

One of the risks of using cellulose material is the risk of mold infestation. One of the application techniques is wet spray-applied CIF, which is commonly applied in building materials. Human exposure to molds is a public health concern, especially to certain type of species. Some risks of mold exposure include chronic allergic rhinitis, chronic sinusitis, asthma, and exposure to potential mycotoxins. Molds require certain levels of humidity, temperature and nutrient source to grow. Wood and paper provide an excellent growth medium to certain mold species. The technique of wet spray applied CIF the product contains usually 30-40% water by weight. The use of borate additives in the manufacturing of CIF provides fire-retardant and biocidal properties, therefore manufacturers claim that the product doesn’t pose a risk of mold growth, however a study showed extensive fungi contamination in buildings when using this application technique, including toxigenic species (Godish & Godish, 2006).

Although borax additives are not compulsory for the use of CIF as packaging material, it’s important to consider humidity as a quality feature to avoid mold infestation. Packaging can sometimes be exposed to long storage times which can increase this type of risk.

2.4 Waste management of paper

Waste is defined as any substance or object that is required or intended to discard and waste management refers to the collection, transport, recovery and disposal of waste. Paper is considered a recyclable material since it can undergo a recovery process to recycle it into the paper market (European-Parliament, 2008). According to CEPI (2013) there are six groups of papers classification, each of them with several subgroups that total 59 categories, englobing all types of board and paper, with specifications in degrees of purity and particular properties. The creation of this categories is important for buyers and sellers of paper materials.

2.4.1 **Waste management of CIF**

CIF manufacturers use category 2.02.00 and 2.02.01 which consist of unsold newspaper. Paper can be recycled up to eight times and recycling facilities are able to sort paper coming from household paper recycling bins with an accuracy of up to 98%, and is classified into three main categories: mixed paper, paper from supermarkets and paper that requires deinking (ALBA-Group, 2019). For the case of CIF, since it's composed of unsold newspaper it falls in the category of paper that requires deinking (CEPI, 2013). The use of borax additives in the CIF limits the product to be recycled as paper. However, these additives are only compulsory if the CIF is used for building materials and they can be taken off production if the final use of the product is for packaging, hence allowing it to be recycled (Lackner, 2019).

2.4.2 **Waste Management Legislation**

The EU Waste Framework Directive (WFD) forms the legally binding principals for the waste legislation in the EU member states, which includes the Packaging and Packaging Waste Directive. The WFD was adopted on 19 November 2008.

The closed-loop Waste Management Act (KrWG) was established on 1 June 2012 and is the main Federal Waste Law in Germany. This law takes the WFD into German Law. This act outlines the legal basis and fundamental principles of circular economy which start by defining waste, the polluter pays principle, the five-tier waste hierarchy and the principle of shared public and private responsibility for waste management. The main aim of this act is to (1) conserve natural resources, (2) protect human health and (3) the environmental impact linked with waste generation and management. The five-tier waste hierarchy is presented in Figure 4 and presents in hierarchical order the measurements of waste prevention. The most sustainable practice would be to not use any packaging at all, but given the requirements of chilled ingredients, packaging is needed to ensure its food safety, and the best practice from packaging developers is to make decisions with the aim of achieving a higher hierarchy waste disposal practice (Federal Ministry for the Environment, 2018).

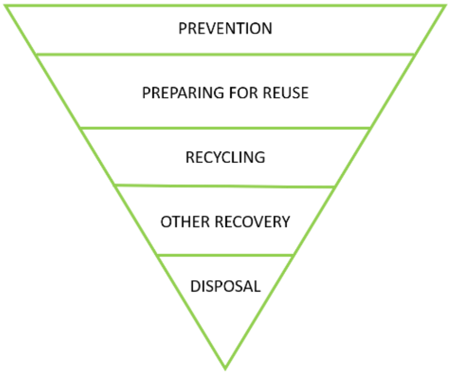

Figure 4. Waste Hierarchy according to European and German Law. Adapted from (Federal Ministry for the Environment, 2018).

2.5 Packaging Performance Methodologies

It has been demonstrated that packaging plays an important role in the supply chain performance and an approach in evaluating them as a whole generates value (Pålsson, 2018).

Performance can be defined as *The quality of execution of such an action, operation, or process; the competence or effectiveness of a person or thing in performing an action; spec. the capabilities, productivity, or success of a machine, product, or person when measured against a standard* (Oxford-English-Dictionary, n.d.).

Packaging performance can be assessed in very specific features, e.g. when evaluating the vibration dampening and thermal insulation properties of a secondary packaging of beer (Paternoster et al., 2017). But is can also be evaluated in holistic terms, e.g. when evaluating an the overall packaging logistics performance of a packaging system using a packaging scorecard (Dominic, 2010; Olsmats & Dominic, 2003; Pålsson, 2018). However, it's possible to obtain feature-specific and packaging level specific data from a holistic packaging performance methodology. For purposes of this work a holistic packaging performance is used to compare features of the CPs.

Olsmats & Dominic (2003) presented the first approach to develop a packaging performance methodology with focus on its role in the product supply chain. In their work they present 14 criteria to evaluate for the packaging scorecard. These criteria have been consolidated based on previous research (Lorentzon & Olsmats, 1992;

Henriksson, 1998; Dominic, Johansson, Lorentzon, & al, 2000) The criteria are presented and described in Table 4. There are three perspectives in which the criteria are classified: technological, business and user-interaction. The technological refers to the physical properties of the packaging. How can you manufacture the packaging? How good does the packaging protect the product? The business perspective refers to aspects related to how the packaging affects a business, for example the price of the packaging and the ability to of the packaging to sell. The user-interaction perspective refers to those aspects in which the user is affected or affects the packaging e.g. how secure is the packaging to protect from theft or how easy can you discard the packaging after using it.

The second approach to develop a packaging logistics performance methodology is presented by (Pålsson, 2018), which is based on the work of Olsmats & Dominic (2003); further developments have been made to present a full methodology. Different from Olsmats & Dominic (2003), Pålsson (2018) describes a step by step approach with specific tools and frameworks that facilitates the assessment of the overall performance of a packaging system for each stakeholder in the supply chain. This last methodology is used for this work and is explained in Section 3.3

Table 4. Criteria used for the packaging performance methodology of Olsmats & Dominic (2003) and its respective descriptions as seen on (Dominic, 2010).

Criteria	Description
	TECHNOLOGICAL
Machinability	Refers to converting packaging material to packaging. Also considers the requirements of packaging machinery for effective use of packaging materials.
Product protection	Product protection refers to the package's ability to protect the product from dynamic impacts such as vibration, shock, compression, temperature.
Flow information	Tracking information refers to the packaging's capacity to provide information to precede with logistics activities in the distribution network.
Volume & weight efficiency	Space & weight efficient refers to the package's ability to exploit the available balance and maximum load capacity.
Stack-ability	Stack-ability concerns effective pallet stack unitization in intermodal shipping.
Reduced use of resources	Reduced use of resources relates to the package's ability to reduce waste and emissions, thus reducing environmental pollution.
Minimal use of hazardous substance	concerns that the package contains the smallest possible quantity of dangerous substances to reduce the burden on the environment and prevent users from injuries.
	BUSINESS
Right amount and size	Refers to the package adapting to the appropriate size concerning customer requirements.
Packaging costs	Refers to the price of the packaging as well as operational costs.
Selling capability	Refers to the package's ability to market and sell the product.
Minimal amount of waste	Refers to the package's generated waste to reduce environmental load and to reduce the costs of waste disposal process logistics flow.
Product information	Includes brand, product and nutritional information to guide the customer to choose the right product as well as product recognition.
	USER-INTERACTION
Reverse handling	Reverse handling is interlinked to a returnable and reusable container that is designed to carry and protect the product that is returned from the producers and product fillers.
Easy to discard	Easy to discard concerns the requirements for removal of unnecessary packaging materials. Packaging can add convenience in the distribution, handling, stacking, opening, reclosing, display, use, and reuse.
Security	Security concerns mainly the ability to protect the product from being stolen or security of the shipment.
	OTHER VALUE-ADDING PROPERTIES
Safety	User safety concerns the packaging's ability to create safety while using the product, for example, concerning child-safety.
Handleability	Handle-ability concerns the package's ability to facilitate easy manual handling. The package provides convenience for handling and storing the product.

3 Methodology

This section presents the methodologies used to answer each of the RQs, starting with an explanation of the ice melt test, followed by the thermography test and finally the packaging performance test.

3.1 Ice melt test

There are many methods available to assess the thermal insulation quality of a package. For example, the ATSM C518 is one of the most commonly used methods to determine the thermal conductivity of the walls of the insulated packaging material. The downside is that it requires a heat flow meter apparatus, which is not available for this work, also it only assesses the thermal conductivity of the packaging walls and not the package as a whole system. The thermal resistance (R-value) is a more accurate indicator to assess the overall thermal insulation capacity of the package. Professor Gary Brugess from Michigan State University has developed a practical, pragmatic and simple methodology to assess the insulating ability of a package by calculating the R-value, parameter that has been explained in section 2.2.1 (Burgess, 1999). This methodology is similar to that of ASTM D3103, but it doesn´t require expensive laboratory equipment. The only problem of this methodology is that the calculated R-value is only comparable to other insulated packaging systems that have fixed inner volume. This methodology was adapted by Bredehoft (2016) to assess different insulation materials in a flexible pouch, rather than a rigid insulation package. In this adaptation, the reciprocal of the R-value is determined and defined as the heat penetration rate (h^*) and is used to compare the different insulation packaging solutions as a whole, rather than the insulation material itself. Insulation packaging solutions can perform good or bad not only because of their thermal conductivity, but also because of their volume, compressibility and design. It is based on the latent heat of fusion or enthalpy of fusion of ice that establishes that 1 kg of ice at 0°C must absorb 334kJ of heat to pass from solid state to liquid state. By placing a certain quantity of ice inside the package, measuring the rate at which ice melts inside the package, and measuring the temperature difference between the outside air and the air inside the package, the h can be determined (Bredehoft, 2016).

3.1.1 **Heat penetration rate calculation**

The heat penetration rate is used to quantify the insulating ability of a package. It is the rate in W at which heat penetrates the container per degree of temperature difference between the outside air and inside air (W/K).

The Fourier´s law of heat conduction is presented in Equation 2 and is used to explain the conduction heat transfer mechanism.

Equation 2

$$Q = -kA\frac{\Delta T}{\Delta x}$$

Where Q is the total amount of heat in W, which is equal to Joule (J) per second (s) that penetrate into the system through conductivity, k is the thermal conductivity of the material in W/mK, A is the area in m^2, ΔT is the difference in temperature between the two sides of the material in K and Δx is the thickness of the material in m. Since k, A, and Δx are fixed on the Paper CP, the three parameters can be combined to create $h*$, which is the heat penetration rate, and has units of W/K as shown in Equation 3:

Equation 3

$$h^* = k * \frac{A}{\Delta x} = \frac{W}{mK} * m^2 * \frac{1}{m} = \frac{W}{K}$$

Therefore $h*$ is simplified in Equation 4

Equation 4

$$h^* = \frac{Q}{\Delta T}$$

In order to determine Q, the amount of melted ice (m_{ice}) is multiplied by the latent heat of fusion of ice (ΔH_{fusion}) which is 334 Joules (J) per gram (g), divided by the time (t) in seconds that the ice was allowed to melt and divided by the temperature (ΔT) difference between ambient air and 0°C. These parameters are simplified and presented in Equation 5.

Equation 5

$$h^* = \frac{m_{ice}\Delta H_{fusion}}{t\Delta T}$$

A low value of $h*$ indicates better insulation, since it means that less heat penetrates the packaging system during the time that the package is exposed to the temperature difference (Bredehoft, 2016)

3.1.2 Experimental set up

The experiment was conducted in the International Test Lab of HelloFresh in Banbury, United Kingdom. The Paper CP was stored at room temperature (18°C). Ice was acquired from the in-house ice production and was allowed to sit at room temperature until it reached melting temperature of 0°C. The ice was crushed in order maintain uniform geometry and facilitate its handling. An approximate amount of 500 g of ice was weighted inside a Ziplock bag and placed inside the Paper CP. The precise amount of ice and the initial time was noted. The Paper CP was placed inside the thermal chamber (Binder KMF720) at 35°C and 50% relative humidity. After 2 hours the Paper CP was taken out of the thermal chamber and the melted water was weighed. The amount of melted water and the final time were noted. All experiments were performed by triplicate.

The reason behind using 35°C is mainly to obtain fast results. The ice melt test is used to compare insulated packaging solutions and when using the same methodology to assess then a comparison of the CPs can be obtained. Given the availability of a thermal chamber, high temperature conditions can be used to force a faster melt rate. The methodology of Burgess (1999) uses ambient temperature for the assessment and doesn’t mention upper temperature restrictions. Iterative preparation experiments were performed merely to assess a reasonable time to let the ice melt in the CP and 2 hours at 35°C was established as a reasonable time to melt enough ice to calculate the *h** for the CPs.

Figure 5. Thermal chamber Binder® KMF 720

3.1.2.1 Experiment 1. Determine the amount of CIF to use in the Paper CP

The Paper CP was developed as a conceptual prototype and it was not until this stage that the CIF was available to test with the Paper CP, therefore it was unknown how much CIF can be introduced inside the Paper CP. By trying different quantities of CIF, it was observed that a quantity of 200 g is the maximum quantity of CIF that can be introduced without jeopardizing the integrity of the Paper CP.

For experiment 1 the full amount (200 g) and half (100 g) of CIF in the Paper CP was used to test if the quantity of CIF gives a different *h**. At this stage, only Supplier-A was available, hence it was the only one used for this experiment. A triplicate of samples was used for the experiment.

3.1.2.2 Experiment 2. Determine differences in insulation performance of the insulation materials using the Paper CP and compare them against the PET and PLA CP of HelloFresh

The second step was to determine the supplier of CIF to use. Three suppliers of CIF were available to conduct the experiment (Supplier-A, Supplier-B and Supplier-C). For this occasion, the prototypes were filled only with 200 g of CIF. The Paper CP were also filled with PET and PLA insulation material. The samples were also compared against HelloFresh CPs that are currently used: PET CP and PLA CP. A negative control (NC) was also tested using the Paper CP without any insulation material

3.1.3 **Data analysis**

The data for all tests and experiments was managed in Microsoft® Excel® Version 1904. Anova and Tukey-Kramer HSD tests were performed with an alpha of 0.05 using JMP® Statistical Discovery Version 14.2.0 from SAS Institute Inc. For the thermograms the software FLIR® Tools Version 5.13.18031.2002 was used.

3.2 Infrared thermography test

Infrared thermography is a testing method to capture the surface temperature distributions (thermograms) based on the amount of radiation emitted in the inspected area (D'huys et al., 2016). The method is contactless and non-destructive and has been used in works ranging from the automotive industry to the packaging industry. It has been used in the packaging field to detect anomalies in seals of pouches, trays (Morris, 2016). It is also widely used to test building elements and detect precise areas where energy leakage occurs. It can be used for quality control to prevent and predict the risk of failure in a product (Akdemir, 2014). The main purpose of using this methodology is to assess the distribution of the insulation material and identify features in the Paper CP that can be of relevance to assure efficient thermal insulation.

3.2.1 **Experimental set up**

The experiment was performed in the Klimatlabb in the Ingvar Kamprad Design Centrum (IKDC) of Lund University. The laboratory has two thermal chambers with controlled temperature and relative humidity. The inside of the chamber can be seen in Figure 6(b). One day before the experiment one of the chambers was set at -5°C and the second chamber was set at 35°C, 50% relative humidity in order to achieve stable conditions. Ice was allowed sit overnight in the -5°C chamber and then was taken out on the day of the experiment to melt until it reached 0°C.

The same procedure performed for the heat penetration test was performed. Additionally, a set of thermograms (infrared camera FLIR T200; FLIR Systems Inc., Danderyd, Sweden; Figure 6(a)) were taken each sample immediately after placing it in the thermal chamber and every 30 minutes for 2 hours. Thermograms of the front, back, left, right and bottom locations of the CP form the set of thermograms.

(a)  (b) 

Figure 6. (a) Infrared camera FLIR T200, used to take the thermograms of the experiment; (b) view inside the thermal chamber in the Klimatlabb

3.2.2 **Data analysis**

The thermograms were then analyzed using the FLIR tools Version 5.13.18031.2002 (FLIR Systems Inc., Danderyd, Sweden). The minimum temperature of the each thermogram was identified and then managed in Microsoft® Excel® Version 1904. Anova and Tukey-Kramer HSD tests were performed with an alpha of 0.05 using JMP® Statistical Discovery Version 14.2.0 from SAS Institute Inc.

3.3 Packaging performance test

The packaging performance methodology is a tool to assess the overall performance of a packaging system for each stakeholder in the supply chain through the use of a number of tools. It aids to make well-founded decisions regarding tradeoffs and to pinpoint potential improvements (Pålsson, 2018). The methodology uses a scorecard that evaluates specific features of the packaging system and that are relevant to the stakeholders of the supply chain of HelloFresh. The methodology is composed of four main steps to assess the performance from a holistic perspective. For this particular case and to answer RQ3, a modified version of the packaging performance test is used to compare only the CP of the packaging system. Three CPs are assessed: Paper CP, PET CP and PLA CP.

This section shows the general steps and descriptions of the tools used to perform the packaging performance test. Since the test consists of a step by step process, the results of step 1 are sued for step 2 and so on. Therefore, detailed development of the steps, tools and information are seen in the Results and Discussion Section 4.3.

3.3.1 **Step 1**

Consists of mapping the packaging system for the product throughout the supply chain. For this, a number of tools are used and are explained in Table 5.

Table 5. Tools used for Step 1 of the packaging performance methodology.

Tool	Description
Supply chain mapping	Consists of mapping the stakeholders involved in the supply chain.
Process mapping	Consists of mapping the specific activities for each stakeholder in the supply chain.
Interaction Framework	Consists of plotting the process map against the packaging system and pinpoint the packaging level that interacts at each process.
Product characteristic typology	Consists of defining the specific product characteristics of the product to then identify what it requires from the packaging solution. For this case it also tells which packaging feature is connected with
Packaging features	Consists of identifying the packaging features that apply to the CP for each stakeholder.

3.3.2 **Step 2**

This step consists of capturing data for the scorecards. In this case, after identifying the stakeholders for the packaging system through the interaction framework a customized scorecard (A.1) was created. A session for each of the stakeholders was scheduled to perform the workshop. Four individuals from each stakeholder category were recruited. For the customers category employees of HelloFresh were used. The criteria of choosing them was that they are customers, are not involved in any packaging decision making neither know about the pick and pack process. A summary of the roles of all the interviewees is presented in Table 6.

The interaction framework analysis was used to choose the stakeholders. The stakeholders that interact with the CP during the supply chain are selected to then proceed to further steps in the methodology. This tool is further developed in section 4.3.1.3.

The scorecards and descriptions of the workshops are shown in Appendix A. The workshops were conducted in scheduled meetings with interviewees for each category. At the beginning of the session the interviewee does a presentation to show the purpose of the whole activity and the step by step approach to answer the scorecards.

Table 6. Summary of interviewee roles per stakeholder group.

Stakeholder Group	Interviewee Role
Customer	1. Customer of HF
	2. Customer of HF
	3. Customer of HF
	4. Customer of HF
HelloFresh Packaging	1. Packaging materials intern
	2. Procurement and sustainability Manager
	3. Head of Packaging
	4. Packaging development intern
PnP Staff	1. PnP Staff from Banbury Distribution Center
	2. PnP Staff from Banbury Distribution Center
	3. PnP Staff from Banbury Distribution Center
	4. PnP Staff from Banbury Distribution Center

The workshop begins with the interviewer presenting the purpose of the whole activity, then the definitions of the features to be evaluated are explained, afterwards an explanation of the importance and satisfaction scores which are shown in Table 7. The importance score is then evaluated without seeing the CPs in order to avoid bias towards a CP. The same importance score is taken for all the CPs. After that, the workshop starts, and the user follows the instructions of the workshop which are presented in detail in the packaging scorecard in Appendix A. In general, the interviewee simulates packing or unpacking each CP, then the interviewer leads a discussion to answer the satisfaction scores for each packaging features shown in the scorecard. This is done first for the PET, then the PLA and last the Paper CP. The interviewees are allowed to change their answers and comment about their answers. This is to give freedom to benchmark the CPs and give time to reflect about their answers. If the interviewees have questions or comments, they are allowed to ask the interviewer at any time.

Table 7. Importance and satisfaction scores used to evaluate the features of the packaging scorecard.

Score	**Importance** How important is that feature for the CP?	**Satisfaction** How satisfied are you with the feature in the CP?
1	Not important	Very low
2	Slightly important	Below average
3	Moderately important	Average
4	Important	Above average
5	Very Important	Very high

3.3.3 Step 3

This step consists in evaluating and graphically presenting the performance of the CPs. For this, the importance scores are normalized for easier comparison and calculations. Normalization helps to evenly distribute the importance of the packaging feature by calculating a relative importance value for each packaging feature. To calculate the normalized importance the importance of each feature (F) is divided by the sum of all the importance scores as shown in Equation 6 (Pålsson, 2018).

Equation 6

$$Normalized\ importance = \frac{importance_{F_i}}{\sum_{i=1}^{n} importance_{F_i}}$$

Plot charts are used to evaluate individual features for each stakeholder and can be seen in the results of this work in section 4.3.3. This type of chart helps visualize and benchmark the features that score high or low in the scorecards.

A normalized average performance score (NAPS) can be calculated with the sum of the multiplication of importance and satisfaction of *n* number of features (F) as shown in Equation 7 (Pålsson, 2018).

Equation 7.

$$NAPS = \sum(Normalized\ importance_{F_1} * Satisfaction_{F_1} + \dots + Normalized\ importance_{F_n} * Satisfaction_{F_n}$$

NAPS can be calculated for each stakeholder and each CP and also represented as an average NAPS considering the three stakeholders for each CP. Representations of this type of charts are used in section 4.3.3.2.

3.3.4 **Step 4**

This step consists in improving the features of the CP. For this a number of suggestions are presented based on the evaluation and discussion of the scores. These suggestions are made on personal judgement in a brainstorming way and then the level of complexity is evaluated to determine how feasible is to implement that suggestion.

3.3.5 **Data analysis**

The data for all tests and experiments was managed in Microsoft® Excel® Version 1904. Anova and Tukey-Kramer HSD tests were performed with an alpha of 0.05 using JMP® Statistical Discovery Version 14.2.0 from SAS Institute Inc. For the thermograms the software FLIR® Tools Version 5.13.18031.2002 was used.

4 Results and Discussion.

This section presents the results of the tests performed to answer each of the RQs. First the ice melt test results are presented, followed by the thermography test and finally the packaging performance test. Each subsection of results is discussed after describing the results; hence the section englobes both results and discussion.

4.1 Ice melt test

The ice melt test was used to assess the thermal insulation performance of the different CPs. As mentioned in the delimitations section, the approach of this experiment was limited to the availability of CIF materials. Suppliers of CIF were contacted and only three suppliers were able to provide CIF before the experimental phase of the project started (Supplier-A, Supplier-B and Supplier-C). The time designated to perform the ice melt test was one week due to the availability of the equipment. The ice melt test is divided in two experiments. The first one is to determine the appropriate quantity of CIF to use in the Paper CP. The second one is to determine if there is a difference in the thermal performance between the three CIF suppliers using the same and PET and PLA insulation material using the same paper surrounding material and additionally compare them against the current PET and PLA CP of HelloFresh. Table 8 shows how the samples are composed and labeled.

Table 8. Identification label for the samples used in the experiment.

Surrounding Material	Insulation material	Type	Quantity (g)	ID label
Paper	CIF	Supplier-A	200	Supplier-A200
			100	Supplier-A100
		Supplier-B	200	Supplier-B200
		Supplier-C	200	SupplierC200
	PET	-	-	PET PB
	PLA	-	-	PLA PB
	None	-	-	Paper NC
PET	PET	-	-	PET CP
	None	-	-	PET NC
PLA	PLA	-	-	PLA CP

4.1.1 **Experiment 1. Determine the amount of CIF to use in the Paper CP**

The main purpose of experiment 1 is to determine if there is a significant difference in the *h** depending on the quantity of CIF used.

The amount was determined using Supplier-A's CIF. The amount of 200 g of CIF was established by testing how much CIF can fit inside the CP concept. Half the CIF was used to verify is there's a significant difference when the amount of CIF. Figure 7 shows the *h** rate of the paper CP filled with 100 g of CIF (Supplier-A100) and 200 g (Supplier-A200) and a negative control (Paper NC). As it can be seen, Supplier-A200 performs significantly better than the Supplier-A100 (a lower *h** indicates better insulation performance). The CIF is a loose insulation material that has the tendency to settle in the bottom due to gravity, this effect is known as sagging. A quantity of 200 g of CIF fills the whole paper CP and doesn't leave unprotected area in the upper part of the pouch. On the other hand, 100 g of CIF settle in the bottom and do not fill completely the paper CP, this leaves the upper part unprotected from heat penetration.

Bomberg & Solvason (1980) mention that the main factor that affects thermal insulation in CIF is the thickness of the insulation layer and the homogeneity of the CIF distribution, given that 200 g fill the Paper CP, a better thermal performance is expected and can justify the lower *h** of Supplier-A200 compared to that of Supplier-A100, which leaves the top area of the CP without insulation.

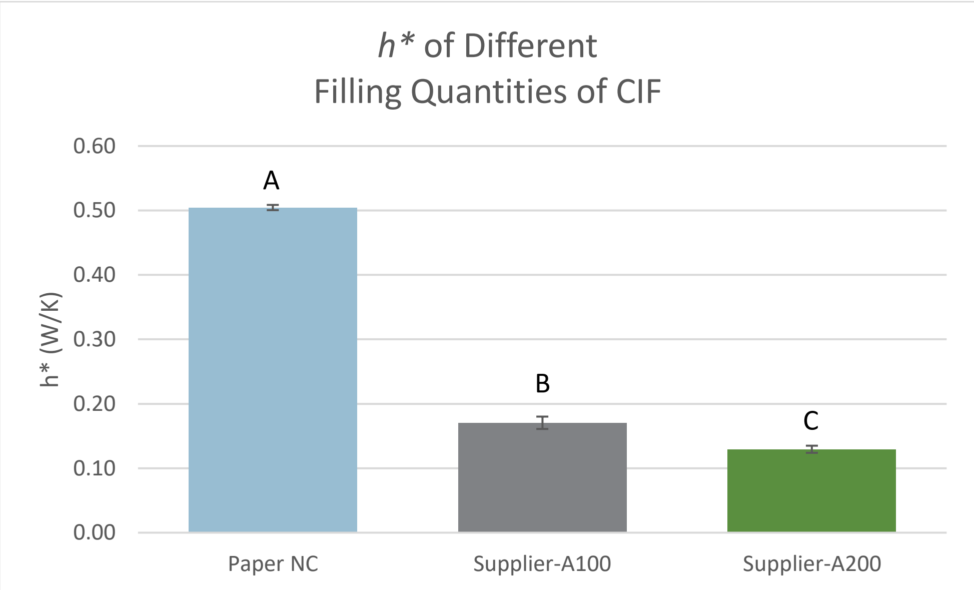

Figure 7. Heat penetration rate of the paper CP filled with 100 g of CIF (Supplier-A100) and 200 g (Supplier-A200) and a negative control (Paper NC). Groups with different letters indicate they have significant difference.

4.1.2 Experiment 2. Determine differences in insulation performance of the insulation materials using the Paper CP and compare them against the PET and PLA CP of HelloFresh

The main purpose of experiment two is to determine if there is a difference in the *h** between the three CIF suppliers, the PET and PLA CPs of HelloFresh.

Figure 8 shows the *h** of the Paper CP using different insulation materials. This means the same type of paper pouch was filled with CIF, PET and PLA insulation material. This, mainly to compare purely insulation materials and take out the factor of the surrounding layer. The samples are explained in Table 8. PET CP and PLA CP were also tested and are plotted in the same figure. A paper bag without insulation was used as a negative control (Paper NC).

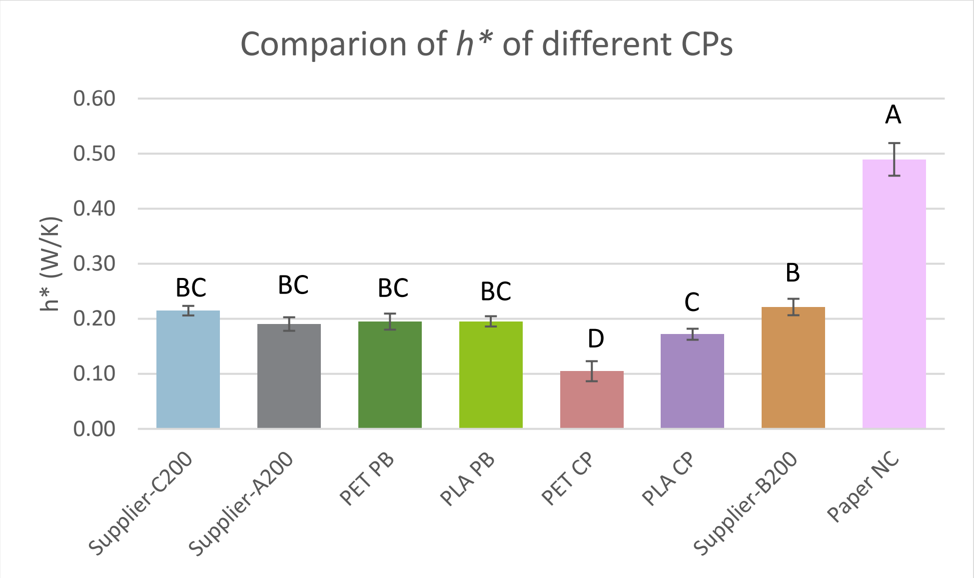

Figure 8. *h of the Paper CP using different insulation materials. CIF suppliers (Supplier-A200, Supplier-C200 and Supplier-B200) and compared to the HelloFresh's current PET CP and PLA CP. A negative control is also tested as a reference (NC PB). Groups with different letters indicate they have significant difference.**

The results show that the three suppliers (Supplier-C, Supplier-A and Supplier-B) have no significant difference between them and they also don't show any significant difference with PET PB and PLA PB. This means that the insulation materials by themselves (CIF, PET and PLA) have no significant difference. The similarity in the *h** of the three CIF suppliers may be due to the way they were placed inside the Paper CP. The density of CIF does not have a significant effect in its thermal resistance in the range of 30 to 55 kg/m^3, which is the normal densities in which the CIF are manufactured. However, the thickness of the material after installation is the one that determines the thermal resistance of it. If the thickness of the CIF is the same for all the samples, it's expected that the thermal resistance is the same (Bomberg & Solvason, 1980).

Figure 9. Insulation materials: (a) PET, (b) PLA, (c) CIF

When comparing the Paper CP samples filled with CIF to PLA CP, Supplier-B200 is the only one that shows significant higher h^*. In comparison to PET CP, all the Paper CP samples showed significantly higher h^*.

It's important to remark that h^* is a modified heat penetration rate for particular use for the experiments of this master thesis, they can't be directly compared against other thermal values such as thermal conductivity or R-values. However, the samples are benchmarked using the same indicators, which gives an order of best performers to worst performers. The ice melt test concludes that PET CP performs better than Supplier-A200, which is also concluded when comparing their thermal conductivities as seen in Table 9.

Table 9. Thermal conductivity and density of the insulation materials of the samples tested and air.

Insulation material	Thermal conductivity ($Wm^{-1}K^{-1}$)	Density (kg/m^3)	Reference
PLA insulation material	0.0275	45	(Wang et al., 2018)
	0.03	20-30	(Standau, Zhao, Castellón, Bonten, & Altstädt, 2019)
PET insulation material	0.036	30	(Ingrao et al., 2014)
CIF	0.039	38-65	Supplier-A
	0.038	33-46	Supplier-B
	0.04	40-60	Supplier-C
Air at 0°C and 1 bar	0.024	-	(Engineering-ToolBox, 2009)
Air at 25°C and 1 bar	0.026	-	(Engineering-ToolBox, 2009)

A factor that can show variations in the thermal performance of CIF it's its moisture content. A high moisture content in the CIF lowers its thermal conductivity (Lopez Hurtado, Rouilly, Vandenbossche, & Raynaud, 2016). The three CIF supplier samples were stored in the same location under the same conditions, although the moisture content was not measured, it can be said that the CIF samples were able to equilibrate with the atmospheric relative humidity for more than one week, allowing similar moisture conditions when testing.

PLA CP has a lower *h** compared to Supplier-B200. Recent papers have shown that PLA is a promising insulation material when used in the form of expanded fibers with low densities (Gong et al., 2018; Kusano, Takagi, Kako, Gennai, & Ousaka, 2008). The PLA insulation material used for this test comes as a loose fiber and maintains its density for prolonged time, whereas CIF tends to settle through time. Table 9 shows a comparison of the thermal conductivities of PET, PLA and CIF insulation materials. In general PLA shows lowest thermal conductivities and densities, followed by PET and finally CIF. This matches the results of the ice melt test in that CIF has significantly higher *h** in comparison to PET CP and PLA. However, PET CP showed the lowest *h**. This may be due to that PET CP consists of a uniform layer of expanded PET as shown in Figure 9 (a), whereas PLA and CIF consist of loose fibers that do not distribute homogeneously in the CP, leaving areas without insulation material where the heat can penetrate.

Going back to RQ1: *How is the thermal insulation performance of the Paper CP compared to HelloFresh's current CPs?* It can be concluded that, in terms of heat penetration rate, the insulation material CIF and PET do perform the same, however when considering the whole CP, the Paper CP performs significantly lower than PET CP but the same as PLA CP.

RQ2 (*Which CP features should be adjusted in order to improve the thermal insulation of the Paper CP and which are the critical limits of these features)* is also partially answered in the discussion of this section by identifying homogeneity as a key feature that plays a role in ensuring thermal insulation. The even distribution of the insulation material in the CP helps ensure that no heat penetrates through the packaging.

4.2 Thermography test

The thermography test was used answer RQ2. This test helps to identifying precise locations in the CP where heat can penetrate easier. The samples used for this test follow the same identification label as shown in Table 8, with the only difference that Supplier-B and Supplier-C samples are not used.

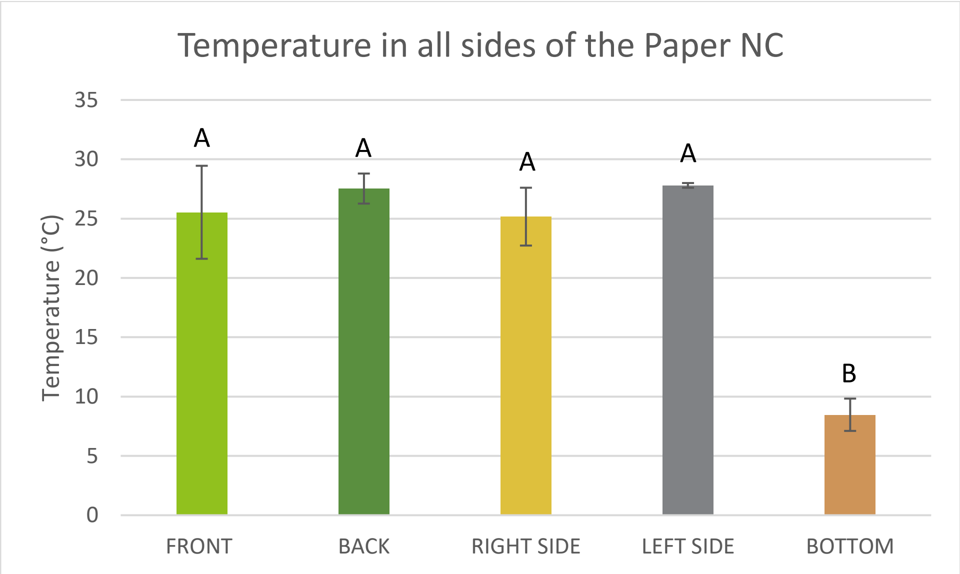

Figure 10. Temperature in areas of CP for NC, average of all measurements. Groups with different letters indicate they have significant difference.

Figure 10 shows the minimum temperature observed in the front, back, right, left and bottom sides of the Paper NC, and is used to illustrate the contrast of the temperature in different sides of the CP. All the other tested samples showed significant lower temperature in the bottom side compared to the rest of the sides ($P<0.05$). This helps identify the bottom side as a location where temperature differences are more noticeable, therefore the thermograms of the bottom side are analyzed in the following paragraphs.

Figure 11 shows the thermograms of the bottom side of the samples at initial time: here it can be seen that how the Paper NC has a minimum temperature of 8°C, followed by PLA with 17.1°C, and then the rest of the CPs have a minimum temperature between 26.5 and 27.9°C. This effect is mainly due to the placement of the ice in the CP. The icepack is placed in the bottom area, having direct contact with the CP, which is in contact with the table inside the thermal chamber. However, a lower minimum temperature indicates a higher heat transfer between the icepack and the outside of the CP, hence a lower minimum temperature indicates lower thermal insulation.

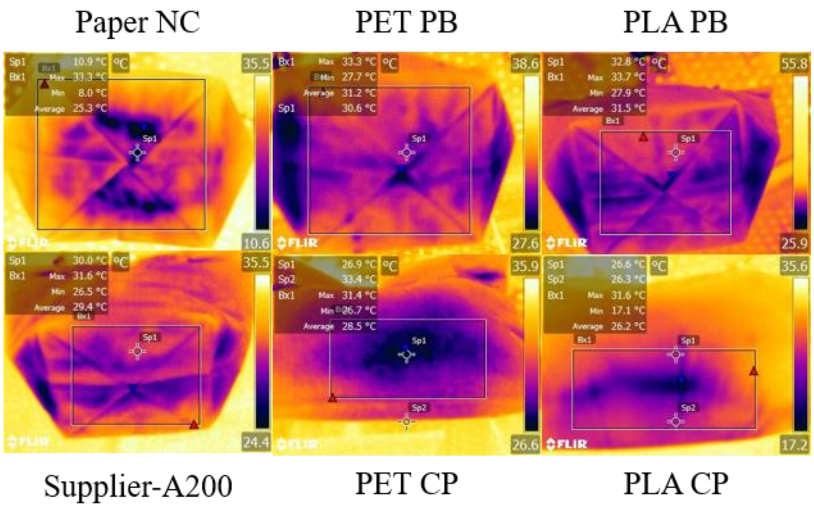

Figure 11. Thermograms of the samples at initial time.

Figure 12 shows a configuration of how the icepack is placed inside the CP during the experiment. This is representative of the normal configuration of the chilled ingredients in the CP in the HelloFresh Box because the chilled ingredients always sit in the bottom of the CP. As it can be seen, the bottom side transfers heat only by conduction mechanism whereas in the upper sides of the pouch both convection and conduction mechanisms apply. The bottom side has only convection mechanism. The ice is exposed directly to the temperatures of the materials it has contact with, in this case it’s the plastic of the icepack, which is surrounding the ice, followed by the inner layer of the paper bag, then the insulation material, then the outer layer of the paper bag and finally the surface where the CP is sitting on. On the other hand, in the upper side of the CP the icepack is exposed to a convection and conduction mechanism due to the air inside the CP, hence having more layers of heat protection. Inside the CP the air is expected to be static and show almost no velocity, because the chilled ingredients are enclosed inside the CP, which is enclosed inside the HelloFresh Box. The CP is expected to be sealed, avoiding the transfer of air between the inside and outside. The convection mechanism depends on the turbulence state of the fluid; when the air is moving or turbulent, the heat transfer is expected to happen fast that when the air is static or laminar (Lienhard, 2001)

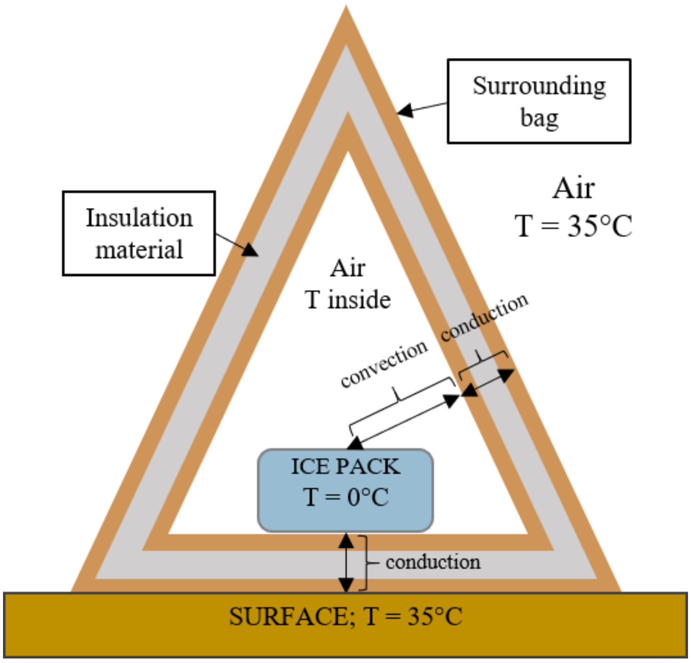

Figure 12. Simplified diagram of convection and conduction mechanism inside the Paper CP.

Taking this into account, air can be considered to have a static state and a thermal conductivity value between 0.024 and 0.026, which corresponds to 0 and 25°C, respectively, as shown in Table 9. Air has a low thermal conductivity compared to most insulation materials and is widely used as an insulation fluid, e.g. bubble-wrap has a thermal conductivity of 0.0271 $W/m^{-1}K^{-1}$, which is very similar to that of air (Eggleston et al., 2013).

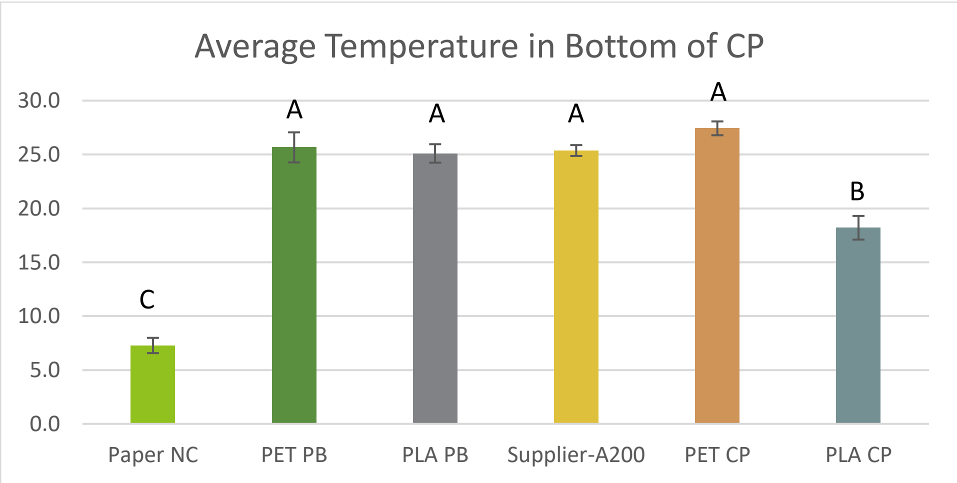

Figure 13. Average temperature of the bottom area for each CP. Groups with different letters indicate they have significant difference

The bottom side of the CP was identified as the side with less layers of thermal resistance. Figure 13 shows the minimum temperature in the bottom side of the samples. As seen in the figure, PET PB, PLA PB, Supplier-A200 and PET CP do not show significant difference, whereas, PLA has a significantly lower temperature compared to the samples previously mentioned. The purpose of a CP is to maintain a low temperature inside. A lower temperature indicates that the insulation is not performing optimally due to the heat exchange in the surface of the pouch. The PLA CP had an average temperature of 18°C on the bottom section whereas the other pouches had an average temperature of 25.9°C.

Since the chilled ingredients are settled in the bottom of the CP an important factor that influences the thickness of the bottom layer is the compressibility of the insulation material, if the material is compressed easily, the thickness decreases, hence the thermal insulation decreases. A parameter that evaluate how easily a material is compressed is the compressive Young's modulus. For PET insulation material, the compressive Young's modulus ranges from 1.16 kPa with 7 kg/m^3 density up to 2.76 kPa when 26 kg/m^3 density (Koh et al., 2018). For CIF, the compressive Young's modulus is between 10-20 kPa in the density range of 47 to 57 kg/m^3 (Lopez Hurtado, Rouilly, Raynaud, & Vandenbossche, 2016). No information was found of the compressive Young's modulus for PLA loose fibers. Empiric observation suggests that the Young modulus is lower than PET insulation material because it is highly compressible by touch and shows a density as low as 20 kg/m^3 as seen in Table 9.

Going back to RQ2: *Which CP features should be adjusted in order to ensure the thermal insulation of the Paper CP and which are the critical limits of these features?* Through the use of thermography and analyzing its results, it can be concluded that thermal conductivity, thickness and compressibility are important features to consider in order to ensure and improve the thermal conductivity of the Paper CP. The three parameters are related among them and should be considered when modifying or developing new packaging. Thermal conductivity of common insulation packaging usually ranges between 0.02 and 0.06 $Wm^{-1}K^{-1}$ (Table 3). Material that fall in this range are known to provide sufficient thermal insulation. However, thickness plays an equally important role, a material with higher thermal conductivity can achieve the same insulation as a material with lower thermal conductivity by adjusting the thickness of the material. Nevertheless, the thickness can be easily modified if the material is easily compressible. This happens due to the weight of the chilled ingredients when they are placed in the CP. The bottom part of the CP has been identified as an important location to pay attention to when assessing the compressibility of the material. The CP is a flexible packaging that should have some degree of rigidity to avoid abrupt changed in thickness. Critical limits for this parameter are hard to establish since they were not evaluated with primary research for this work, however PET insulation has a compressive Young's modulus of 1.16 kPa and the material is known to provide sufficient thermal insulation, hence this number can serve as a reference point for future assessments.

4.3 Packaging performance

The packaging performance methodology has been used to assess Supplier-A200, PET CP and PLA. The results of this section are presented following the four main steps of the packaging performance methodology.

4.3.1 Step 1. Map the packaging system for the product throughout the supply chain

4.3.1.1 Supply chain mapping

HelloFresh has a very complex supply chain due to the broad portfolio of ingredients that are managed. A generalized supply chain map was developed with the unique aim to illustrate the role of the CP and is shown in Figure 14.

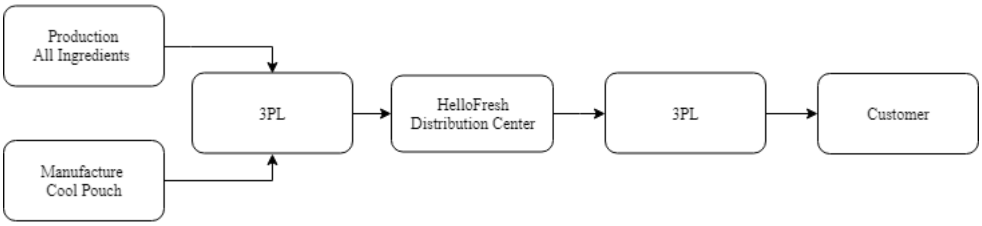

Figure 14. General supply chain with focus in the CP.

HelloFresh has thousands of ingredients and packaging that come from all around the world, but in general they all undergo production, then are managed by a 3PL, afterwards managed by the DC of HelloFresh, and finally sent through a 3PL to deliver the product to the customers. This generalized approach was established to then go into detail in the process map.

4.3.1.2 Process mapping

The main processes and activities were established through interviews and observations with the Site Operations Engineer International of HelloFresh and are shown in Figure 15 (Vanderput, 2019). For the manufacturers of ingredients & packaging and 3PL, a generic set of activities were established, and a more detailed set of activities were described for HelloFresh and customers.

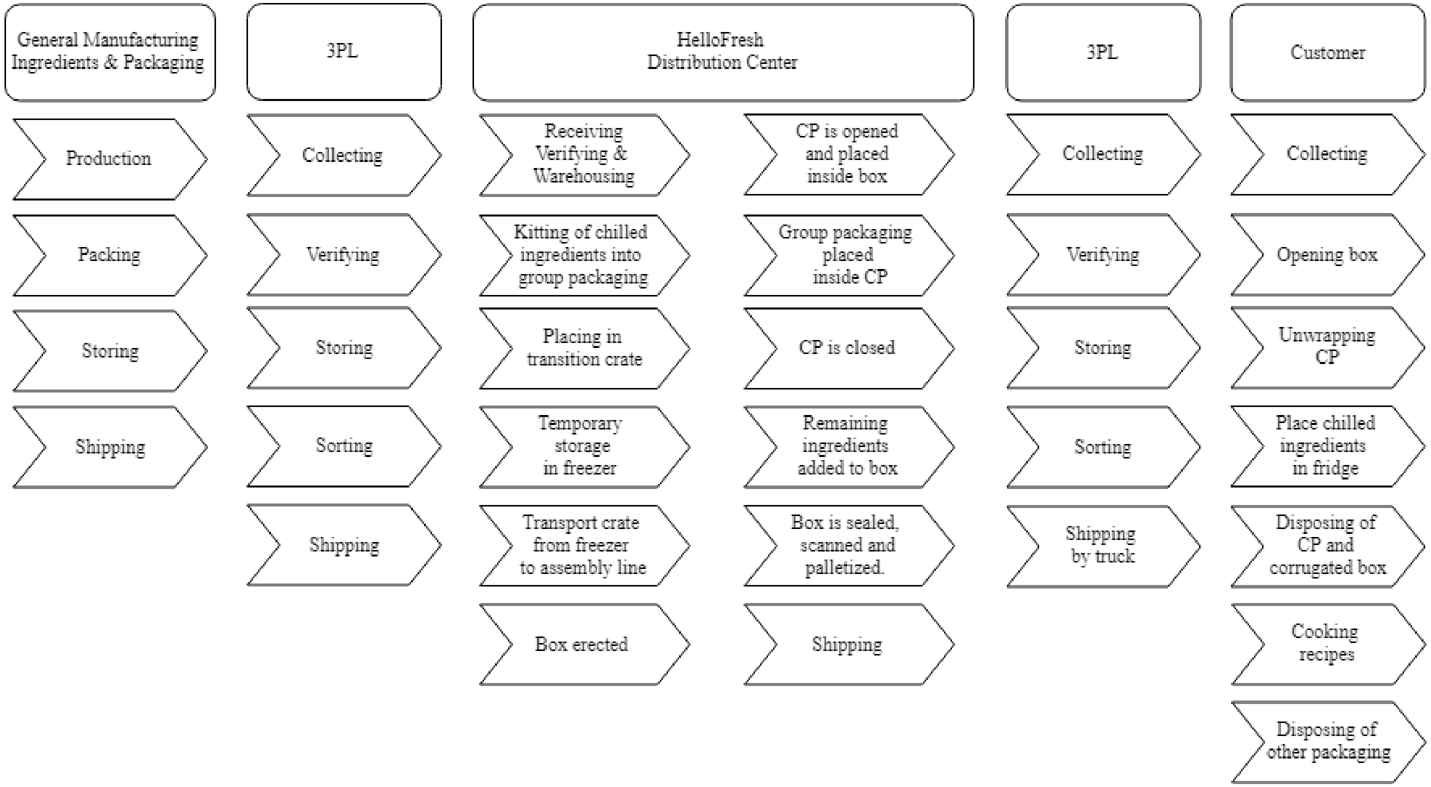

Figure 15. General supply chain and process map for HelloFresh with focus on activities that involve the CP.

4.3.1.3 Product characteristics typology

The product characteristics for the chilled ingredients of HelloFresh were identified and are shown in Table 10. The first column refers to the product characteristic, the second column shows a description of the characteristic. The characteristics were first proposed by taking the example presented by Pålsson (2018) and then were discussed in an interview with the Head of Packaging of and the International Food Safety Manager of HelloFresh (HelloFresh H. o., 2019).

Table 10. Characteristics typology of the product that is packed by the CP.

Product characteristics typology of chilled ingredients	
Product Characteristics	**Description**
Price	Price of the product that is packed.
Fragility	Refers to how prompt is the product to physical damage.
Temperature sensitive	Refers to the temperature requirements of the product and how strict are these requirements.
Content (fluid, food)	Refers to the physical state of the product and if they need to be contained or held at a certain position.
Weight	Refers to the weight of the product and the effect that it has on the packaging, e.g. a very heavy chilled ingredient might need a sturdier CP.
Volume	Refers to the volume that the product requires, hence the CP needs to have an appropriate size.
Consumption patterns	Refers to the customer perception on the appearance and materials used for the CP, e.g. is sustainable packaging appreciated by the customer?
Production	Refers to how the product are packed in the production site.

4.3.1.4 Interaction Framework

Table 11 shows the interaction framework of the general process map of the HelloFresh, 3PL and Customer with focus on the CP (marked in green). This tool aims to help visualize how the packaging interacts in the processes of each stakeholders or actor involved in the supply chain. As it can be seen, the CP is only involved in HelloFresh and Customer, the 3PL is not concerned with it, since they only interact with the Box and PL. HelloFresh can be subdivided into many different categories, but the ones that play a role in the CP are the people that make decisions over packaging purchasing (HF Packaging) and the pick and pack staff of the distribution center, since they are the ones that use the CP. Therefore, for purposes of evaluating the CP with the packaging scorecard only three stakeholders were defined: (1) PnP staff, (2) HelloFresh Packaging and (3) customers of HelloFresh.

Table 11. Interaction framework of the general process map of the HelloFresh, 3PL and Customer with focus on the CP. Primary packaging (1P), group packaging (GP), crate (CR), CP, corrugated box (Box), pallet (PL)

Stakeholder	Process	1P	GP	CR	CP	Box	PL
HelloFresh	Receiving						x
	Verification						x
	Warehousing						x
	Kitting of chilled ingredients	x	x				
	Placing in transition crate			x			
	Temporary storage in freezer			x			
	Transporting crate from storing to assembly line			x			
	Box erected					x	
	CP is opened and placed inside Box				x	x	
	Group packaging is placed inside CP		x		x	x	
	CP is sealed				x	x	
	Box is sealed, scanned and palletized					x	x
	Shipping						x
3PL	Receiving, Sorting, Delivering					x	x
Customer	Receiving					x	
	Opening Box					x	
	Unwrapping CP				x		
	Placing chilled ingredients in fridge		x				
	Disposing of CP and Box				x	x	
	Cooking recipes	x	x				
	Disposing of GP and 1P	x	x				

4.3.1.5 Packaging Features

Table 12 shows the packaging features that apply to the CP. These were adapted from the packaging scorecard of (Pålsson, 2018) and from those presented by Olsmats & Dominic (2003). The feature “Flow Information” was added, since it is thought to be pertinent to evaluate for this particular project, also Hazards was generalized to include any type of hazards whereas it is a physical, chemical or biological hazard. The last three columns are used to show which features apply to each stakeholder.

Table 12. Packaging features that apply to the CP for each stakeholder.

Area	Feature	Code	HelloFresh Packaging	PnP Staff	Customer
Product waste	Protection and containment	PW1	x		x
	Apportionment	PW2	x	x	
Logistics	Material handling	L1		x	
	Volume and weight efficiency	L2	x		
	Production efficiency	L3	x		
	Flow information	L4		x	
Value adding	Product information	V1			x
	Convenience	V2			x
	Promotional attributes	V3			x
Packaging material	Packaging cost	PM1	x		
	Packaging waste	PM2	x		x
	Hazards	PM3	x	x	x

The following definitions of the features were summarized from the works of Olsmats & Dominic (2003) and Pålsson (2018) and taking into account feedback from the interviewees to better delimit what each feature evaluates.

Protection and containment refer to both thermal insulation that ensures the required temperature and protection of dynamic impacts that could harm the integrity of the chilled ingredients. Feedback from interviewees indicated thermal insulation is the main protection that is concerned.

Apportionment refers to the appropriate size and dimensions to place the chilled ingredients inside the pouch, e.g. the CP facilitates the easy placement of packing of the chilled ingredients.

Material handling refers to the handling of the packaging when opening, filling and sealing the CP. It relates to apportionment and convenience to some extent, but differs in that material handling takes opening and sealing and convenience takes into account disposing of the CP.

Volume and weight efficiency refer to the packaging's ability to efficiently use the available space and weight capacity.

Production efficiency refers to the packaging's ability to facilitate production efficiency, e.g. faster packing of HelloFresh Boxes.

Flow information refers to the use of the packaging as an information carrier for logistical purposes.

Product information refers to information about the content and branding of HelloFresh.

Convenience refers to the ease of opening, emptying and disposing of the CP.

Promotional attributes refer to the packaging as a tool to market and sell the product.

Packaging cost refers to the cost that englobes the packaging, including production and final disposing of it. Feedback from the HF Packaging interviewees (Procurement and sustainability manager) indicated that packaging licensing fees are considered for this criterion from HelloFresh Packaging.

Packaging waste refers to the environmental load of the packaging and costs of waste disposal. Feedback from the interviewees indicated that the perception on the recyclability from Customers and HelloFresh Packaging has a high load in the score and packaging licensing fees are also considered from HelloFresh Packaging in this criterion.

Hazards refers the packaging exposing the user to any type of danger, these could be physical, chemical or biological.

4.3.2 Step 2. Capture data for the packaging system performance in the supply chain

The scorecards were assessed by performing workshops and interviews with four individuals of each stakeholder group. Figure 16 shows pictures of the workshops done to answer the packaging scorecards for 17a, PnP Staff and 17b, customers of HelloFresh. The full scorecard can be seen in Appendix A, and it shows the instructions for the workshop and discussion. A presentation was made for each workshop to explain concepts and instructions to answer the scorecards as well as to moderate a discussion about the CPs to obtain feedback on the methodology and the features for each CP.

Figure 16. Photos of the workshop done to answer the packaging scorecards. (a) PnP Staff and (b) customers.

4.3.3 **Step 3. Evaluate and visualize the packaging system performance**

4.3.3.1 Plot chart evaluation of individual features for each stakeholder

Plot charts of importance and satisfaction were used to better visualize the packaging features for each stakeholder and to compare the satisfaction and importance between CPs. A red rectangle is used to highlight the area that is considered important and that has below average satisfaction scores.

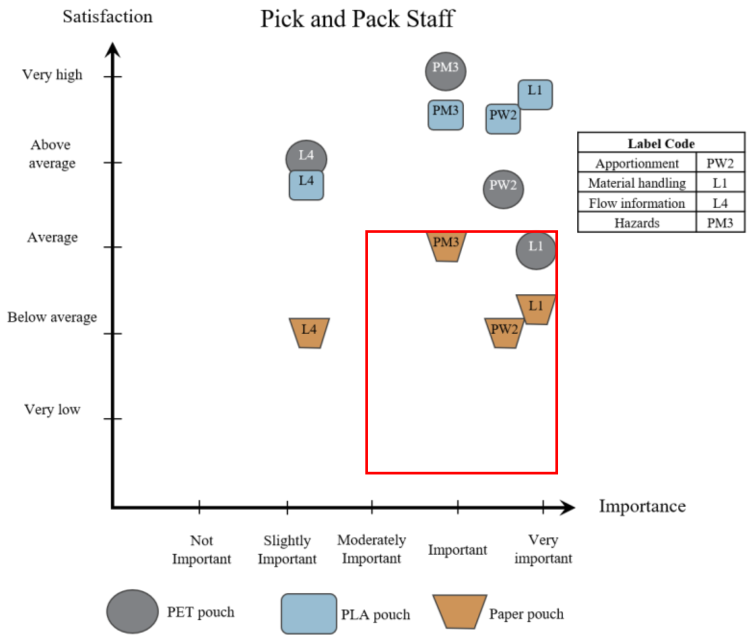

Figure 17. Plot chart of importance and satisfaction of the features that apply for the PnP Staff of HelloFresh.

4.3.3.1.1 PnP Staff

Figure 17 shows the plot chart for PnP Staff. As it can be seen, the features that fall in the red rectangle are material handling and apportionment for the Paper CP. Material handling scored as a very important feature and for the paper bag it scored a below average satisfaction. This mainly due to that the Paper CP needs a double folding to be sealed., compared to the PET CP, PLA scored very high satisfaction because it has a zipper closing mechanism, which facilitates the material handling of it. The apportionment feature scored a 4.5 importance and for the Paper CP it showed below average satisfaction. This is mainly due to the bulkiness of the Paper CP. Different from PET CP and PLA, the Paper CP is not as flexible. The Paper CP makes noise when being handled, and wrinkles when managed repeatedly. Also, the CIF tends to agglomerate in the bottom part of the part reducing the volume available and making it difficult to place the chilled ingredients inside. On the other hand, the PET CP is a flexible blanketlike CP, that doesn't have the agglomeration effect that the Paper CP has. The PLA CP also tends to aggregate, but it has a lower density and an observable higher compressibility when handled, hence it doesn't become an obstruction when placing the chilled ingredients inside. The hazards feature was scored as important and all interviewees mentioned the potential risk of paper cuts for the Paper CP.

4.3.3.1.2 HelloFresh Packaging

Figure 18 shows the plot chart for HelloFresh Packaging. As it can be seen, the features that fall in the red rectangle are apportionment for both the Paper PC. This is mainly due to the shape of the CP. On the one hand, the PET CP and PLA are flexible and compressible and adapt easily to the HelloFresh Box size and to the chilled ingredients placed inside. On the other hand, the Paper CP has a rigid upper area that limits the way it can be placed in the HelloFresh Box and as mentioned before the agglomeration effect decreases the volume available in the bottom section, making it difficult to place chilled ingredients inside. Figure 19 shows a visual of the way each CP fits. Production efficiency scored low for Paper PC and PET CP, this is due to the need of a sticker to seal the CP, they also need two PnP Staff to close it, the first one makes the folding and holds the CP and the second one places the sticker. The PLA one scored better due to the zipper closing mechanism it has, which allows a fast closing and the need of only one PnP Staff to seal it.

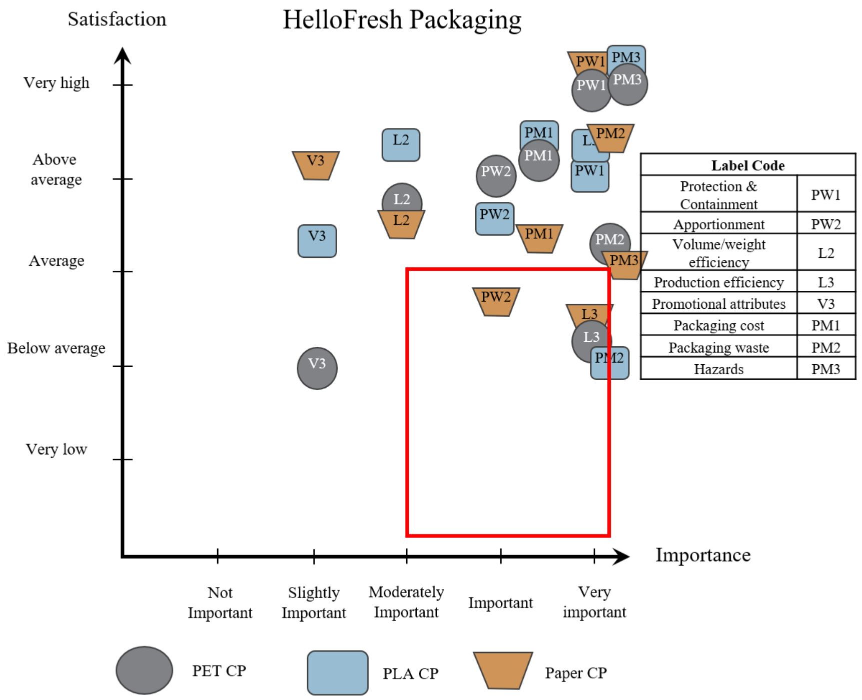

Figure 18. Plot chart of importance and satisfaction of the features that apply to HelloFresh Packaging experts.

Figure 19. CPs in HelloFresh Box (a) PET CP, (b), Paper CP and (c) PLA CP.

Packaging waste scored below average for the PLA CP, due to the fact that the current waste management situation doesn't allow PLA to be industrially composted. First, due to that it's sorted out of the composting stream. Second, due to that composting cycles are shorter than that needed for PLA to compost (Burgstaller, Potrykus, & Weißenbacher, 2018). The streams of paper and plastic recycling in Germany are well established which allows the Paper CP and PET CP to enter the cycle (Federal Ministry for the Environment, 2018; Nelles, Grünes, & Morscheck, 2016; Schulze, 2013).

Packaging waste is very related to cost of packaging and is an important driver for decisions from HelloFresh Packaging and given the new packaging legislation that applies for Germany, companies not only consider the packaging price but also its licensing cost (Wörrle, 2018). Table 13 shows a reference from Lizenzero, a company that manages packaging licensing. As it can be seen, plastic is the material with higher licensing costs and is 5.18 folds more than that of Paper. This lower fee plays a role in the packaging waste and cost of packaging score for the Paper CP. On the other hand, biodegradable packaging such as PLA hasn't been categorized in the German licensing scheme, which is controversial because it could not be subjected to a license if its categorized as organic waste and doesn't bay a licensing fee, although ends up not being composted due to unmatching composting cycles as mentioned before. Due to that, PLA has been scored as above average satisfaction, although the cost of packaging is more expensive than PET, which does pay a high licensing fee, but the packaging cost is very low in comparison to PLA. A study comparing licensing fees of packaging materials show that only Netherlands, Austria and Latvia have fees for PLA packaging, which is classified as "bioplastic" for purposes of this comparison (Denison, 2017). This information is shown in Table 14. Fees are different in every country. However, plastic is always the highest fee and is followed by paper or bioplastic. For the case of Netherlands bioplastics is only 5% of the fee of that of plastic, whereas for Austria it's 75% and for Latvia 22%. This means the use of PLA in Austria is not incentivized as much as Paper, whereas in Netherlands, the low fee incentives the use of bioplastics such as PLA. In Latvia, PLA has the same fee as Paper, hence its equally incentivized.

Table 13. Reference of licensing cost of materials for companies (Lizenzero, 2019)

Material	€/ton	Description
Glass	75	Non reusable glass bottles of color and colorless.
Other materials	95	Refers to cotton, rubber, cork or ceramic which are commonly used as packaging for certain products.
Paper	165	This category refers to cardboard, paper or carton which are used for delivery, packaging and paper bags.
Ferrous metals	765	Refers to common ferrous metal packaging such as tin cans, tubes, and bottle lids.
Aluminum	795	Aluminum packaging components such as can closing lids, cans, tubes which are commonly used in the food, cosmetics and pharmaceutical industry.
Carton Packaging for Liquids	805	Compounds of carton for beverages, e.g. milk, juice and other liquid food. It consists of carton and thin layers of plastic or aluminum.
Other compound packaging	825	Refers to packaging composed of at least two different materials that are connected between them along all the surface, e.g. pill tablets.
Plastic	855	Any plastic packaging such as flexible packaging, bottles, films that are generally used in the food industry. The usual materials are PE, PP, PET or PS

Table 14. Licensing fees for per country and material. [1](Lizenzero, 2019). [2](Denison, 2017)

Country	Licensing fee (€/ton)			% of Bioplastic Fee over Plastic Fee
	Bioplastic[a]	Plastic	Paper	
Germany[1]	NA[b]	855.0	165.0	NA
Netherlands[2]	21.2	387.6	23.3	5%
Austria[2]	450.0	610.0	95.0	74%
Latvia[2]	33.0	149.0	33.0	22%

[a]Bioplastics refer to a packaging made of plastics that is proven to be biodegradable e.g starch, starch blend, biotechnologically produced such as PLA; [b]Not Available.

4.3.3.1.3 Customers

The packaging waste feature was also assessed for the customers of HelloFresh as shown in Figure 20. In this case, the PET CP showed a below average score, the comments from the interviewees about this was that plastic is bad for the environment and that paper and bio-compostable plastic is a better for the environment. This subject is a well-known debate and it all depends on the parameter used to evaluate packaging waste and environmental impact. A paper shows a comparative LCA of paper and plastic packaging bags, which shows that plastic paper bags have less environmental impact in terms of global warming potential, acidification, human toxicity impact and photochemical ozone creation (Biona, Gonzaga, Ubando, & Tan, 2015).

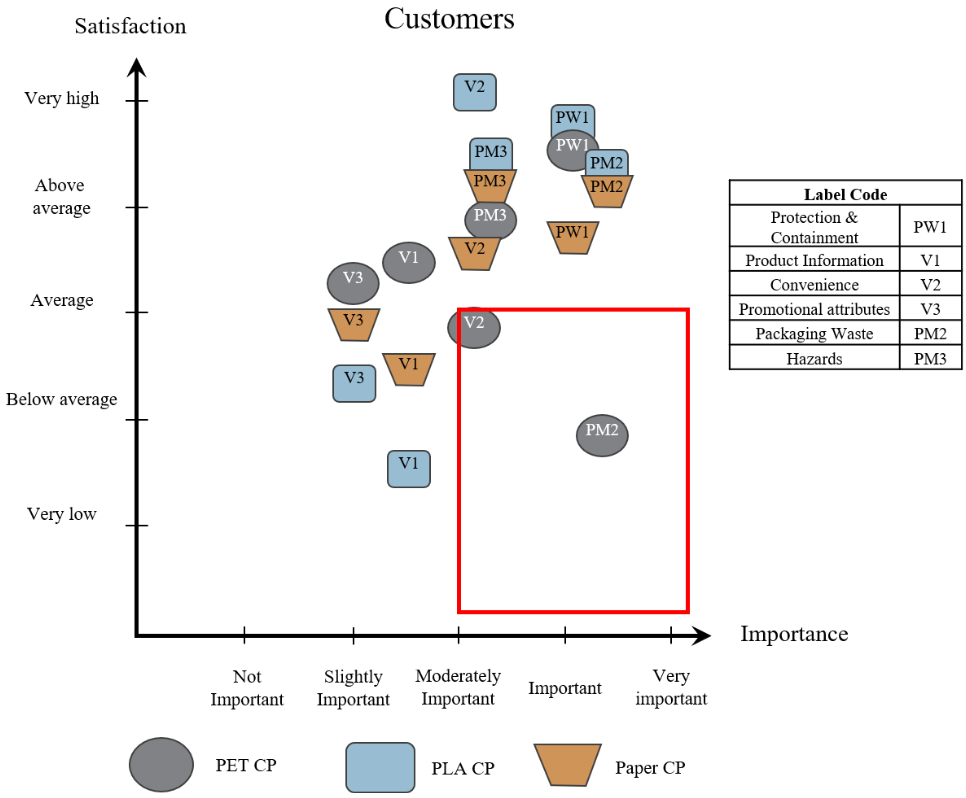

Figure 20. Plot chart of importance and satisfaction of the features that apply for the Customers of HelloFresh.

The convenience score for the PET CP for the customers of HelloFresh also scored low, due to the bulkiness of it when disposing of it. The comments from the interviewees indicated that they evaluated convenience mainly on the ease of disposing of opening and disposing the CP. In that sense the PLA scored high satisfaction due to the zipper and its high compressibility when disposing of it.

4.3.3.2 Overall score evaluation for each stakeholder

Figure 21 shows the overall score for each CP and for each stakeholder. For PnP Staff the PLA pouch scored 4.5 in satisfaction between above average and very high. This is mainly due to the material handling and apportionment which scored higher in satisfaction than the other CP. On the other hand, Paper CP scored below average satisfaction in those features. Three out of four featured were plotted in the red rectangle for the Paper CP.

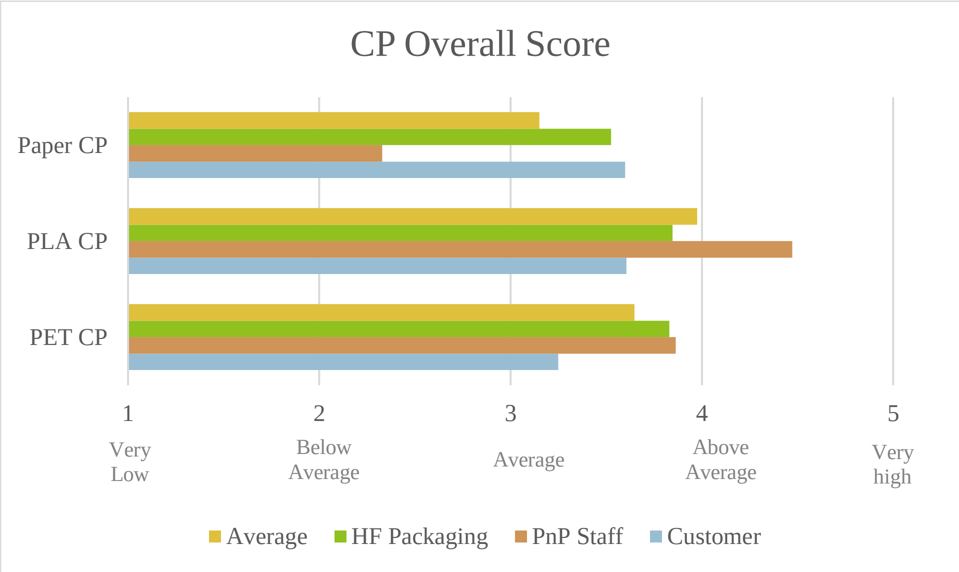

Figure 21. Overall score of each CP (Paper, PLA and PET CP) for each stakeholder.

For the HelloFresh Packaging decision makers, all CPs scored between average and above average. The distribution of the scores among the features was very competitive among the CPs. The score packaging waste and production efficiency balanced the scored of the CPs. Paper CP had high satisfaction in packaging waste but low in production efficiency. The PLA CP had the opposite scores, high satisfaction in production efficiency and low in packaging waste. PET had in general above average and average satisfaction scores and its only below average score was production efficiency. In the end, production efficiency was the deal breaker feature that made the overall score lean slightly towards the PLA CP.

For the Customers, the scores behaved slightly different since PET showed a slightly lower overall satisfaction score than the other CPs mainly due to the packaging waste score. The overall scores of the PLA and Paper CPs were almost a tie with around 3.6, between average and above average. Most of the features that were above the average score were evenly distributed for PLA and Paper CP.

The average score for the three stakeholders is also plotted in Figure 21 and it's of great importance to answer RQ3, *How does the Paper CP perform in comparison to HelloFresh's current CP made out of PET and PLA? Specifically, for the stakeholders that interact with the CP in the supply chain*. This average gives equal importance to PnP Staff, HelloFresh Packaging and Customers. The three CPs scored between average and above average. The lowest score was for the Paper CP, the below average satisfaction score from the PnP made the Paper CP be the option with less satisfaction among the three. PET CP scored slightly higher satisfaction than Paper CP. For PET CP all stakeholders rated it between average and above average. This can be due to the fact that PET CP is the CP that has been widely used in HelloFresh and most stakeholders are used to this option. The feature that made this CP to score slightly lower than the PLA CP was its production efficiency for the HelloFresh packaging decision makers and packaging waste for the customers. PLA scored the highest of all, mainly due to the above average satisfaction from PnP Staff and production efficiency from the HelloFresh Packaging decision makers.

4.3.4 Step 4. Improving the packaging system

Taking into account the features that fall in the red rectangle in 4.3.3.1 Table 15 was created and it aims to show in a matrix the stakeholder and CP that applies for that particular feature. It also shows a suggestion to improve that particular feature and in the last column an indicator of the level of complexity is presented. Although the focus of this work is to improve the Paper CP, suggestions for the PET and PLA CP are also included

The apportionment feature for the Paper CP is shared between HelloFresh Packaging and PnP Staff. Feedback from the PnP Staff indicated that the upper side of the Paper CP is too wide as shown in Figure 19**(**b), in order to improve this feature it is suggested to change the CP dimension so that it fits inside the HelloFresh Box along with the other ingredients. By lowering the height and making the upper section shorter the Paper CP could fit easier inside the HelloFresh Box. Since this CP is still in the prototype stage there is room for changes in design, therefore a medium level of complexity was set.

For the hazards feature, papercuts from the Paper CP was the only one that was commented during the scorecard evaluation. This feature is hard to avoid in the design of the CP, but it can be easily prevented by assuring that the PnP Staff uses protection gloves when handling the CP, therefore a low level of complexity is set.

Production efficiency scored below average for PET CP and for the Paper CP mainly due to the need of two people for closing and placing the sticker in the CP. The PLA CP lacks this problem due to the use of a zipper mechanism. A similar feature could be implemented for both the PET and Paper CP. However, for the Paper CP, this will jeopardize its recyclability and lower the “above average” satisfaction score in the packaging waste feature. For the PET CP this will only mean an improvement in the production efficiency score because the zipper can be made out of PET, making it mono-material. The level of complexity is set high due to the need of redesigning the packaging and its production process.

Material handling scored low in Paper and PET CP for the same reason as production efficiency and apportionment. The same suggestion is presented: a change in the dimensions of the upper side of Paper CP and the adaptation of a zipper mechanism.

Table 15. Matrix of features with score lower than average, stakeholders, CP and suggested improvements.

Feature with score lower than average	Stakeholder	CP	Suggested improvement	Level of Complexity
Apportionment	HelloFresh Packaging	Paper	Change of CP dimensions so that it fits inside the HelloFresh Box along with the other ingredients.	Medium
	PnP Staff			
Hazards	HelloFresh Packaging	Paper	Paper cuts can be avoided by assuring use of protection gloves for the PnP Staff.	Low
	PnP Staff			
Production efficiency	HelloFresh Packaging	Paper	Adapt a zipper closing mechanism to the PET and Paper CP.	High
		PET		
Material handling	PnP Staff	PET		
		Paper	Change of CP measurements so that it fits inside the HelloFresh Box along with the other ingredients and adaptation of a zipper mechanism.	High
Packaging waste	Customer	PET	Information about end of life of packaging to change customer perception of packaging waste.	Low
	HelloFresh Packaging	PLA	Collaboration between Industries that use PLA and waste management facilities.	Very High
Convenience	Customer	PET	Reduce density and compressive Young's modulus of PET insulation to increase the compact-ability of the CP	High

Packaging waste scored below average for the PET CP in customers and for PLA CP in HelloFresh Packaging. Considering recyclability as criteria for the score, PET is highly recyclable, whereas PLA is not (Burgstaller, Potrykus, & Weißenbacher, 2018), hence the problem with the below average score in PET using this criteria in customers is misinformation about concepts regarding sustainability indicators such as global warming potential, recyclability, biodegradability and general end-of-life misunderstanding of as well as a wrong perception of priority categories (Poole, 2019). The suggestion here is to increase the information provided to customers about recyclability of materials so that they are better informed about the packaging decisions that HelloFresh makes. Currently HelloFresh makes high efforts in informing how the packaging should be disposed and sorted for recycling (HelloFresh P. a., 2019), but extra information could benefit the misperception of

PET as a packaging material. On the other hand, PLA has an above average score from Customers but below average score for HelloFresh Packaging. The opposite effect of that of PET CP is seen here. Customers perceive biodegradable packaging as a better option than plastic. However, PLA is not well sorted, and its composting cycles don't match industrial composting practices (Burgstaller, Potrykus, & Weißenbacher, 2018). An informative campaign placing PLA as a more sustainable option than its PET counterpart could fall in a practice of greenwashing (Schmuck, Matthes, & Naderer, 2018). Therefore, a suggestion that is proposed to actually solve the problem is to collaborate and communicate between industries that use PLA and waste management facilities in order to match composting cycles of industrial composting facilities to that of industrially compostable materials used in the market such as PLA. However, this is a very ambitious suggestion because it involves the coordination of thousands of companies and a change in current practices, hence a very high level of complexity is set.

5 Conclusion and Suggestion for Further Development and Research

This section wraps up the initial aim of this work, answers the RQs and presents suggestion for further development of this particular work. It also presents suggestions of research that could contribute to the area of paper based insulated packaging.

5.1 Conclusion

Paper based insulated packaging hasn't been fully developed in the market and the available options face challenges such as: ensuring sufficient thermal insulation, affordability and product/packaging compatibility (HelloFresh H. o., 2019). This work aims to contribute in solving the first challenge, additionally it aims to understand better the features that affect the insulation performance of cool pouches. Finally, it aims to evaluate the packaging performance of cool pouches for its stakeholders in the supply chain to better understand the needs and features that contribute to good performer cool pouch. To solve each of these aims, three RQs were set and are answered in the following paragraphs.

RQ1. How is the thermal insulation performance of the Paper CP compared to HelloFresh's current CP made out of PET and PLA?

In conclusion, the Paper CP has significantly lower thermal insulation performance in comparison to the PET CP and no significant difference compared to PLA CP. It is known. This indicates that the Paper CP can't be a one to one replacement to the PET CP, but it can be to the PLA CP. When comparing purely insulation materials. Supplier-A200 showed the same thermal performance as PET insulation, therefore the overall design of the Paper CP and the PET CP make the difference in their thermal performance.

RQ2. Which CP features should be adjusted in order to improve the thermal insulation of the Paper CP and which are the critical limits of these features?

Through the use of thermography and analyzing its results, it can be concluded that thermal conductivity, thickness, compressibility and homogeneity are important features to consider in order to ensure and improve the thermal conductivity of the Paper CP. The first three parameters are related among them and should be considered when modifying or developing new packaging. Thermal conductivity of common insulation packaging usually ranges between 0.02 and 0.06 $Wm^{-1}K^{-1}$. Materials that fall in this range are known to provide sufficient thermal insulation, however, thickness plays an equally important role. A material with high thermal conductivity can achieve the same insulation as a material with low thermal conductivity by adjusting the thickness of the material. It's important to note that thickness can be easily modified if the material is easily compressible. This happens due to the weight of the chilled ingredients when they are placed in the CP. The bottom part of the CP has been identified as an important location to pay attention to when assessing the compressibility of the material. The CP is a flexible packaging that should have some degree of rigidity to avoid abrupt changes in thickness. Critical limits for this parameter are hard to establish since they were not evaluated with primary research for this work, however PET insulation has a compressive Young's modulus of 1.16 kPa and the material is known to provide sufficient thermal insulation, hence this number can serve as a reference point for future assessments. Homogeneity of the insulation material allows equally distributed insulation in the CP. This last feature is the main weakness of the Paper CP and it's suggested to improve equal distribution of CIF in the Paper CP. For this, further develop and research is necessary.

RQ3. How does the Paper CP perform in comparison to HelloFresh's current CP made out of PET and PLA; specifically, for the stakeholders that interact with the CP in the supply chain.

In conclusion, the Paper CP performed overall "below average" for the PnP Staff of HelloFresh and slightly "above average" for HelloFresh Packaging. The main features that lowered this score are apportionment, production efficiency and material handling. PLA scored the highest of all with a mean score of "above average", this mainly due to the "above average" satisfaction scores in apportionment and material handling from PnP Staff and "above average" production efficiency from the HelloFresh Packaging decision makers. The main reason attributed to these scores is the zipper mechanism of the PLA CP. PET CP had a mean score of "average" with a slightly lower score from customers in the feature packaging waste due to the perception of better recyclability of PLA CP and worst for PET CP.

5.2 Suggestion for Further Development

Based on the answer to RQ1, for further development, it's suggested to adjust the parameters identified in RQ2 to achieve an insulation equal to the of PET, since both insulation materials have equal insulation performance. Based on RQ2, to improve homogeneous distribution of CIF, an idea is suggested. To develop compartmentalization of the CIF in the design, this is mainly involved in the packaging design and manufacturability rather than changing the properties of the insulation material. A final suggestion is to develop a better closing mechanism for the Paper CP that could achieve the same satisfaction of that of the zipper in the PLA CP.

5.3 Suggestion for Further Research

Further research could follow the track of developing CIF into a rigid floc or sheet instead of a loose fiber, without jeopardizing its paper recyclability. This will potentially decrease sagging effect or segregation in clusters which can improve the apportionment and material handling features in the Paper CP.

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Appendix A

Scorecards, set-up and presentation for the packaging scorecard workshop.

A.1 Packaging scorecard for stakeholders of cool pouch.

Scorecard for Customers

Name:	**Instructions:** This scorecard aims to evaluate particular features of the cool pouch used in the HelloFresh box. Use the **importance and satisfaction scale** presented below to fill the last four columns of the **Table**. **Step 1**: Read the scale of importance and satisfaction shown below. **Step 2**: Read thoroughly the whole features and its description, if you have any doubts please ask the instructor. **Step 3**: Go through each feature one by one and evaluate the importance. **Step 4:** (1) Open box, (2) Take out the pouch and place it in the table, (3) Open the cool pouch, (4) Take out the ingredients, (5) Dispose of the cool pouch.
Date:	

Feature	**Description**	**Importance**	**Satisfaction**			**Comments**
			Grey	**White**	**Brown**	
Protection and containment	*How important is that the cool pouch protects and contains the ingredients inside? E.g. consider physical damage. How satisfied are you with the protection and containment that the cool pouch gives?*					
Product information	*How important is that the cool pouch provides information about the content and disposing of the packaging? How satisfied are you with the information provided about the content and disposing of the packaging?*					
Convenience	*How important is that the cool pouch is convenient to use? e.g. consider opening, disposing procedures. How satisfied are you with the convenience of the packaging?*					
Promotional attributes	*Refers to the cool pouch as an attractive feature that sells. E.g. consider design, sustainability. How important is this feature? How satisfied are you with this feature?*					
Packaging waste	*Packaging waste refers to the amount of waste generated and disposal of the cool pouch. e.g. consider recyclability. How important is this feature? How satisfied are you with this feature?*					
Hazards	Refers to exposing the user to physical injuries when opening, taking out ingredients and disposing of the packaging. How important is this feature? How satisfied are you about this feature?					

Score	**Importance** In your opinion, how important is that feature for the cool pouch?	**Satisfaction** In your opinion, how satisfied are you with the feature in the cool pouch?	**Comments?**
1	Not important	Very low	
2	Slightly important	Below average	
3	Moderately important	Average	
4	Important	Above average	
5	Very Important	Very high	

Scorecard for HelloFresh -Berlin Packaging

Name: **Date:**	**Instructions:** The following scorecard evaluates the cooling pouch presented before you. Use the **importance and satisfaction scale** presented below to fill the last four columns in the **Table**. **Step 1**: Read the scale of importance and satisfaction shown below. **Step 2**: Read thoroughly the whole features and its description, if you have any doubts please ask the instructor. **Step 3**: Go through each feature one by one and evaluate the importance. **Step 4**: (1) Grab the grey cool pouch, (2) open it, (3) place it in the box, (4) grab the ingredients and place inside pouch, (5) close the cool pouch. **Step 5**: Evaluate the satisfaction score. *Then, **repeat Step 4** for the **white** pouch and then the **brown** pouch*					
Feature	**Description**	**Importance**	**Satisfaction**			**Comments**
			Grey	**White**	**Brown**	
Protection and containment	*How important is that the cool pouch protects and contains the ingredients inside? E.g. physical damage. How satisfied are you with the protection and containment that the cool pouch gives?*					
Apportionment	*How important is that the cool pouch has an appropriate size and shape for it to contain the ingredients? E.g. packing and fitting ingredients inside. How satisfied are you with it?*					
Volume and weight efficiency	*Refers to cool pouch's ability to exploit the available volume and maximum load capacity. (consider wasted space/volume inside the cool pouch). How important is this feature? How satisfied are you with this feature?*					
Production efficiency	*Refers to the cool pouch's ability to facilitate production efficiency in the packing line. E.g. consider speed of opening, filling and closing procedures. How important is this feature? How satisfied are you with this feature?*					
Promotional attributes	*Refers to the cool pouch as an attractive feature that sells. E.g. consider design, sustainability. How important is this feature? How satisfied are you with this feature?*					
Packaging cost	*Refers to the price of the packaging. How important is this feature? How satisfied are you with this feature?*					
Packaging waste	*Packaging waste refers to the amount of waste generated and disposal of the cool pouch. e.g. consider recyclability. How important is this feature? How satisfied are you with this feature?*					
Hazardous substances	*Refers to the packaging exposing the user to injuries. Eg. consider sharp edges, staples, metals that could cut or potentially harm someone. How important is this feature? How satisfied are you with this feature?*					

Score	**Importance** How important is that feature for the cool pouch?	**Satisfaction** How satisfied are you with the feature in the cool pouch?	**Comments?**
1	Not important	Very low	
2	Slightly important	Below average	
3	Moderately important	Average	
4	Important	Above average	
5	Very Important	Very high	

Scorecard for HelloFresh - Pick and Pack Staff

Name:	**Instructions:** The following scorecard evaluates the cooling pouch presented before you. Use the **importance and satisfaction scale** presented below to fill the last four columns in the **Table**. **Step 1**: Read the scale of importance and satisfaction shown below. **Step 2**: Read thoroughly the whole features and its description, if you have any doubts please ask the instructor. **Step 3**: Go through each feature one by one and evaluate the importance. **Step 4**: (1) Grab the **grey** cool pouch, (2) open it, (3) place it in the box, (4) grab the ingredients and place inside pouch, (5) close the cool pouch. **Step 5**: Evaluate the satisfaction score. *Then, **repeat Step 4** for the **white** pouch and then the **brown** pouch.*
Date:	

Feature	**Description**	**Importance**	**Satisfaction**			**Comments**
			Grey	**White**	**Brown**	
Apportionment	*How important is that the cool pouch has an appropriate size and shape for it to contain the ingredients? E.g. packing and fitting ingredients inside. How satisfied are you with it?*					
Material handling	*Refers to manual handling of the cool pouch during packing. (consider opening, filling, closing procedures). How important is this feature? How satisfied are you with it?*					
Flow information	Refers to the cool pouch's ability to provide information about handling the product. E.g. Instructions, information. *How important is this feature? How satisfied are you with this feature?*					
Hazardous substances	*Refers to the packaging exposing the user to injuries. E.g. sharp edges, staples, metals that could cut or potentially harm someone. How important is this feature? How satisfied are you with this feature?*					

Score	**Importance** How important is that feature for the cool pouch?	**Satisfaction** How satisfied are you with the feature in the cool pouch?	**Comments?**
1	Not important	Very low	
2	Slightly important	Below average	
3	Moderately important	Average	
4	Important	Above average	
5	Very Important	Very high	

A.2 Set-up for workshop with stakeholders

Workshop set-up with customers

Duration: 1 hour

Who? 4 HelloFresh workers that are not involved in packaging but are constant users of the service.

Materials:

- PET pouch
- PLA pouch
- Paper pouch
- Scorecards
- Labels
- Kit bags with ingredients to simulate 3 recipes. (prepare them)
- Printed scorecards
- Pens
- Presentation (printed?)
- Bag to dispose of packaging.

Set up:

The users are presented with a closed HelloFresh box.

The instructor explains how to do the procedure

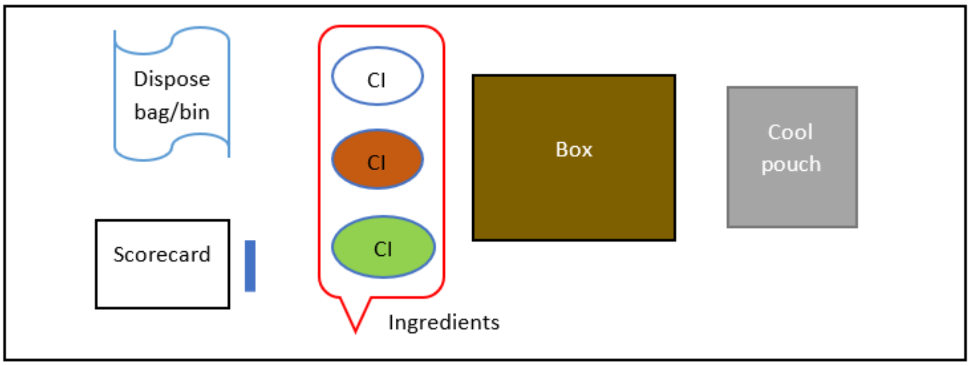
(1) Open box

(2) Take out the pouch and place it in the table

(3) Open the cool pouch.

(4) Take out the ingredients

(5) Dispose of the cool pouch



Workshop set-up with PnP Staff and HF Packaging

Evaluation of 3 cool pouch packaging using the packaging performance methodology.

Who? 4 English speaking PnP staff (nor supervisors nor high level staff)

Where? Meeting/training room in HelloFresh Banbury.

Duration? 1 hour

Materials for the experiment:

- PET, PLA and Paper CP
- Scorecards
- Labels
- Kit bags with ingredients to simulate 3 recipes.
- Printed scorecards
- Pens
- Presentation (projected or printed)

Procedure.

The users are presented with the configuration shown in Figure 1.

The instructor explains how to do the procedure and explain how to close the pouches.

(1) Grab the grey cool pouch

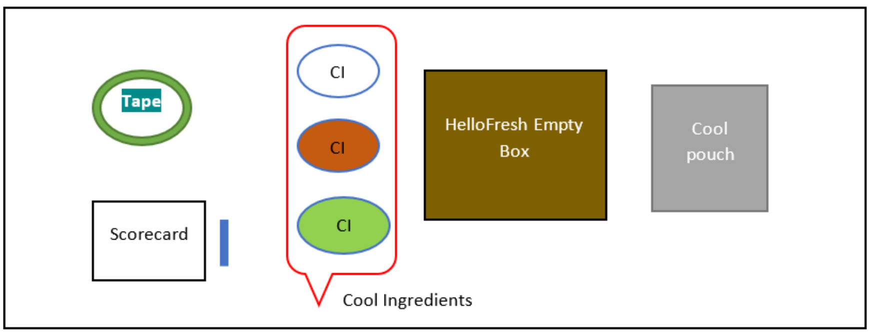
(2) open cool pouch

(3) place cool pouch in the box

(4) grab the chilled ingredients (CI) and place inside pouch

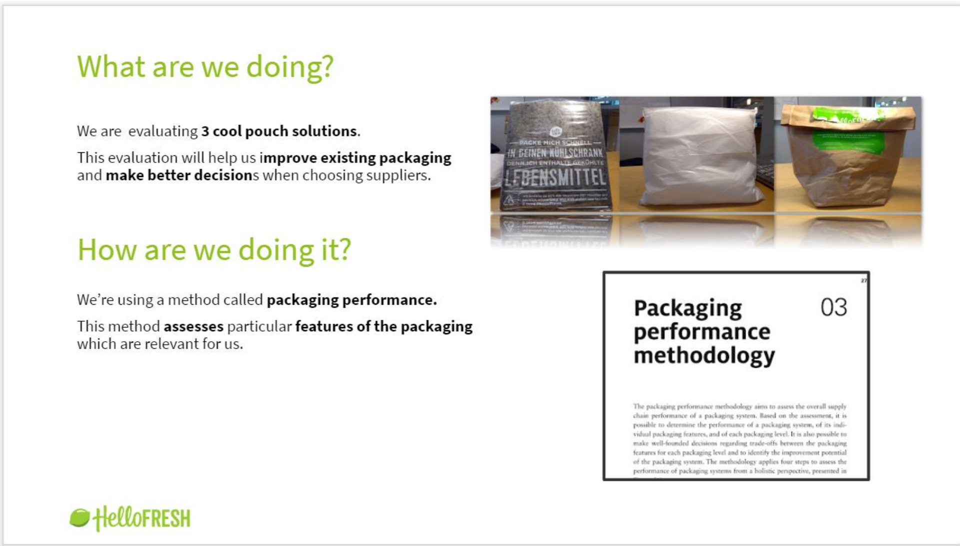
(5) close the cool pouch with tape.

(6) Repeat procedure for white cool pouch and brown cool pouch.



A.3 Presentation for HelloFresh Packaging

Presentation for HelloFresh Packaging



The Packaging Scorecard

Scorecard for Customers						
Name: **Date:**	**Instructions:** This scorecard aims to evaluate particular features of the cool pouch used in the HelloFresh box. Use the **importance and satisfaction scale** presented below to fill the last four columns of the **Table.** **Step 1**: Read the scale of importance and satisfaction shown below. **Step 2**: Read thoroughly the whole features and its description, if you have any doubts please ask the instructor. **Step 3**: Go through each feature one by one and evaluate the importance. **Step 4:** (1) Open box, (2) Take out the pouch and place it in the table, (3) Open the cool pouch, (4) Take out the ingredients, (5) Dispose of the cool pouch.					
Feature	**Description**	**Importance**	**Satisfaction**			**Comments**
			Grey	**White**	**Brown**	
Protection and containment	*How important is that the cool pouch protects and contains the ingredients inside? E.g. consider physical damage. How satisfied are you with the protection and containment that the cool pouch gives?*					
Product information	*How important is that the cool pouch provides information about the content and disposing of the packaging? How satisfied are you with the information provided about the content and disposing of the packaging?*					
Convenience	*How important is that the cool pouch is convenient to use? e.g. consider opening, disposing procedures. How satisfied are you with the convenience of the packaging?*					
Promotional attributes	*Refers to the cool pouch as an attractive feature that sells. E.g. consider design, sustainability. How important is this feature? How satisfied are you with this feature?*					
Packaging waste	*Packaging waste refers to the amount of waste generated and disposal of the cool pouch. e.g. consider recyclability. How important is this feature? How satisfied are you with this feature?*					
Hazards	Refers to exposing the user to physical injuries when opening, taking out ingredients and disposing of the packaging. How important is this feature? How satisfied are you about this feature?					

Score	**Importance** In your opinion, how important is that feature for the cool pouch?	**Satisfaction** In your opinion, how satisfied are you with the feature in the cool pouch?	**Comments?**
1	Not important	Very low	
2	Slightly important	Below average	
3	Moderately important	Average	
4	Important	Above average	
5	Very Important	Very high	

HelloFRESH

The Score

IMPORTANCE

It help us distinguish if some features are more important than other ones.

SATISFACTION

How good is that feature?
Are you happy with its performance?
Could it be improved?

Score	**Importance** How important is that feature for the cool pouch?	**Satisfaction** How satisfied are you with the feature in the cool pouch?
1	Not important	Very low
2	Slightly important	Below average
3	Moderately important	Average
4	Important	Above average
5	Very Important	Very high

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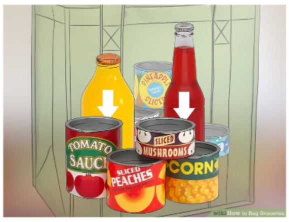
Feature definitions

Some features might seem obvious or self-explanatory, but it important that **we all have the same understanding.**

Packaging Features

Feature	Description
Protection and containment	Product protection refers to the **package's ability to protect the produc**t from **dynamic impacts such as vibration, shock, compression, temperature fall and drops, from the producer to the consumer.**
Apportionment	**Right amount and size** concerns the **package adapting to the appropriate size concerning customer requirements** How important is that the cool pouch has an appropriate size and shape for it to contain the ingredients? E.g. packing and fitting ingredients inside. How satisfied are you with it?
Volume and weight efficiency	Space & weight efficient refers to the package's ability to **exploit the available balance and maximum load capacity.** Refers to cool pouch's ability to exploit the available volume and maximum load capacity. (consider wasted space/volume inside the cool pouch). How important is this feature? How satisfied are you with this feature?



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Packaging Features (continue)

Feature	Description
Production efficiency	The packaging facilitates **production efficiency in the packing place**. For example is a box easy to erect, or is a bag fastly sealed. Refers to the cool pouch's ability to **facilitate production** efficiency in the packing line. E.g. consider speed of opening, filling and closing procedures.
Promotional attributes	Refers to the cool pouch as an **attractive feature that sells**. E.g. consider design, sustainability. How important is this feature? How satisfied are you with this feature?
Packaging cost	Refers to the **cost of the packaging material** and its **packaging operations**. How many people are needed to close the packaging?

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Packaging Features (continue)

Feature	Description
Packaging waste	Packaging waste refers to the **amount of waste generated** and **disposal of the cool pouch**. e.g. consider **recyclability**, **cost of waste disposal**.
Hazards	Refers to the packaging **exposing the user to injuries**. Eg. consider sharp edges, staples, metals that could cut or potentially harm someone.

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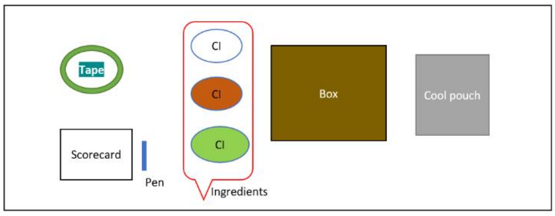
Procedure

1. Grab the grey cool pouch.
2. Open cool pouch.
3. Place cool pouch in the box.
4. Grab the chilled ingredients (CI) and place inside pouch.
5. Close the cool pouch with tape.



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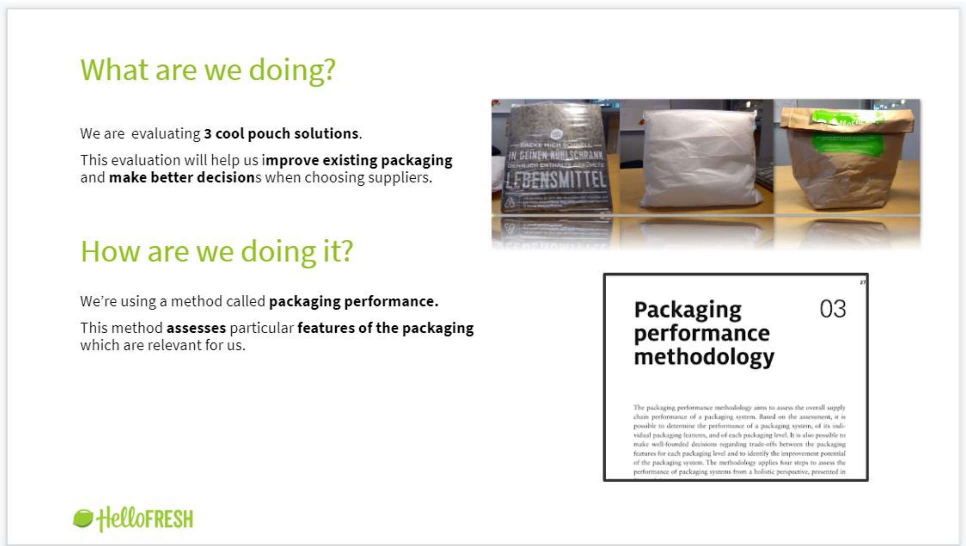
Presentation for Customers



The Packaging Scorecard

Scorecard for Customers

Name:

Date:

Instructions:
This scorecard aims to evaluate particular features of the cool pouch used in the HelloFresh box. Use the **importance and satisfaction scale** presented below to fill the last four columns of the **Table**.
Step 1: Read the scale of importance and satisfaction shown below.
Step 2: Read thoroughly the whole features and its description, if you have any doubts please ask the instructor.
Step 3: Go through each feature one by one and evaluate the importance.
Step 4: (1) Open box, (2) Take out the pouch and place it in the table, (3) Open the cool pouch, (4) Take out the ingredients, (5) Dispose of the cool pouch.

Feature	Description	Importance	Satisfaction			Comments
			Grey	White	Brown	
Protection and containment	*How important is that the cool pouch protects and contains the ingredients inside? E.g. consider physical damage. How satisfied are you with the protection and containment that the cool pouch gives?*					
Product information	*How important is that the cool pouch provides information about the content and disposing of the packaging? How satisfied are you with the information provided about the content and disposing of the packaging?*					
Convenience	*How important is that the cool pouch is convenient to use? e.g. consider opening, disposing procedures. How satisfied are you with the convenience of the packaging?*					
Promotional attributes	*Refers to the cool pouch as an attractive feature that sells. E.g. consider design, sustainability. How important is this feature? How satisfied are you with this feature?*					
Packaging waste	*Packaging waste refers to the amount of waste generated and disposal of the cool pouch. e.g. consider recyclability. How important is this feature? How satisfied are you with this feature?*					
Hazards	Refers to exposing the user to physical injuries when opening, taking out ingredients and disposing of the packaging. How important is this feature? How satisfied are you about this feature?					

Score	**Importance** In your opinion, how important is that feature for the cool pouch?	**Satisfaction** In your opinion, how satisfied are you with the feature in the cool pouch?	**Comments?**
1	Not important	Very low	
2	Slightly important	Below average	
3	Moderately important	Average	
4	Important	Above average	
5	Very Important	Very high	

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The Score

IMPORTANCE

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SATISFACTION

How good is that feature?
Are you happy with its performance?
Could it be improved?

Score	**Importance** How important is that feature for the cool pouch?	**Satisfaction** How satisfied are you with the feature in the cool pouch?
1	Not important	Very low
2	Slightly important	Below average
3	Moderately important	Average
4	Important	Above average
5	Very Important	Very high

HelloFRESH

Feature definitions

Some features might seem obvious or self-explanatory, but it important that **we all have the same understanding.**

We will answer together the **importance** score.

Packaging Features

Feature	Description
Protection and containment	Product protection refers to the **package's ability to protect the product** from **dynamic impacts such as vibration, shock, compression, temperature fall and drops, from the producer to the consumer.**

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Packaging Features

Feature	Description
Product information	How important is that the cool pouch provides **information about the content** and **disposing of the packaging**?

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Packaging Features (continue)

Feature	Description
Convenience	How important is that the cool pouch is convenient to use? e.g. consider opening, disposing procedures. How satisfied are you with the convenience of the packaging?

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Packaging Features (continue)

Feature	Description
Promotional attributes	Refers to the cool pouch as an attractive feature that sells. E.g. consider design, sustainability. How important is this feature? How satisfied are you with this feature?

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Packaging Features (continue)

Feature	Description
Packaging waste	Packaging waste refers to the **amount of waste generated** and **disposal of the cool pouch**. e.g. consider **recyclability**, **cost of waste disposal**.

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Packaging Features (continue)

Feature	Description
Hazards	Refers to the packaging **exposing the user to injuries**. Eg. consider sharp edges, staples, metals that could cut or potentially harm someone.

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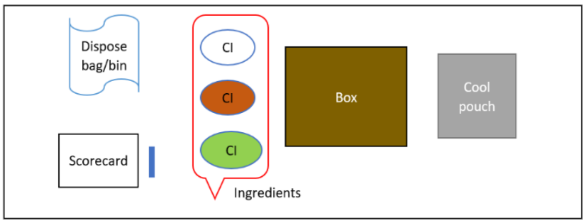
Procedure

1. Open box.
2. Take out the pouch and place it in the table.
3. Open the cool pouch.
4. Take out the ingredients.
5. Dispose of the cool pouch.
6. Answer the satisfaction score for each feature.

Score	**Satisfaction** How satisfied are you with the feature in the cool pouch?
1	Very low
2	Below average
3	Average
4	Above average
5	Very high



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Now we answer the satisfaction scores.

Score	**Satisfaction** How satisfied are you with the feature in the cool pouch?
1	Very low
2	Below average
3	Average
4	Above average
5	Very high

Presentation for PnP Staff

The Packaging Scorecard

Scorecard for HelloFresh - Pick and Pack Staff						
Name: **Date:**	**Instructions:** The following scorecard evaluates the cooling pouch presented before you. Use the **importance and satisfaction scale** presented below to fill the last four columns in the **Table**. **Step 1**: Read the scale of importance and satisfaction shown below. **Step 2**: Read thoroughly the whole features and its description, if you have any doubts please ask the instructor. **Step 3**: Go through each feature one by one and evaluate the importance. **Step 4**: (1) Grab the **grey** cool pouch, (2) open it, (3) place it in the box, (4) grab the ingredients and place inside pouch, (5) close the cool pouch. **Step 5**: Evaluate the satisfaction score. *Then,* ***repeat Step 4*** *for the* ***white*** *pouch and then the* ***brown*** *pouch.*					
Feature	**Description**	**Importance**	**Satisfaction**			**Comments**
			Grey	**White**	**Brown**	
Apportionment	*How important is that the cool pouch has an appropriate size and shape for it to contain the ingredients? E.g. packing and fitting ingredients inside. How satisfied are you with it?*					
Material handling	*Refers to manual handling of the cool pouch during packing. (consider opening, filling, closing procedures). How important is this feature? How satisfied are you with it?*					
Flow information	Refers to the cool pouch's ability to provide information about handling the product. E.g. Instructions, information. *How important is this feature? How satisfied are you with this feature?*					
Hazardous substances	*Refers to the packaging exposing the user to injuries. E.g. sharp edges, staples, metals that could cut or potentially harm someone. How important is this feature? How satisfied are you with this feature?*					

Score	**Importance** How important is that feature for the cool pouch?	**Satisfaction** How satisfied are you with the feature in the cool pouch?	**Comments?**
1	Not important	Very low	
2	Slightly important	Below average	
3	Moderately important	Average	
4	Important	Above average	
5	Very Important	Very high	

HelloFRESH

The Score

IMPORTANCE

It help us distinguish if some features are more important than other ones.

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How good is that feature?
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Score	**Importance** How important is that feature for the cool pouch?	**Satisfaction** How satisfied are you with the feature in the cool pouch?
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HelloFRESH

Feature definitions

Some features might seem obvious or self-explanatory, but it important that **we all have the same understanding.**

We will answer together the **importance** score.

Packaging Features

Feature	Description
Apportionment	**Right amount and size** concerns the **package adapting to the appropriate size concerning customer requirements** How important is that the cool pouch has an appropriate size and shape for it to contain the ingredients? E.g. packing and fitting ingredients inside. How satisfied are you with it?

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Packaging Features

Feature	Description
Material handling	Refers to **manual handling** of the cool pouch during packing. (consider opening, filling, closing procedures). How important is this feature?

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Packaging Features (continue)

Feature	Description
Flow information	Refers to the cool pouch's ability to provide **information about handling the product**. Example: instructions, warnings, important information. How important is this feature?

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Packaging Features (continue)

Feature	Description
Hazards	Refers to the packaging **exposing the user to injuries**. Eg. consider sharp edges, staples, metals that could cut or potentially harm someone.

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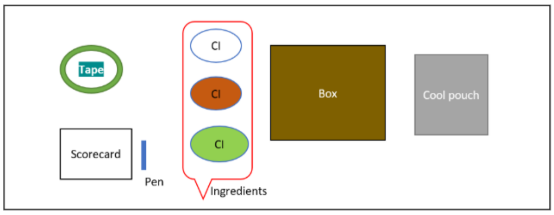
Procedure

1. Grab the grey cool pouch
2. Open cool pouch
3. Place cool pouch in the box
4. Grab the chilled ingredients (CI) and place inside pouch
5. Close the cool pouch with tape.
6. Answer the satisfaction score for each feature.

Score	**Satisfaction** How satisfied are you with the feature in the cool pouch?
1	Very low
2	Below average
3	Average
4	Above average
5	Very high



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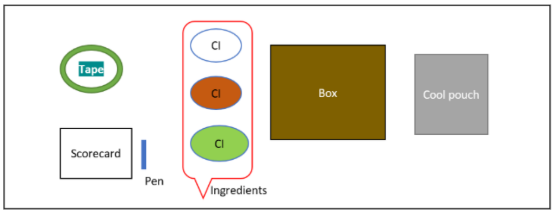
We repeat for White and Brown Pouch

1. Grab the grey cool pouch
2. Open cool pouch
3. Place cool pouch in the box
4. Grab the chilled ingredients (CI) and place inside pouch
5. Close the cool pouch with tape.
6. Answer the satisfaction score for each feature.

Score	Satisfaction How satisfied are you with the feature in the cool pouch?
1	Very low
2	Below average
3	Average
4	Above average
5	Very high



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