Folding carton and internal printing: a technical approach to consumer differentiation and food safety

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MASTER THESIS

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This thesis means the last journey of a two-year adventure. The last six months have been a new chapter in my professional and personal life. The present work collects a part of the experience and knowledge got during my stay at Unilever.

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Abstract

Title: Packaging material and decoration – features that offer differentiation and consider food safety

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Issue of Study: Packaging can be used to offer to consumers a complete brand experience. The emotional level enhanced during opening moment make consumers engage with the product and therefore, with the brand. Brands can firstly use printing to stand out at the point of sale and can use internal printing to enhance consumer experience at home. Internal printing needs to be analyzed through the lenses of three pillars for a right execution: technical feasibility, consumer perception and safety. This thesis evaluates the necessary work to achieve internal printing, asks what do consumer think about internal printing and evaluates how to do it in a safe way.

Purpose: Provide recommendations of technical and legal relevant approaches to achieve an attractive Packaging System with internal printing considering different product and primary pack combinations.

Method: A secondary research through a literature research; a primary research through a market screening, expert interviews, safety assessment, technical assessments and a quantitative survey.

Conclusion: Internal printing exists in the food industry, it follows a determinate packaging system structure of consumer unit containing multiple individually packed units, different artwork design can be found and direct contact between food product and substrate does not exist. Internal printing is technically feasible, this does not allow the conclusion to state that internal printing is achievable for all applications and hence every internal printing scenario needs to go through a similar evaluation one case at a time. It is highly recommended to run an overall migration test once a final artwork(s) is developed.

Key Words: Internal printing, food packaging, printing ink, printing technologies, consumer safety, technical feasibility, consumer perception, wrapper, board, survey.

Executive Summary

Introduction

Packaging can become a great resource for brands during the interactions between the consumer and a product, starting with the purchase decision in-store until the disposal time (Löfgren et al., 2005). Brands can evoke emotions through packaging decoration on consumers during the First Moment of Truth and can offer a consumption experience during the Second Moment of Truth (Stallard, 2014). Unilever is looking for a feasible option to enrich the overall in-use experience by gaining differentiation in a safe way during the Second Moment of Truth.

Internal printing allows to design a new experience for the consumer based on innovative decorating solutions printed on the internal side of the product (Ampuero et al., 2006). An example is the inclusion of a recipe, an inspirational quote or a creative artwork. Internal printing is increasingly being used by few companies and categories, despite it can become a key factor to increase the consumer perception of a product (Zeithaml, 1988). In the FMCG Industry, brands can firstly use printing to stand out at the point of sale and can use internal printing to enhance consumer experience at home. The development of internal printing on a packaging must be evaluated considering all the external and internal aspects involved in the topic. It is compulsory to consider from the beginning the intended end use for the consumer unit, to identify and control the opportunities and risks. This includes, for instance, the material specifications, the food product and the utilized printing inks.

The technical feasibility, consumer perception and consumer safety assessment results are discussed and a conclusion is offered to the Unilever packaging development team, as well as a recommendation for future work. Based on the findings of this thesis, Unilever will have a better understanding of opportunities and constraints on internal printing.

Objective

The purpose of this master thesis is to offer recommendations of the most technically feasible alternatives to present an attractive food packaging with internal printing in a safe way. The research objective was achieved considering a three-pillar perspective: feasibility, safety and perception.

The thesis evaluates the necessary work to achieve internal printing, using offset technology, on a board based consumer unit pack containing multiple individually sealed aluminum based sachets or unsealed aluminum based wrappers. The formulation of the food product to be considered is not strictly mentioned, therefore, the packaging solution proposed applies for a range that goes from a dry powder product to a fatty paste product.

Methodology

The research process carried out in this thesis is designed by secondary and primary researches. The secondary research considered an extent literature research on the topics regarding the three pillars with a special focus on regulation frameworks. On the other hand, the primary research consisted on an initial market screening and interviews with an ink supplier, convertor, risk assessment expert and a consumer insight expert. Additionally, data was collected through one risk assessment and three feasibility assessments and then translated into insights to be used on a final consumer perception assessment, where innovation tools helped to understand consumers´ thoughts about different internal printing technical concepts through an online survey

Results

Results from Safety assessment

For the individual sealed aluminum based sachet scenario, it can be considered that a well-sealed sachet can guarantee the protection against migration. Regarding the unsealed aluminum based wrapper scenario, gas migration may occur if fractures on the wrapper film happen. For this thesis, corner fractures were analyzed through microscopy on 23 preselected samples to assess the effect of packaging process on the material and consequently, a possible negative impact on its functional barrier in the folded corners. Fractures were found in some of the corners, with aluminum ruptures from 520 µm to 2250µm.

Results from Feasibility assessment

A comparative technical short run test of two offset inks was run to get an initial feasibility insight. A potential direct food contact ink and a low migration not-intended food contact ink were printed on both side of the board in the same machine, the test proved that both inks show a similar machine behavior, the potential direct food contact ink achieved technically feasibility. The uncoated internal side of the board and the ink ingredients properties impact the final appearance on the substrate. A color space assessment showed differences between the potential direct food contact ink application on the inside and the low migration ink application on the outside. A final Robinson test showed a non-perceptible transfer of odor from the inks.

Results from Perception assessment

The collected technical feasibility insights from the market screen and the feasibility assessment were used to develop a morphological chart to create technical artwork concepts. These concepts were then used on an online survey through a prototype. After collecting 123 surveys, it has been shown that internal printing has a positive impact on consumer perception. Additionally, an insight showing a preference for a completely printed surface on the internal printing was obtained.

Conclusions

To ensure consumer safety of the product, each execution needs to have an in-depth assessment and an overall migration test is recommended. The integrity of the primary pack needs to be ensured in case a direct food contact has been identified as a consumer safety risk. Regarding regulations, it could be shown that there are specific regulatory details which varies depending on the region and country were the final good is to be sold, however, the basis to achieve safe food products for consumption is the same all around the world.

The initial market screening showed that internal printing already exists in different food products with different artwork designs It has been observed that most of the products were multi-pack: several consumer unit per selling unit. The initial feasibility assessments during this thesis are quite promising: internal printing is achievable under the current specifications of the packaging materials. This thesis only considered the offset printing technology and a technical assessment for a direct food contact intended ink and a low migration ink for food products, both printed on the same board. The technical insights regarding final appearance need to be considered by Unilever for their further research.

Thanks to the innovation tools used for the artworks concepts creation, the survey was useful to achieve the purpose of the thesis and even more, a robust set of recommendations were offered to Unilever for further discussions. The technical developed concepts pointed out that consumers are more likely to have an internally printed folding carton, specially a fully multicolored printing, increasing the consumer positive perception. In this way, Unilever can offer differentiation on their products.

This thesis only considered a specific series of conditions over the vast world of possibilities and solutions the Packaging Industry offers. Two packaging systems scenarios were raised from the beginning and analyzed through the thesis, the insights and recommendations about internal printing obtained can be relayed to other technologies, materials or inks.

List of Contents

List of Figures

List of Tables

List of Equations

1. Introduction

1.1 Project background

Packaging has always helped to preserve the contained food over its shelf life, from filling to consumption and has helped to transport food products, from the shelfs to the consumer household. In other words, Packaging has helped to protect and transport food products. Additionally, packaging has been used to differentiate products through its brand name, shape, material, size and specially, through its decoration (Mininni, 2009). An attractive decoration with an eye-catching artwork enhances the perception of added value on the consumer, bringing brand distinctiveness and growth, and at the same time, uniqueness and prevalence (Olsson et al., 2010).

Packaging is beside product, price, place and positioning, a key differentiator in the Fast-Moving Consumer Good (FMCG) Industry of modern days. Packaging can be used to offer to consumers a complete brand experience (Mininni, 2009). At the early days of convenience food products, including a basic print on the pack showed to be a meaningful differentiator, that was the early stage of branding.

Figure 1 Coca Cola evolution of branding (Wordpress, 2014)

Since those days, packaging has evolved much further, leading products to have a great differentiation at the selling point, grabbing attention, facilitating liking and driving purchase decision. Besides the innovative step of conserving foods or producing products in a large scale, branding, through printing a brand name and an image, has helped to create well-known brands and products over the past decades (Mittal, 2013).

Packaging can become a great resource for brands during the interactions between the consumer and a product, starting with the purchase decision in-store until the disposal time (Löfgren et al., 2005). Every moment when a consumer interacts with a product or brand, she or he confronts the Moments of Truth. The First Moment of Truth is the first physical interaction consumer-product at the selling point, the Second Moment of Truth starts when the consumer purchases a product, take it home and evaluates its quality (Löfgren, 2005; Mininni, 2009). Brands can evoke emotions through packaging decoration on consumers during the First Moment of Truth and can offer a consumption experience during the Second Moment of Truth (Stallard, 2014). It is during this Moment when a new story begins and the chance to trigger emotional reactions make consumers engage with the product and consequently, with the brand.

While the interaction in-store between consumer and product is rising expectations, which lead to the purchase decision, the initial opening at home is when multisensorial experiences can be created. This is the moment to astonish the consumer. There are some features that can be grasped during every opening, such as easy-opening or a re-sealing closure and furthermore, internal printing. Internal printing allows to design a new experience for the consumer based on innovative decorating solutions printed on the internal side of the product (Ampuero et al., 2006). An example is the inclusion of a recipe, an inspirational quote or a creative artwork. Internal printing stretches the brand emotive asset further (Mininni, 2009). The arduous task is to convert an internal printing from a practical benefit into an emotional payoff.

Coming back to the FMCG Industry, brands can firstly use printing to stand out at the point of sale and can use internal printing to enhance consumer experience at home. The development of internal printing on a packaging must be evaluated considering all the external and internal aspects involved in the topic. It is compulsory to consider from the beginning the intended end

use for the consumer unit, to identify and control the opportunities and risks. This includes, for instance, the material specifications, the food product and the utilized printing inks.

The company is looking for a feasible option to enrich the overall in-use experience by gaining differentiation in a safe way during the Second Moment of Truth.

Internal printing needs to be looked at from three perspectives to ensure a value adding and feasible execution:

- Technical feasibility
- Consumer perception
- Consumer safety.

This thesis evaluates the necessary work to achieve internal printing on a consumer unit containing multiple individually packed consumer units. Furthermore, the thesis gets an approach on consumer perception about internal printing and evaluates how to do it in a safe way. Internal printing is increasingly being used by few companies and categories, despite it can become a key factor to increase the consumer perception of a product (Zeithaml, 1988).

The technical feasibility, consumer perception and consumer safety assessment results are discussed and a conclusion is offered to the Unilever packaging development team, as well as a recommendation for future work. Based on the findings of this thesis, Unilever will have a better understanding of opportunities and constraints on internal printing.

1.2 Purpose

The purpose of this master thesis is to offer recommendations of the most technically feasible alternatives to present an attractive food packaging with internal printing in a safe way.

The purpose is accomplished by mapping available technologies, identifying the legal boundaries and doing an initial technical feasibility study. The outlined technical different attributes are used to create technically driven artworks during an initial quantitative consumer study.

With the insights captured, the thesis offers recommendations for a further development. The research objective raises following questions that will be answered from considering the three-pillar base, feasibility, safety and perception: while only solutions addressing the requirements of all three pillars sufficiently can be considered as a relevant option.

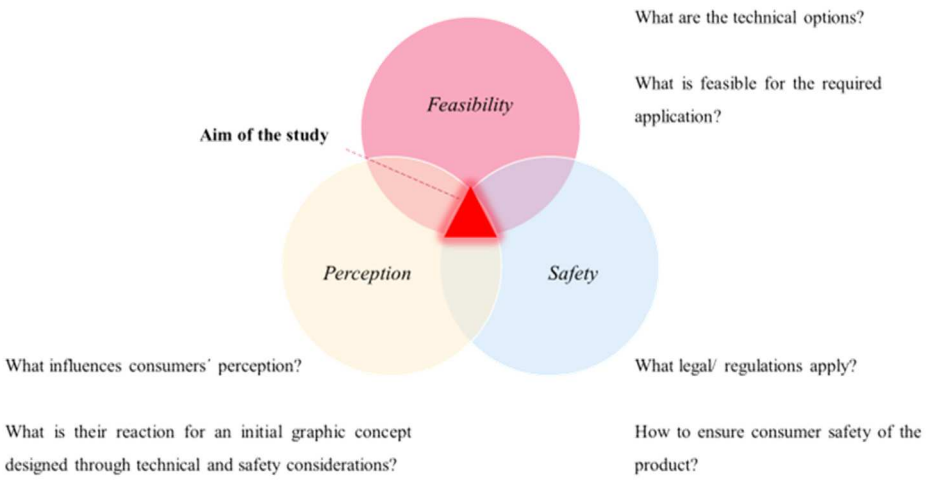


Figure 2 Areas and research questions

1.3 Delimitations

Based on the bandwidth of the topic, a selection regarding food formulation and packaging system had to be done, what will be kept in scope of this piece of work.

- The formulation of the food product to be considered is not strictly mentioned, therefore, the packaging solution proposed applies for a range that goes from a dry powder product to a fatty paste product.
- The packaging system baseline is formed by:

  a) **Secondary packaging**: refers to the consumer unit, the pack the shopper purchases at point of sale. In this thesis, the application is a folding carton containing one or more individual unit(s). At least one of its internal faces will contain the internal printing (substrate).

  b) **Primary packaging:** refers to the individual unit, which is a mono-portion pack, either fully sealed or wrapped. Hence the primary pack is in direct contact with the foodstuff and besides the convenience aspects, its role is to protect its content until first opening/ use.

  c) **Foodstuff/ food product:** refers to the food product, which in this consideration is a mix of ingredients, to be used in the cooking process, therefore, it is not the final food. It comes in a range of different consistencies, from a dry free flow able powder to a fatty shaped mass.

The combination of Primary pack with the foodstuff, is considered from a perspective of which combinations between sealed and non-sealed, dry and fatty are the two most extreme and relevant execution. Potential controls might be part of a recommendation where applicable. At the same time, modification of those are not in scope of this assessment.

Figure 3 Example of dry powder product in an individual primary packaging (sealed sachet), contained in a secondary packaging (folding carton)

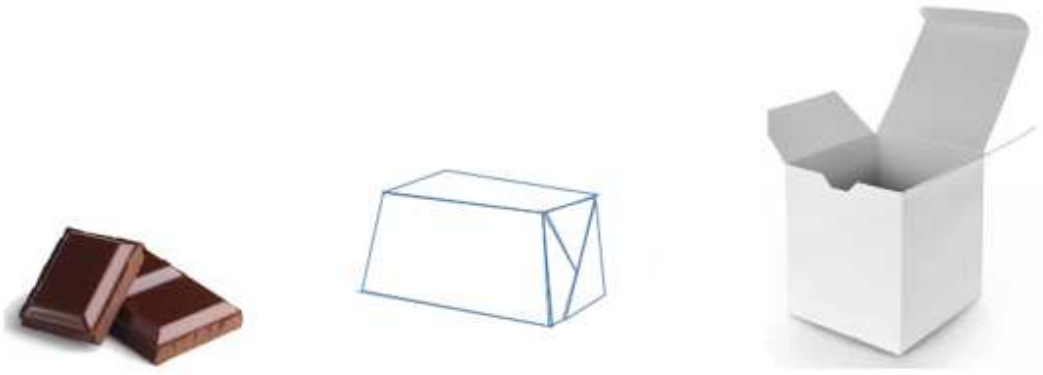


Figure 4 Example of fatty solid product in an individual primary packaging (folded wrapper), contained in a secondary packaging (folding carton)

2. Methodology

This chapter presents the research process used to achieve the objective of the thesis. The chapter consists of three main topics explaining (1) the research process, (2) the quantitative research and (3) the data collection.

2.1 Research process

The research process for this thesis consisted in secondary and primary researches. The secondary research considered an extent literature research while the primary research consisted on a market screening, expert interviews, risk assessments, technical assessments and a survey. Based on the collected data, recommendations are proposed to the Unilever packaging team for their further research.

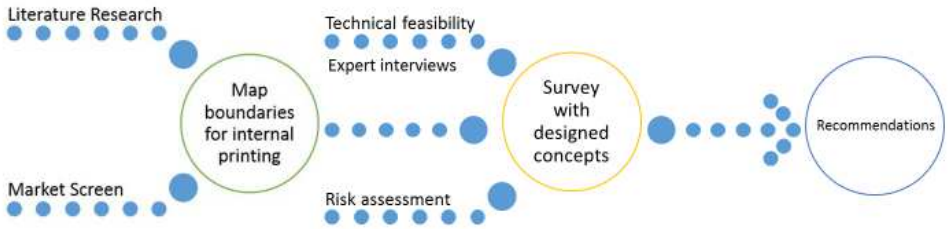


Figure 5 The research process

2.2 Quantitative research

Quantitative research is commonly used to measure facts and data to convert them into numbers that can be analyzed using mathematical process and express results using statistical technologies (Golafshani, 2003). For this

thesis, a quantitative research was done through a survey. The purpose of the survey was to collect data from at least 100 participants about consumer feedback of a specific topic and to analyze it to come to first conclusion.

The integration of the primary data with the insights from the secondary data provided a thorough understanding and helped to answer the research questions.

2.3 Data collection

The first data collected came from the secondary research, based on a literature research on the three pillars mentioned in Chapter 1:

- Technical feasibility
- Consumer perception
- Consumer safety

	DESK RESEARCH	PRIMARY RESEARCH
Technical Feasibility	• Market screening • Printing technologies • Food contact printing inks	• Experts interview • Feasibility test • Color space assessment • Robinson Test
Consumer Perspective	• Consumer experience	• Experts interview • Consumer Survey • Morphological Chart
Consumer Safety	• Food safety • Regulation framework • Migration • Mechanisms of migration • Functional barriers • Pinholes and fractures	• Experts interview • Barrier assessment

Table 1 Data collection chart

After creating and initial understanding on the key considerations of internal printing in the food industry, in depth data was collected from a primary research.

2.3.1 Desk Research

a. Market screening

A first approach to internal printing was done through a market screening of commercialized food products available in supermarkets. Samples were collected from different food groups, always fulfilling the packaging system condition (product-individual unit-consumer unit). A market screening is relevant for a research because it offers a first benchmark and put available options on the table.

The objective was to collect samples from the market and run an analysis of technical solutions available, this way an initial benchmark and solutions.

Germany has been selected for this market screening as on one hand site market screening because its internal market states as one of the strongest in the European Union (GTAI, 2017), and can be translated into competitiveness and consequently, into large product offer. Apart from this, the focus has been on available technologies and execution and in this way, a good overview from a European perspective can be assumed. The market screening was done in German supermarkets during February 2017.

b. Literature research

A specific theoretical framework for further empirical research of an existing or new topic is created through a literature research (Bewerton et al., 2001). A theoretical framework was created collecting data about printing technologies, inks, consumer perception on packaging and consumer safety. A regulatory affairs research was run to understand the legal framework of the topic.

The literature research demanded search engines such as Google, ScienceDirect, LUBsearch, as well as hardcopy publications, for instance, technical data sheets, suppliers´ manuals, leaflets, packaging magazines, etc. This research was conducted from 16th of January to the 28th of April.

2.3.2 Primary Research

a. Expert Interviews

Four experts were consulted to get detailed insights and advice on specific topic identifies during desk research. Intention was to use their expertise and experience on specific fields and advices to make the best decisions for the further research. Semi-structured interviews were used for resolving questions and allow the interviewers a degree of freedom to advice and explain their opinions (Flick, 2009).

- Ink supplier

The interviewed partner was selected following the market screening. The intention was to have a discussion with an expert who, based on its portfolio, has in-depth knowledge on internal printing. A medium-sized supplier is working on a special solution directly related to the topic of this thesis, understanding the rising demands for this market. The supplier was reached out to discuss the overall topics of a “potential direct food contact”. The interview was done in March face to face at their facilities with a length of four hours.

- Convertor

One key convertor of folding carton material was selected as the technical expert in different ink types utilized for food contact applications, including implications on converting steps, such as printing and die-cutting. An initial phone interview was done in February for one hour, presenting the topic and discussing their current work on this topic. The interview was continued through mail exchange. A second one hour length interview happened two months after, where specific feasibility questions were address for one hour.

- Consumer insight expert (internally).

An internal expert on consumer insight was consulted to discuss the best way to collect information, asking for software, questions type, interpretation, etc. The face to face interview happened at Unilever in May for one hour.

- Risk assessment expert (internally).

The first approach to consumer safety was done through an internal interview with two risk assessment experts, asking for the legal boundaries and compulsory information to look for. This happened in February via Skype meeting for two hours.

b. Barrier assessment

As described in the Delimitations section, this thesis will focus on two Primary Pack types, a sealed sachet and a non-sealed wrapper. In case of wrappers, two areas need to be assessed: pinholes and fractures. Both topics are explained in Section 3,2,5.

It is necessary to identify the level of protection offered by the primary packaging to the food product. The presence of fractures is related to the functional barrier loss, this means that the aluminum layer does not offer the same protection level to the foodstuff and possible migration from the ink components may occur through gas and liquid phase (Barnes et al., 2007; Majeed, 2012).

The method consists in a material inspection of the current aluminum based packaging to identify the presence of fractures. The samples assessed were previously selected from a leaking assessment, this way 20 samples out of 10´000 samples were analyzed through microscopy to assess the effect of packaging process on the material and consequently, a possible negative impact on its functional barrier.

For this assessment, samples of the current aluminum-based packaging under normal production conditions were evaluated on a Heerbugg Macroscope M400 (magnification 6,3x-32x), aiming on the intensity of fractures on

corners and folds. The assessment was made at the Unilever R&D Analytics Laboratory during May 2017.

c. Feasibility test

It is necessary to understand the technical feasibility of novel inks from a converting perspective. The internal side of the board is uncoated, this influences the final appearance and performance of the ink on crease lines, as advised during an interview. A comparative technical short run test of two offset inks was run to allow an initial perspective. A potential direct food contact ink and a low migration mineral oil free not-intended food contact ink were printed on both side of the board in the same machine. The first ink mentioned option claims to have a potential direct contact with food, therefore, it is vital to understand its capabilities before considering it as an internal printing ink option.

To run this assessment, a convertor (secondary packaging manufacturer) was contacted to make use its printing machines with both inks using Unilever board in March 2017.

d. Color space assessment

When comes to color perception of a printed paperboard, three parameters come into play: substrate, ink and luminosity. The substrate has different properties on both sides, so the final color perception of the inks varies. A standardization method for the color evaluation was needed to measure the color space of each ink application, regardless individuals´ perception. The Lab* color space is based on the three attributes of color: Hue (tone), saturation (brightness) and lightness (Oetjen, 2015).

Data is collected through a spectrophotometer that shines a light on the sample´s surface and examines the wave lengths of the reflected light. Then, the data is converted to three numerical values and mapped on a three axes graph creating a three-dimensional color space, as exemplified in the figure below. The L* axis stands for lightness, going from a high luminous color to an obscure color. The a* coordinates indicate a high red hue color or a high green tone color. Finally, the b* coordinates indicate a high yellow tone color

or a high blue tone color. A diagram of this method can be consulted on Appendix A.

The equations below were used to calculate the difference between each value and the total difference of a color between two ink application. On a typical scale, the ΔE^* up to 1 means there is not perceptible difference by human eyes, from 1 to 2 there is a perceptible difference thorugh close observation and above 3, a perceptible difference at a glance exists (Oetjen, 2015).

$$\Delta L^* = L_2^* - L_1^*$$

$$\Delta a^* = a_2^* - a_1^*$$

$$\Delta b^* = b_2^* - b_1^*$$

$$\Delta E^{*2} = \Delta L^{*2} + \Delta a^{*2} + \Delta b^{*^2}$$

Equations 1 Color space calculations

The basic colors of the CMYK model were evaluated using a spectrophotometer CM-5 from Konica Minolta (8mm disc, SCI mode) at the Unilever R&D Analytics Laboratory, on the 4th of May.

e. Robinson test

This test is used to evaluate deteriorative organoleptic properties potential (Barnes et al., 2007) and is applied to assess the ink performance. Aligned to Regulation EC 1935/2004, a printing ink must not bring a deterioration in the organoleptic characteristics of the food. The printed samples are stored in a glass jar for 24 hours and an odor test is conducted in a 5-step rating system. When the mean is equal or greater than the limit given, the material is considered as unacceptable. This test is based on the methodology EN 1230.

The Robinson test was run to approve the ink type (low-migration, mineral-oil free ink), regardless the final quantity used. The printed samples with both ink applications from the feasibility test were used to evaluate the odor intensity. Six testers were required to carry out an odor test panel, defining

an approval mean value above 1. The mean was calculated using the formula below:

$$\overline{x} = \frac{\sum x}{n}$$

Equation 2 Mean formula for Robinson test

f. Consumer survey

Surveys can help to perform a market segmentation analysis of a specific topic in a quick and easy way, they can either be used to measure consumer satisfaction, detect product potential improvements or develop new products. Consumers' answers are translated into insights that help to correctly drive into consumer´s perception, additionally, surveys may be useful to know undisclosed consumers' thoughts that are not so easy to get from a first approach and to identify unknown needs (Brewerton et al., 2001).

Unilever performed an initial qualitative research in the UK market which outlined a positive reaction to internal printing, getting first insights about multicolor internal printing. For this thesis, an online survey was carried out as the quantitative research with the purpose of assessing executions based on different technical constraints.

The online survey was divided in three parts. The first part required respondents to provide some background information to ensure that a representative sample of the population has been obtained. Two decision questions regarding internal printing were presented and one more decision question regarding uncoated external printing was asked. The purpose of these inquiries was to get a consumer perception overall between packaging with and without internal printing. The second part presented the four designed artworks internally printed and an internally unprinted packaging, the respondents were asked to rank three attributes: Attractiveness, Modernity and Trust. The images came randomly to ensure the consumer perception was always authentic. The last part of the survey set the five images together and the respondents were asked to choose their top three.

As described before, the online survey was used as an initial perception assessment on the artwork concepts to study the technical feasibility implied, it did not represent an artwork test nor an artwork content evaluation.

Innovation process

It is important to mention that two innovation tools were required to achieve a good survey performance: morphological chart and prototyping. Both ideas generation processes were developed before the survey execution, considering the technical feasibility insights collected from the market screening to the technical feasibility assessment.

The morphological chart is a technique based on the basic functions of a product (Suárez, 2016). Its visual aid boosts the continuos ideas generation and helps to discard incompatible alternatives, always led by logic and feasibility. On the left side of the table the different functions are listed and consequently, different mechanisms to achieve that functions are sketched.

Prototyping is an innovation tool where engineers and designers verify and validate assumptions, calculations and first decisions in a development process, all this through a prototype (Flick, 2009). In the case of this thesis, the developed prototype helped on the creation of visuals, in this way, it helped to answer the question “What does a consumer think when internal printing is displayed this way?”

The two innovation tools´ results are described in Chapter 4. The online software “Unipark” from Questback was used, 123 online surveys were collected from the 6th of May to the 14th of May.

3. Desk research

This chapter presents the results of the market screening and of literature research. A conclusion for each section is included as well, containing the main insights and its importance to the research objectives.

3.1 Market Screening

The first step was to set a benchmark and have a look on the actual situation of internal printing commercialized on the market and executed for foods products. Samples were collected and analyzed from a technical perspective. The technical execution of the artworks used on the internal face of the packages have been clustered into five different groups, depending on its quantity of inks applied and content, as shown on Table 3. The packaging materials for each unit level were analyzed based on the packaging system proposed.

- Primary packaging, considered the direct contact material to the product, it specifies the barrier level (Barnes et al., 2007). For this thesis, a special focus on the closure was crucial to understand the barrier level effectiveness.
- Secondary packaging, as the carrier of the internal printing, it was important to map the kind of board and printing technology used.

The following Figures contain examples of internal printing commercialized in the food industry. They show a consumer unit containing several individual units.

- The Figure 6 shows a fatty product from the confectionery category. The individual unit has a plastic unsealed wrapper.
- The Figure 7 shows a dry powder product from the beverage category. The individual unit has a plastic sealed wrapper.

Figure 6 Internal printing in fatty product, confectionery

Figure 7 Internal printing in dry products, beverage

The following chart presents the results of the market screening. Products were clustered by food category and formulation, then the primary and secondary packaging materials were analyzed.

	PRODUCT			PRIMARY PACKAGING			SECONDARY PACKAGING			INTERNAL PRINTING	
	Name	**Food group**	**Formulation**	**Material**	**Closure**	**Functional Barrier**	**Material**	**Substrate**	**Printing technology**	**Artwork design**	**Number of inks**
	Cheese	Dairy	*Fatty product*	Plastic wrapper	*Folded*	*No*	Recycled board	Uncoated	Offset	*Fully printed*	4
	Chewing gum	Confectionery	*Dry product*	Paper wrapper	*Folded*	*No*	Virgin board	Uncoated	Offset	*Pattern*	1
	Chewing gum	Confectionery	*Dry product*	Paper wrapper	*Folded*	*No*	Virgin board	Uncoated	Offset	*Fully printed*	2
	Chewing gum	Confectionery	*Dry product*	Foil wrapper	*Folded*	*Yes*	Virgin board	Uncoated	Offset	*Pattern*	1
	Chocolate	Confectionery	*Fatty product*	Foil wrapper	*Sealed*	*Yes*	Virgin board	Uncoated	Offset	*Fully printed*	4
	Chocolate	Confectionery	*Fatty product*	Foil wrapper	*Sealed*	*Yes*	Virgin board	Uncoated	Offset	*Pattern*	1
	Chocolate	Confectionery	*Fatty product*	Plastic wrapper	*Sealed*	*No*	Virgin board	Uncoated	Offset	*Pattern*	1
	Chocolate	Confectionery	*Fatty product*	Paper wrapper	*Folded*	*No*	Virgin board	Uncoated	Offset	*Pattern*	1
	Chicken Bouillon	Jelly Bouillon	*Semi-wet product*	Plastic cup with foil closure	*Sealed*	*Yes*	Virgin board	Uncoated	Offset	*Text + picture*	1

	PRODUCT			PRIMARY PACKAGING			SECONDARY PACKAGING			INTERNAL PRINTING	
	Name	Food group	Formulation	Material	Closure	Functional Barrier	Material	Substrate	Printing technology	Artwork design	Number of inks
	Egg	Meat	*Fatty product*	Shell	*Sealed*	*No*	Recycled board	Uncoated	Inkjet	*Small text*	2
	Egg	Meat	*Fatty product*	Shell	*Sealed*	*No*	Recycled board	Uncoated	Offset	*Text + picture*	1
	Coffee	Beverage	*Dry product*	Foil capsule	*Sealed*	*Yes*	Virgin board	Uncoated	Offset	*Pattern*	1
	Coffee	Beverage	*Dry product*	Foil capsule	*Sealed*	*Yes*	Virgin board	Uncoated	Offset	*Fully printed*	4
	Tea	Beverage	*Dry product*	Paper wrapper	*Folded*	*No*	Virgin board	Uncoated	Offset	*Text + picture*	1
	Tea	Beverage	*Dry product*	Paper wrapper	*Sealed*	*No*	Virgin board	Uncoated	Offset	*Small text*	1
	Tea	Beverage	*Dry product*	Fiber-based sachet	*Sealed*	*No*	Virgin board	Uncoated	Offset	*Small text*	2
	Tea	Beverage	*Dry product*	Plastic wrapper	*Sealed*	*No*	Virgin board	Uncoated	Offset	*Text + picture*	1

Table 2 Market screening from technical perspective

The following chart clusters the artwork execution observed during the market screening based on following parameters:

- Content
- Background
- Layout
- Quantity of inks used

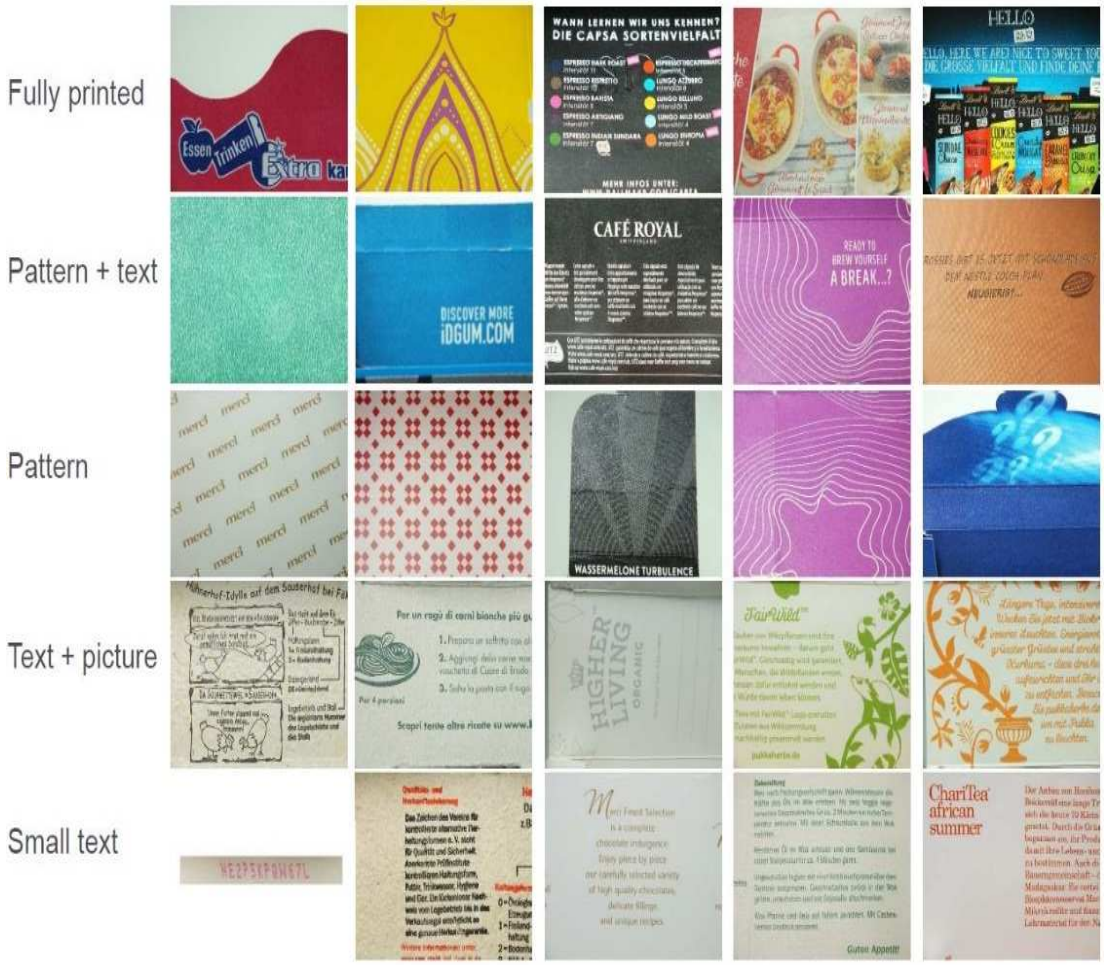


Table 3 Artworks clustered by content

3.1.1 Conclusion of market screening

Internal printing is not an innovation in the market, it has been shown that this feature already exists in different food products with different artwork designs, therefore, brands from this market screening have discovered that this feature means an option to offer new valuable information of the product (e.g. recipes), as way to promote other products or simply to include promotion codes.

The secondary packaging development needs to consider that during opening, the frontal internal face can be displayed in such a way that the internal printing has enough visualization. This means that the panel with the internal printing must be shown every time the consumer opens the consumer unit.

It has been observed that most of the products were multi-pack: several consumer unit per selling unit. This makes sense when thinking that the secondary packaging need to be re-opened several times, repeating the experience offered by the internal printing.

The primary packaging avoids the direct contact between the substrate and the food product. It should be noted that internal printing already exists for a wide range of products, from a fatty product such as chocolate to a dry product such as tea or chewing gum.

Different primary packaging materials were observed, in terms of this thesis, the food safety assessment was considered for an aluminum based wrapper and a sealed pouch or sachet.

Item	*Scenario 1*	*Scenario 2*
Product Type	Dried powder	Fatty paste product
Individual pack style	Sealed	Folded
Individual packaging material structure	Foil sachet	Plastic wrapper
Consumer unit pack	Virgin board based folding carton	

Table 4 Options range considered for this study

3.2 Literature research

3.2.1 Food safety

When it comes to food product, safety must be guaranteed over its intended usage period, from filling, over transport and storage to initial opening of the individual unit. For this thesis, the potential migration of substances of an ink through the primary pack into the food product is the issue in question. An industry guideline has been proposed for evaluation of a printed food contact material (EuPIA, 2008). The following scheme describes the target migration limits used in food packaging inks with no formal Specific Migration Limit and is based on the guidance developed by the Council of Europe for food packaging materials, in accordance with the European Food Safety Authority (EFSA) guidelines (Council of Europe, 2007):

- In case the substance has no or insufficient toxicological data, 10 micrograms per kilogram.
- In case the substance is demonstrated not to be genotoxic, 50 micrograms per kilogram.
- If the substance is supported by favorable toxicological data, a value higher than 50 micrograms per kilogram.

In addition to the guideline, an exclusion list of substances that must be avoided during the complete packaging chain and production of printing inks is given in the industry guideline (EuPIA, 2008).

To guarantee food safety, industries need to run risk assessments to identify the possible migrating substances that may move into the food from external materials. The tolerable daily intake values are set by national and international health organizations, considering the exposure time, hazard level, hazardous characteristics and general consumption habits of a population. These assessments consist in migration tests using different simulants depending on the type of food involved. Some other factors such as temperature and contact time are considered in migration tests.

Type of Food	Simulant
Aqueous Food	10% Ethanol (simulant A)
Acidic Food (pH <4.5)	3% Acidic Acid (simulant B)
"Ethanolic" Food	20% Ethanol (simulant C)
Semi Fatty Food Products	50% Ethanol (simulant D1)
Fatty Food	Vegetable Oil (simulant D2)
Dry Food	TENAX (simulant E)

Table 5 Simulants used in migration test (Flintgroup, 2017)

Nowadays, private and public research have demonstrated that packaging may face safety issues when protecting food, it has been shown that there is a potential that volatiles migrates through or from packaging materials to the food product and literally, any kind of packaged food could present migration unless they have a good functional barrier (Skillington, 2014).

3.2.2 Migration

Since different packaging materials constantly come in contact with food products, it is well known that chemical substances depending on the actual material might be released and transferred from packaging materials into the foodstuff over its shelf life (Barnes et al., 2007).

Aluminum is widely used and is known for its high functional barrier, however, its barrier properties are based on the way it is closed (Figure 8). Printing inks applied on packaging material surfaces might have substances´ migrating into the food products even if there is not direct contact with food (Siegwerk, 2015).

From a physics point of view, migration is a partition and diffusion controlled transfer process of small molecules, of approximately less than 1000 Dalton molecular mass (EuPIA, 2008). This means that low molecular substances in ink ingredients permeate through or from the packaging material into the food. In addition, temperature can enhance a higher migration rate as well as the contact time (Begley et al.2008).

Migrate properties	Substrate properties
• Polarity • Molecular size • Molecular weight • Affinity • Volatility (vapor pressure) • Concentration • Diffusion	• Packaging material properties • Contact time • Functional barrier • Temperature • Humidity • Permeability • Raw material condition

Figure 8 Migration factors

3.2.3 Mechanisms of migration

The transfer of substances from the packaging materials to the contained food product may happen in four different ways:

- Penetration (physical migration). It is the transportation of a substance from the substrate onto the unprinted side, enabling a direct contact with the food product. This is driven by an environmental condition change such as temperature, pressure or humidity (Barnes et al., 2007).
- Set-off (physical migration). Commonly called “invisible migration”, it shows up when the packaging material is reeled or stacked, so inks substances have contact with the reverse side of the packaging resulting in a potential migrates transfer.
- Evaporation and condensation (gas phase migration). Volatile ink components, such as mineral or vegetable oils, move from the printed packaging material to the food product due to heating. Low molecular weight compounds with higher vapor pressures will permeate faster in comparison with the high molecular weight compounds with lower vapor pressures (Ewender et al., 2013).

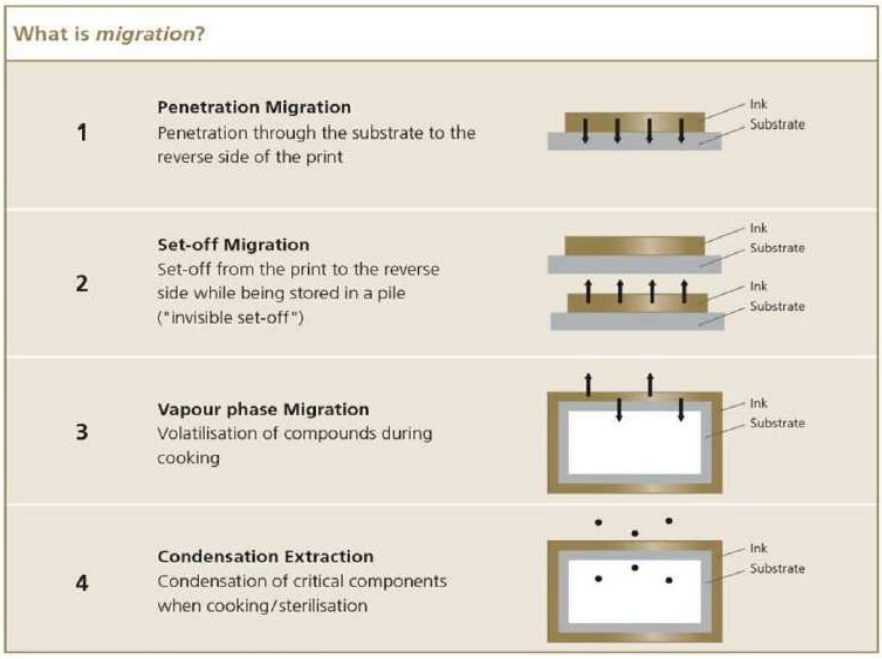


Figure 9 Migration Mechanisms (Flintgroup, 2017)

Finally, a risk assessment must be run for the full packaging system considering its end use to ensure the innocuousness on the food product; an overall migration test is always recommended (EuPIA, 2008). For this test, a simulant is used to measure the migration rate under the maximum exposure time and temperature reached of the system. The food product formulation determines the simulant to be used.

3.2.4 Functional barrier

This property refers to the migrating substances reduction offered by a packaging material. The reduction can either be on authorized substances to below their specific migration limit or to a not detectable level (Ewender et al., 2013). Only a few packaging materials, such as glass and aluminum foils, work as an excellent barrier to substances (Barnes et al., 2007).

The requirement of a protection against external threats can be explained in a better way through the emerging concept known as “functional barrier doctrine”. This principle dictates that, if a substance is not part of the food-contact surface of a package and is separated from the food by a barrier that prevents migration of the substance to food, then the substance is not reasonably expected to become a component of food, thus, is not a food additive, according to the Food, Drug and Cosmetic Act (Heckman, 2001).

3.2.5 Pinholes and fractures

Foil packaging materials face two main issues, the presence of pinholes and the fracture of the aluminum layer. Pinholes are caused during the manufacturing process of the aluminum layer (Murray, 2005). Several factors such as contaminants in the aluminum matrix, filtration of particles from lubricants and oils or rolling conditions enhance the appearance of pinholes during the production process.

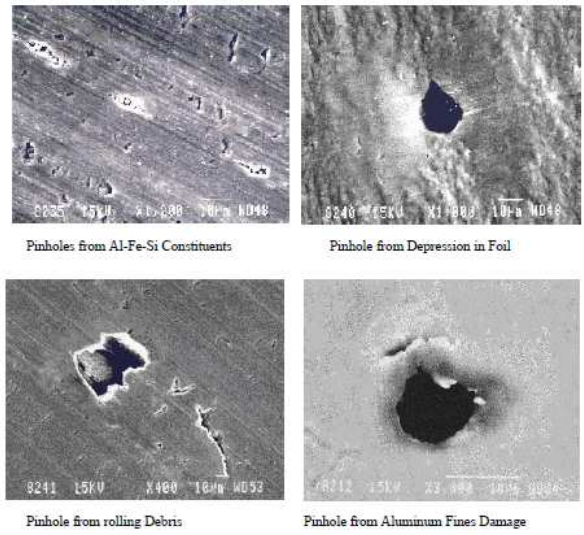


Figure 10 Pinholes in foil wrappers (Murray, 2005)

On the other hand, fractures appear during the handling or transportation of a package. They are caused because the energy applied during bending or folding is higher than the resistance of the material (Majeed, 2012). The average diameter of a pinhole is so small, that it is extremely difficult to have any transmission of oxygen and water (Murray, 2005). Therefore, any kind of migration from printing inks is discarded as well.

In the case of fractures, the permeation rate depends on the size and depth of the rupture. As mentioned before, aluminum represents a barrier to the ink migrates (Barnes et al., 2007). Consequently, it is necessary to determinate if the fractures break the aluminum layer, leaving the food product exposed to possible migration.

Figure 11 Fractures in foil wrapper (Murray, 2005)

3.2.6 Regulations

This section contains the regulatory frameworks for the following markets: European Union, Nordic countries, USA, Latin America and the Philippines. It should not be considered as extensive for complete regions. This information has been collected on May 2017.

To ensure a comprehensive coverage of the topic, it is compulsory to know majority of regulation involved in the countries where the final good is aimed to be distributed. The standards relating to inks used in food packaging applications vary between regions and countries. The final regulatory research will show the best general compliance scenario and will help to understand the whole picture of what is needed to achieve. Below is presented a review about the main regulations involved in the approval:

a) European Union regulations

The legal bases are European Regulations by the European Commission (EC) No 1935/2004 and No 2023/2006, they detail the overall requirements regarding selection and use of materials and articles intended to come into contact with food. Specific Migration Limit (SML) restrictions are defined by the European Food Safety Authority (EFSA) for substances based on toxicological evaluations followed by a risk management decision by the European Commission. For most of the accepted substances, the overall migration limit contained in a food product is 60 mg/kg (Council of Europe, 2007). Some countries work under their own legislation considered to be aligned with the mains European Regulations and guidelines suggested by EuPIA.

Traceability is a general obligation derived from the general food law to ensure material can be easy to identify and, if needed, easy to recall. As is known, an appropriate traceability system helps an industry to maintain a high level of control over its production.

- Regulation (EC) No 1935/ 2004

Since 1976, this regulation has been the core framework for EU legislative requirement regarding food contact materials. This regulation states that all those materials intended to come into direct or indirect contact with food must avoid deterioration and changes in the composition of the food.

In accordance with article 3: “Materials and articles, including active and intelligent materials and articles, shall be manufactured in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could:

- ✓ Endanger human health, or
- ✓ Bring about an unacceptable change in the composition of the food, or
- ✓ Bring about a deterioration in the organoleptic characteristics of the food.”

- Regulation (EC) No 2023/2006

A guideline that offers the requirements which shall be followed to provide the assurance of Good Manufacturing Practice. As defined on Article 3, “Good Manufacturing Practice (GMP) purpose is to ensure that materials are produced with the quality standards appropriate to their intended use by not endangering human health or causing an unacceptable change in the composition of the food”.

Additionally, this regulation details Good Manufacturing Practices regarding formulation, production, application and most important, handling and storage in such a manner that substances from the printed surface are not transferred to the food-contact side.

- European Printing Ink Association (EuPIA)

Founded in 2003 as a division of the European Council of the Paint, Printing Ink and Artists´ Colours Industry (CEPE), EuPIA contributes to the packaging industry with frameworks safeguarding the health, safety and environment (EuPIA, 2008). EuPIA has published guidance documents and other reliable information for their member companies and their supply chain partners to continuously increase the awareness of the printing ink industry (Barnes et al., 2007). Some of the key relevant aspects proposed by EuPIA for ink producers are:

- ✓ Comply with Exclusion Criteria:
  - Cancerogenic, mutagenic, reprotoxic (CMR)
  - “Toxic” or “Very Toxic”
  - Sb, As, Cd, CR(VI), Pb, Hg, Se compounds
- ✓ Purity requirements.
- ✓ Operate under Good Manufacturing Practices.

The rules set out by the European Printing Ink Association are well-regarded worldwide and include reference to commonly used lists of raw materials that can or cannot be used.

- Council of Europe

A committee of experts on food packaging materials known as the Council of Europe (CoE) prepared a resolution on "Packaging inks applied to the non-food contact surface of materials and articles intended to come into contact with foodstuffs". The resolution states that the ink supplier is responsible for the composition of the ink and every detail regarding manufacturing, traceability and used substances must be communicated to the printer (Barnes et al., 2007).

The CoE resolution is accompanied by three technical documents (TDs). TD1 provides a scheme and a list of substances used by the printing industry including an exclusion list. TD2 is a guide for Good Manufacturing Practice. Finally, TD3 gives guidance on conditions to be used for testing packaging inks applied to the non-food contact surface of food packaging materials (Council of Europe, 2007). It is important to mention that the resolution does not apply when:

- ✓ There is evidence that a substrate stops the migration of any component.
- ✓ Gas phase transfer and set-off can be excluded.
- ✓ Glass bottles, aluminum tins and corresponding materials are used as primary packaging.

- Switzerland and Germany

In Switzerland, a new regulation was issued in 2010 where a complete list of substances used on printing inks is provided based on the inventory list given by EuPIA and the Council of Europe. Such list states that regulated substances must comply with the Specific Migration Limits set in the EU Policy Statement and non-regulated substances can be used if the detection limit is up to 10 micrograms per kilogram. The Legislation is known as Regulation SR 817.023.21.

A new law on food contact materials and articles will become effective in May 1, 2017 (Safeguards, 2017). Under this law, food contact materials are to be manufactured using the good manufacturer practices described in Regulation 1935/2004, the highlight related to paperboard and printing inks s of the Swiss law are:

1) For paper and cardboard articles, food must be able to be separated from these materials.
2) For printing inks, prohibited if these are in direct contact with food or migration of color occurs and may only be manufactures using substances in Annexes 2 and 10 of the Ordinance of the FHDA on materials and articles intended to come into contact with foodstuff.

In Germany, the Swiss regulation on printing inks functioned as starting point for a draft regulation including a list of substances which are approved for food contact ink formulations. Such substances are approved due to evaluations by the European Food Safety Authority and the Federal Institute for Risk Assessment. The non-regulated substances may be used if the migration rate is under 10 micrograms per kilogram food and if they are not classified as toxic agents.

- Nordic Countries

So far there is no additional legislation on printing inks. However, Denmark, Finland and Norway request declaration of compliance for all type of food contact material, i.e. printing inks.

b) Americas regulations

Regulations across the continent are mainly guided by the Food and Drug Administration (FDA) and are similar to the European guidelines and standards. It is the FDA who evaluates and authorizes the substances in the positive lists through very demanding industry notifications and toxicological evaluations (Barnes et al., 2007).

- Food and Drug Administration (FDA).

This governmental agency from the United States of America oversees regulating matters related to Health and Safety, including food and all of its related packaging materials. Food packaging inks and coatings are typically catalogued as Indirect Food Additives, in turn indirect additives are those materials in the packaging that have no functional effect in the food but that may reasonably be expected to become components of food or to affect its characteristics (Gettis, 1995). Under this definition, printing inks are subject

to FDA regulations and as detailed in the Food Additives Amendment to the Federal Food, Drug and Cosmetic Act (FFDCA), a food additive shall be deemed unsafe unless it conforms to an exemption, a regulation listing or an effective food contact notification. However, this statement heads to the discussion that if the packaging material shows to be a barrier impermeable to migration into the food product, the material would not be considered as a food additive. This is known as the functional barrier doctrine (Heckman, 2001).

- Latin America Regulations

Mercosur countries (Argentina, Brazil, Paraguay, Uruguay and Venezuela) developed a regulation on food contact materials known as GMC (´Grupo Mercado Común´), based on the current EU and U.S. regulations. One of the most important considerations is that overall migration limit in Mercosur countries for foreign substances into food is 50 mg/kg food. Brazilian Health Department issued two regulations for food packaging material: the GMC framework Resolution DOU DE 20/05/99 provides general criteria for all food contact materials and states that all materials to be in contact with foodstuff must achieve the positive list principle with foreign substances migration rates below the limits. Resolution DOU DE 30/06/2016 describes the general restrictions for fiber-based food packaging materials. Both regulations describe migrations test using food simulants, like the European methodology.

Thus far, there has not been a specific legislation in Mexico regarding printing inks nor food packaging materials. It is expected that there will be new standards put in place by the Mexican Organization for Standardization and Certification which will be based on the U.S. regulations (Siegwerk, 2015). The NOM-252-SSA1-2011 regards heavy metals limits on toys and works as benchmark for food packaging materials and packaging material ink matters.

c) Asian regulations

- The Philippines

In the Philippines, the food safety regulatory system protects consumer´s health through the Republic Art No. 10611, known as the “Food Safety Act of 2013”. In Section 18 it is stated that “The Department of Health shall ensure the safety of all food processing and product packaging activities” (Siegwerk, 2015). Like the FDA declaration, printing inks are considered as packaging components that may become part of the food as food additives. The Bureau Circular No.2006-016 contains a list of permitted food additives with maximum allowed amounts in different food categories.

d) Regulatory framework review

- Europe: Regulation 1935/2004, 2023/ 2006 & Swiss Law.

Food contact materials should not transfer their constituents to food in quantities which could endanger human health, bring an unacceptable change in composition or organoleptic characteristics of the food.

- North America - FDA guideline 21 CFR Parts 173-178.

Food contact materials are catalogued as indirect food additives "materials with in the packaging that have no functional effect in the food but may reasonably be expected to become components of food".

- Latin America - Resolution DOU DE 20/05/99 *(Mercosur members)* NOM-252-SSA1-2011 *(Mexico).*

Food contact materials migrates rate below limits.

- Asia - Republic Art No. 10611, Section 18 *(The Philippines)*

Packaging components listed as food additives with maximum allowed amounts.

	Food Packaging Legislation	Positive List	Printing Inks Legislation	Positive List
EUROPE				
European Union	X	X		
Switzerland	X	X	X	X
Germany	X	X	X	X
Nordic countires	X	X		
NORTH AMERICA				
USA	X	X	X	X
LATIN AMERICA				
Mercosur countries	X	X		
Mexico	X	X		
ASIA				
The Philippines	X	X	X	X

Table 6 Regulatory framework

3.2.7 Printing technology

Printing technologies offers a wide range of options to the paperboard industry. Different visual choices and features are well covered due to the high flexibility of the board properties. The main printing processes used in this industry are offset, flexography, gravure printing and recently, digital printing. After applying the ink on the surface of the packaging material, or substrate, the drying process takes place. Different mechanisms of drying can be used depending on the final printed material and on the technology method used, for instance, evaporation, oxidative drying, absorption and lately curing systems, like UV and EB, have been developed with time-cost benefits. It is important to mention that during this thesis, curing systems are not considered due to the remaining risk of uncontrolled monomers (Richter et al., 2009).

- *Offset*: This technique is the most used one for printing paper and cardboard Food Contact Materials.
- *Flexography*: Can be applied to all kind of materials used in the food industry, such as plastics, metal and paperboard.
- *Gravure*: Capable of detailed printing of high quality but more expensive (Pederson et al., 2012).

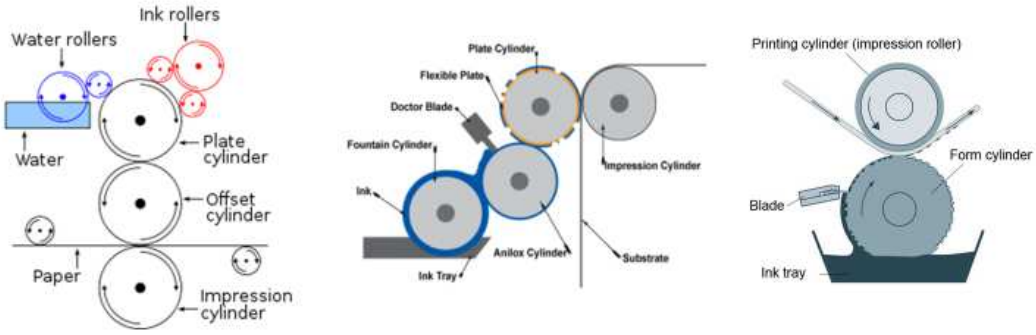


Figure 12 Comparison between printing technologies

Offset (left), Flexo (middle) and Gravure (right)

3.2.8 Printing inks

Printing inks are crucial for the packaging industry, colors help to easily differentiate a product on shelf from another, they can enhance its benefits and can help the consumers to notify about its claims (Ampuero et al., 2006). When talking about food packaging, the ink topic must be managed under specific supervision: toxicological and migration properties must be observed (Barnes et al., 2007), particularly regarding direct contact articles where a specific risk assessment must be achieved.

For this thesis, two types of ink are considered for the food industry: Low migration inks which are not used on a food-contact side and food contact intended inks. It is important to clarify the difference between direct and indirect contact, direct contact refers to the materials intended to be in contact or touching the food, while indirect contact is defined as materials that might come in contact with food, such as the outside of bags, boxes or cartons (Gettis, 1995).

The major printing ink components are colorants, binders, additives and solvents, the latter composed by mineral or vegetable oil that tend to be the most migrated substances (Richter et al., 2009). Mineral oil components must be avoided in food packaging printing materials because of its pronounced migration potential, nowadays it is possible to substitute it by less hazardous compounds, e.g. unsaturated fatty esters (Ewender et al., 2013).

The European Printing Ink Association (EuPIA) published on 2015 a guideline named “Suitability of sheetfed offset printing inks and varnishes for the manufacture of food packaging” where a brief of inks options for non-food contact side packaging material application is suggested. Regarding suitable solutions for the manufacture of food packaging without effective barrier, a low-odor and low-migration sheetfed mineral oil free offset ink and varnish must be considered as long as they fulfill all the regulation affairs explained in the Regulatory Affairs section. Typically, every ink layer is followed by a varnish, to protect it from scratches and depletion, in terms of food contact inks, food grade varnishes must be selected as well, with the same low-migration properties. Suppliers offer low-migration sheetfed offset inks formulated specially for printing on the outside face for the food industry

demands. These options must contain only special vegetable oils or fatty acid esters approved in the EU for food contact (EuPIA, 2015).

For intention of this thesis, UV cured inks are not considered as a relevant option. This is because of a potential risk of uncontrolled monomers transmission rates into food. There have been a few reported cases through the years by some of the most important associations regarding inks.

There has been done an overall market assessment, to identify potential supplier of printing inks solutions for food contact materials considering four printing technologies. The table below presents suppliers with an offer for inks for direct food contact packaging and of direct food contact inks.

	Printing Technology							
	Offset		Flexo		Gravure		Digital	
	Food contact intended inks	low migration inks non food contact side	Food contact intended inks	low migration inks non food contact side	Food contact intended inks	low migration inks non food contact side	Food contact intended inks	low migration inks non food contact side
Colorcon								
Domino Printing Sciences								
Doneck Euroflex S.A.								
Epple Druckfarben AG								
Flint Group								
Follmann GmbH & Co. KG								
Hubergroup								
Jänecke + Schneemann								
LaSorgente SPA								
Siegwerk Druckfarben AG								
Sun Chemical								
Zeller + Gmelin GmbH								

Table 7 Suppliers of food contact intended inks (EuPIA certification)

3.2.9 Consumer experience

Consumer´s preference is the main aim of every product development and in a high-competitive sector such as Food, products need to be differentiating from their competitors (Ampuero et al., 2006). The consumers may evaluate a product when they purchase it and when they consume or use it, this means that the perception of quality is created both at the point of purchase and during use (Löfgren et al., 2005). Consequently, the quality attributes of

packaging must be designed for displaying quality both when on the selling point and during the consumption. The consumer experience with the product and package use after purchase is equally or even more important for customer satisfaction (Olsson et al., 2010). This is known as the second moment of truth, the moment when the consumer uses, consumes and disposes or stores the packed product.

Every consumer, no matter its preferences, has a main common point: the opening experience. This moment can be a key factor to increase the consumer perception of the product, converting an internal printing from a practical benefit into an emotional payoff (Zeithaml, 1988). An effective execution can achieve a brand distinctiveness and bring growth, and at the same time, uniqueness and prevalence.

3.2.10 Conclusions of literature review

Safety is an essential requirement in the food industry. The food product formulation is as relevant as the packaging materials used, so only by having full visibility of all production steps and the intended end us, a relevant assessment can be done. This must be assessed individually case by case considering its specific situation and the Regulation needs, for instance, Regulation 1935/2004 in the European Union.

When a project involves activities where any of these levels may be endangered, an exhausting assessment to minimize and control the threats must be managed, as recommended by the risk assessment expert. An overall migration test is always recommended as a method to ensure the migration rate is below the specific limit.

Functional barriers increase the food integrity and prevent contamination by the inclusion of functional barriers into the packaging assembly. As explained by Ewender et al. the most favorable strategy to reduce or prevent migration of chemical contaminants is the use of functional barriers, that can be in the form of an inner linear bag or a barrier coating. In the case of the packaging system proposed for this thesis, the primary packaging of the

individual unit needs to prove that it offers a high protection level to the food product.

The technical options have been described and the difference between a regular ink and an ink with potential direct food contact have been explained. The technical feasibility needs to consider various elements during its testing, for instance, the kind of substrate to be used, type of ink and an evaluation of the printing technology.

Regarding technology, offset is the printing technology available today to print folding cartons in all regions, therefore, an in-depth discussion took place with various supplies in this field. To do a suitable comparative technical assessment, it was important to only consider printing inks formulated for the food industry application, considering UV cured inks out of scope.

4. Results of primary research

This chapter presents the findings from the different pieces of primary research on: (1) food safety assessment, (2) technical feasibility of internal printing and (3) consumer perception of technical artwork execution based on certain limitations. The implications of the research results are discussed in Chapter 5.

4.1 Food safety assessment

A food safety assessment was run for a product which formulation range goes from a dry powder to a fatty paste. Two scenarios for the packaging system need to be considered, as presented in Section 1.3:

- Powder in an aluminum-based sealed sachet in a folding carton
- Fatty product in a plastic folded wrapper in a folding carton

4.1.1 Barrier assessment

As mentioned before, one of the primary packaging considered during this assessment is a sealed aluminum based sachet. The chemical barrier offered by Aluminum can be discarded if pinholes or fractures happen. The average diameter of a pinhole is so small, that it is extremely difficult to have any transmission of oxygen and water (Murray, 2005). Therefore, any kind of migration from printing inks is discarded as well.

Pack format: Sealed sachet.

Following the Burst testing method, there has been sufficient measurement data available confirming that a sealed aluminum based sachet is sufficiently well-sealed. Seal integrity can be guaranteed on a consistent basis.

Pack format: Unsealed wrapper

In non-sealed packaging, it is apparent that migration via gas phase cannot be excluded and this meets to be considered. To assess migration through this packaging material, a three-step approach was taken.

Step one:

Prescreening of a sample size of minimum 10´000 samples was taken to identify samples showing a potential risk of leaking. These samples were storage at high temperature (45°C) as a worst-case scenario. After one week, 23 samples were identified and used for an in-depth assessment.

Step two:

The preselected samples were considered to have corners fractures and were analyzed through microscopy to assess the effect of packaging process on the material and consequently, a possible negative impact on its functional barrier in the folded corners.

Due to the functional barrier offered by the aluminum layer of the wrapper, it is compulsory to evaluate the level of protection offered by the primary packaging. The shape of the specific food product evaluated on this thesis makes the corners and folds more tempted to this damage. Fractures were found in some of the corners, with aluminum ruptures from 520 µm to 2250µm.

Step three:

The shape and location of the fracture could as well be identified and the respective machine pack material interaction captured and outlined. This helps to ensure that controls are provided and from a quality assurance perspective, prevention of occurrence. Therefore, this allows that the structural properties of the primary packaging material can be guaranteed throughout the shelf life of the product.

4.2 Technical feasibility of internal printing

4.2.1 Expert interviews

The takeaways of each interview were:

- Ink supplier

The ink supplier outlined the reason of having a special solution, there has been an increasing demand for this market. Regarding the ink solution, technical matters were discussed, for instance, ink properties and composition, benefits and threats during the application. Questions on topics regarding feasibility, supply chain, applications and artwork design were discussed. The interview was a good opportunity to watch real examples of application of the solution ink on current products of their portfolio. Additionally, the ink supplier recommended to run a Robinson Test to determine the effectiveness of the in as a low-migration option.

- Convertor

The interviews put on the table vital insights from the two of the three pillars, they have been working with internal printing for a couple of years. Their in-depth knowledge helped to remark topics during the printing and die-cutting. The technical feasibility was discussed, the convertor advised that crease lines need oversight because some inks used on this kind of applications may have quality issues. Internal artworks development needs to consider the same tolerances and concerns as with external artworks.

- Consumer insight expert

During the interview, an initial review of the consumer perception objectives helped to get first insights on how to approach to consumers, depending on the kind of information needed is the way a survey must approach. The recommendation of Unipark as a robust and free software helped to get the survey done, as well as other tool such as Wordle for the word map. This way, an online survey with specific questions was built up to get vital consumer insights with the support of the expert.

- Risk assessment expert

After presenting the scope of the thesis and the packaging system involved, the risk assessment gave their insights regarding food safety. During the interview, it was planned to assess the primary packaging from a previous leakage assessment to evaluate the effect of packaging process that could lead to a functional barrier issue.

4.2.2 Feasibility test

The parameters and characteristics selected for the board and the ink are featured below. Only one supplier was reached out for the test because it had both options available by the time of this thesis. However, it is not the only supplier with ink options.

Board properties

- Virgin board based
- Grammage: 225 g/m²
- Thickness 0,40 mm
- Coated on the outside, uncoated on the inside
- Base color: White opaque on the outside (CIELab L* 93 a* 0,9 b* -1,3) and slightly yellow on the inside (CIELab L* 91 a* -0,2 b* 9,3)
- Printing method: Sheetfed Offset

Food contact intended ink properties

- Supplier: Epple Druckfarben
- Name: BoFood Organic
- Potential direct food contact
- Low migration mineral oils free ink, suitable for the food industry
- Low-odor binding agents
- Density of 0,6 for the primary colors (CMYK)
- The overall migration values are below limits

Low migration ink properties

- Supplier: Epple Druckfarben
- Name: BoFood
- Not-intended food contact ink
- Low migration mineral oils free ink, suitable for the food industry
- Low-odor binding agents

Machine behavior for both inks was similar, no big issue was reported. The test proved that the tested ink is technically feasible from a machinability perspective. The following figure shows a comparison between the ink applications.

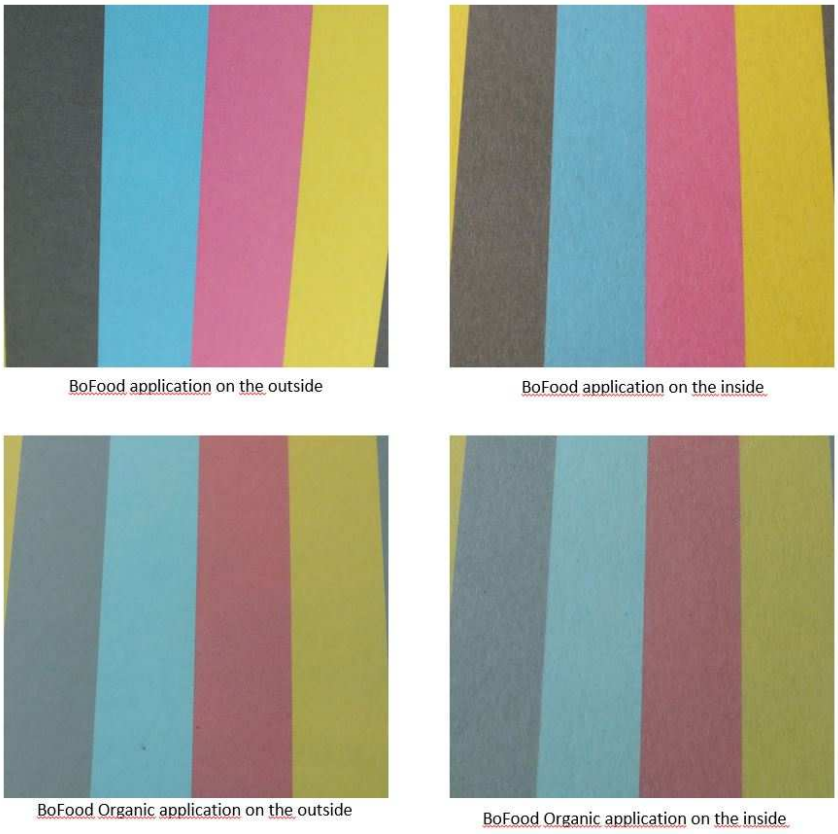


Figure 13 Inks applied on both sides of the board

4.2.3 Color space assessment

Following the methodology described in Section 2.3.2 b, the color space measurements of the potential direct food contact ink (BoFood Organic) samples and the regular ink samples are reported on the Table 6. The Lab* values for Cyan, Magenta, Yellow and Black colors were obtained for both inks applied on the two substrates. The results show that the printing quality of the tested food contact ink is acceptable, however, there are important differences compared to the regular printing ink on the outside. A graphic explanation of this test is shown in the Appendix section of this thesis.

	Yellow			Cyan			Magenta			Black		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
BoFood Organic on the Outside	*86,3*	*-3,8*	*37,9*	*84,4*	*-16,0*	*-11,0*	*66,7*	*25,4*	*2,9*	*67,1*	*-4,3*	*-3,4*
BoFood Organic on the Inside	*85,0*	*-5,3*	*36,8*	*84,6*	*-11,9*	*1,7*	*69,0*	*19,1*	*8,7*	*68,8*	*-4,1*	*4,3*
Regular ink on the Outside	*88,5*	*-1,7*	*51,3*	*74,2*	*-19,0*	*-23,8*	*67,3*	*33,6*	*-7,4*	*53,0*	*0,1*	*-0,9*
Regular ink on the Inside	*86,6*	*-1,9*	*56,1*	*73,3*	*-20,3*	*-13,9*	*66,2*	*32,4*	*-2,7*	*56,8*	*-0,2*	*6,0*

Table 8 Color space results

4.2.4 Robinson Test

The testers indicated the odor intensity by smelling the headspace of the jars containing the samples. The odor intensity was ranked through the following criteria:

- 0: No perceptible transfer of odor
- 1: Transfer of odor just perceptible (still difficult to define)
- 2: Moderate transfer of odor
- 3: Moderately strong transfer of odor
- 4: Strong transfer of odor

During the interview with the convertor, they commented that this method is used in one of their current internal application, pointing out that the organoleptic properties of the food product must never change. The samples tested all used the same board, the ink applications were:

- Low migration ink printed in feasibility trial
- Food contact intended ink printed in feasibility trial
- Low migration ink from commercialized product, supplied separately

Four stripes of 3,0x 1,0 cm of all three internally printed boards in every jar were independently stored for 24 hours using an aluminum layer to close the jar. The mean reported values of the 6 testers on the three inks were below 1, meaning that there is not perceptible transfer of odor in any of the three inks applications. The tested food contact ink does not seem to influence organoleptic properties of the food product.

4.3 Consumer perception of internal printing

4.3.1 Survey input

The collected technical feasibility insights from the market screen and the feasibility assessment were translated into technical concepts to assess the consumer perception impact through a survey. The new insights will help to understand the level of differentiation offered by internal printing compared to an internally unprinted board.

As explained during the Methodology Section, before the survey it was necessary to develop conceptual artworks based on the technical briefing. To achieve this, two innovation tools were used.

Morphological chart

Based on the technical feasibility insights previously collected, four functions were examined: background, content, layout and quantity of inks.

- Background: Determines the base of the final internal printing
- Content: Represents the message to be communicated
- Layout: Determines the arrangement of the content
- Inks used: Defines the quantity of colors to be used

Different options for each function were sketched out and the ideas generation started to build up the technical concepts. To reach suitable artwork concepts, a graphic design agency was briefed with the technical concepts and developed with the artwork concepts.

This was an unbranded test where the wording was kept consistent, on any of the concepts to avoid consumer´s bias. It is important to mention that the concepts were used to assess consumer perception from the technical feasibility insights, they were not designed to be used for an artworks evaluation.

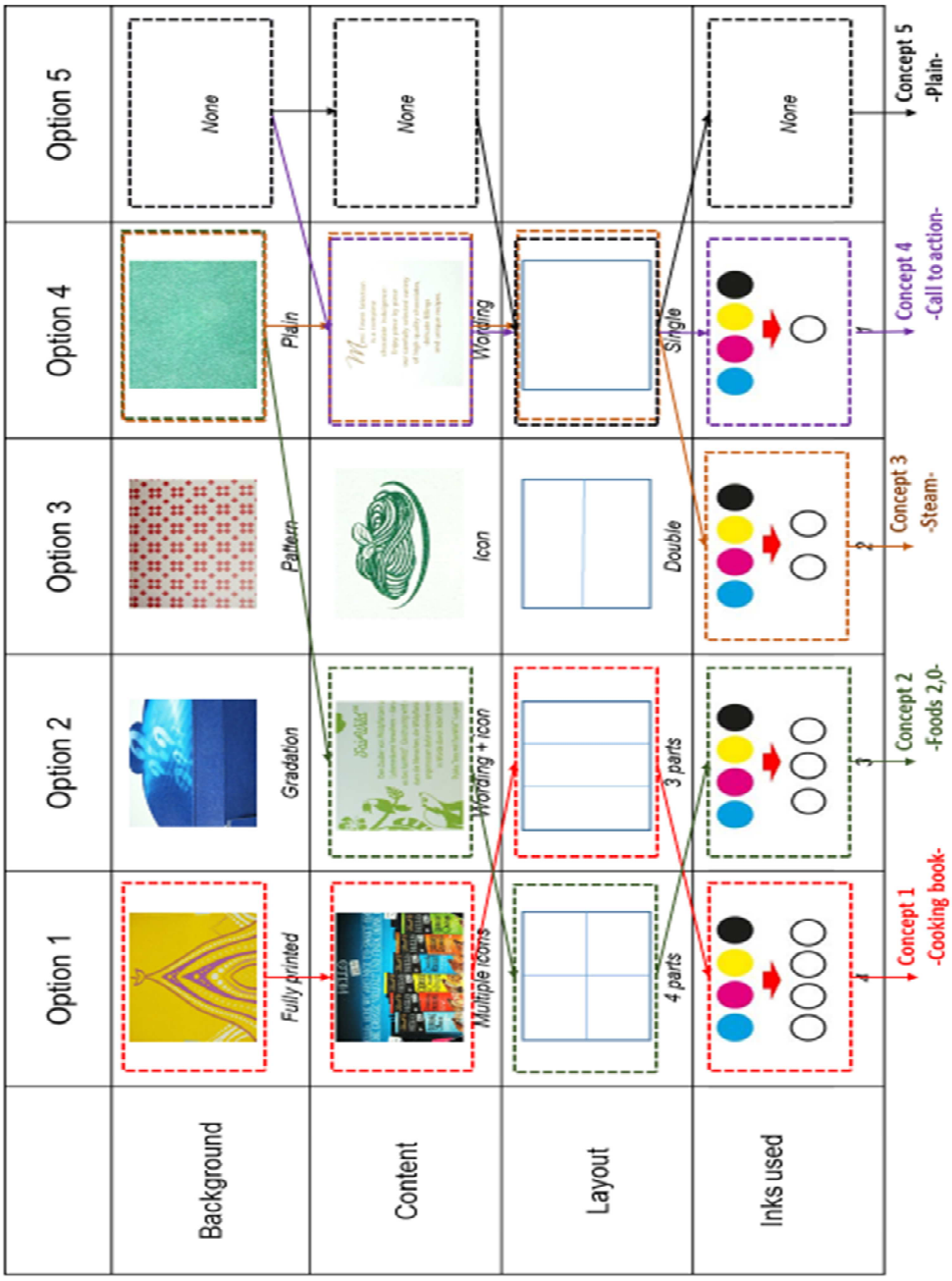


Table 9 Morphological chart developed and code names for artworks concepts

Creation of visuals

One physical packaging prototype was developed to be used in the consumer online survey. To have an excellent visualization of the developed artwork concepts, the protoype was designed to be opened in a way that the frontal internal panel showed the full graphics, as learnt from the market screening. The final prototype had the following characteristics.

- Board used: Current material (same characteristics as the one used for the technical feasibility assessment).
- Shape: Folding carton (L: 10,3cm, H: 3,5cm, W: 6cm)
- Both sides without printing
- Filled with 26 sealed orange sachet (L: 6cm, H: 3,5cm, W: 0,4cm)

Figure 14 Prototype used to show the developed concepts

Regarding the content on the artwork concepts, the technical insights pointed out that text and icons are tended to be used in the market, as well as more "plain" concepts are also well-exploited. It was arranged to use a generic wording, when needed. The final wording relates the packaging concept to a

food product in an “organic” way, therefore, the following text was used in spanish (translation down below):

“Buen sabor, naturalmente”

Buen sabor, that means “Good flavor”, stands for the objective of the final application, being a relevant claim for any food product.

Naturalmente, that means “Naturally”, stands as an excellent claim for any food brand enhancing the natural origin of its ingredients.

Finally, the concepts used on the creation of visuals were as following:

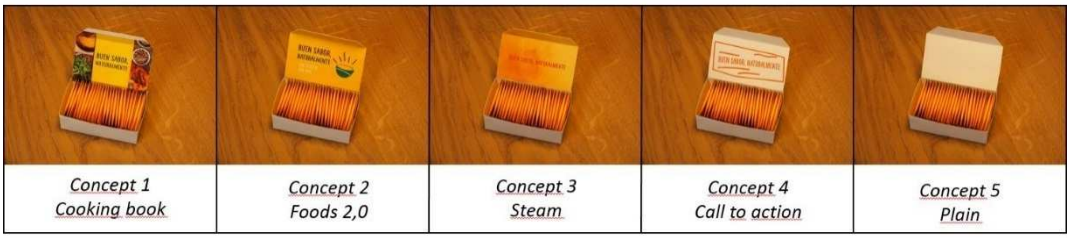


Figure 15 Concepts developed for consumer perception assessment

The images were taken under predefined settings and under controlled light conditions.

To facilitate the analysis, the answers were clustered into five different categories and results are presented using charts and plots. The questions used on the survey can be consulted in the Appendix section of this thesis.

1) Demographics: Explains the statistical data of the respondents, showing age category and gender. As seen on the results, around 50% of the respondents belong to the range of 21-30 years. This generation, known as “Millennials”, showed more enthusiasm to

answer the survey. This may mean that they are more into trying new products and therefore, may represent an interesting market.

Figure 16 Answers to question 1 & 2

Figure 17 Answer to question 3

2) Habits: Explains the cooking habits of the respondents, showing how often do they cook and to who do they use to cook.

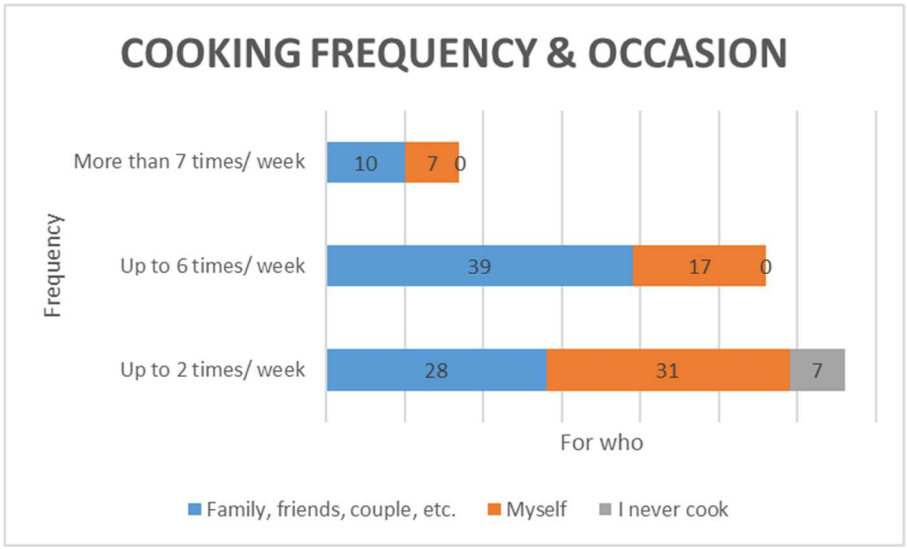


Figure 18 Answer to question 4 and 5

3) Products preference: From question 6 to question 9, respondents were asked to choose the packaging they consider more attractive. In question 7, they were asked to write a brief description of the reasons. The attributes were selected and plotted on a "word cloud" using the software *Wordle*, this plot gave more distinction to words appearing more frequently.

From the packagings below, which one do you find more attractive?

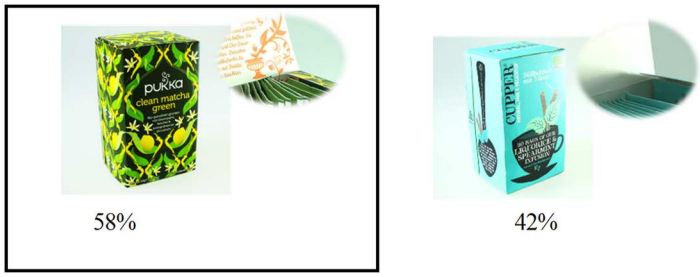


Figure 19 Answer to question 6

Please, write briefly the reason. Spanish answers (left) and english translation (right).

Figure 20 Answer to question 7, using software Wordle.

From the packagings below, which one do you find more attractive?

Figure 21 Answer to question 8

From the packagings below, which one do you find more attractive?

Figure 22 Answer to question 9

4) Artwork concepts attributes evaluation: From question 10 to question 14, respondents were asked to rank three attributes: Attractiveness, Modernity and Trust, Attractiveness evaluates the level of empathy and "eye-catching", Modernity evaluates how innovative the concept is and Trust stands for level of confidence built. These attributes were ranked under a five points scheme where:

- *Totally* stands for a complete approval of the evaluated attribute.
- *High* stands for a major approval of the evaluated attribute.
- *Regular* stands for a medium approval of the evaluated attribute.
- *Low* stands for a minor approval of the evaluated attribute.
- *None* stands for a complete disapproval of the evaluated attribute

The pictures came in a random order every new survey. Results are presented below under a predefined order. The following chart presents the answers to question 10 to 14, next to the concept picture is a radar chart presenting the percentage of respondents that assigned one of the five ranks to the selected attribute. For instance, 52% of the respondents assigned the *High* ranking to *Attractiveness*, 27% assigned the *Regular* ranking to *Modernity* and 16% assigned the *Totally* ranking to *Confidence*.

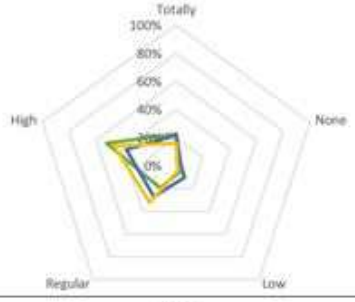
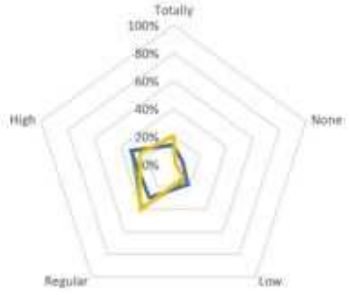
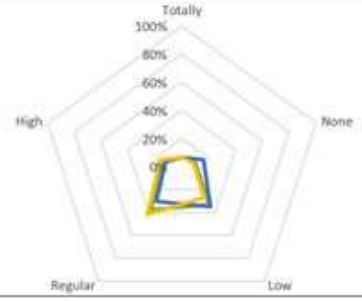
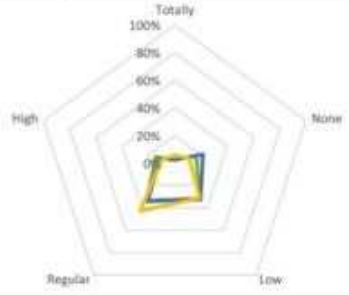
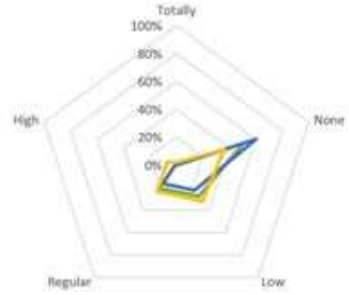
Concept	Attributes results
 *Cooking book*	
 *Foods 2,0*	
 *Steam*	
 *Call to action*	
 ***Plain***	

Figure 23 Attributes result

5) Artworks concepts preference: Finally, respondents were asked to choose their top three among the five artwork concepts through a forced ranking, choosing one excellent concept, one great concept and one good concept.

		Excellent	Great	Good	Number of answers
	*Cooking Book*	64	23	9	96
	*Foods 2,0*	42	59	13	114
	*Steam*	13	27	64	104
	*Call to Action*	2	9	24	35
	*Plain*	2	5	13	20

1st place
2nd place
3rd place

Table 10 Preference results

As shown on the table, it is hard to define the top three selected options. Therefore, it was convenient to ponder the results according to the position. For instance, the *Excellent* column was pondered with a X3, the *Great* column with a X2 and the *Good* column with a X1. In this way, the top three stated as:

Figure 24 Concepts top ranked

The survey worked as an interesting consumer perception assessment, helped to translate the consumer perception of the artwork concepts of three attributes ranking them. Finally, by putting the concepts together forced the respondents to choose three. The results of this survey and its analysis are the core of the recommendations to be given to Unilever. Consequentially, are to be discussed in the following Chapter alongside the rest of the assessments results.

5. Discussion

One of the aims of this thesis is to provide the consumer safety inputs to take into consideration when designing a consumer packaging with internal printing. The packaging systems taken into consideration for the thesis are:

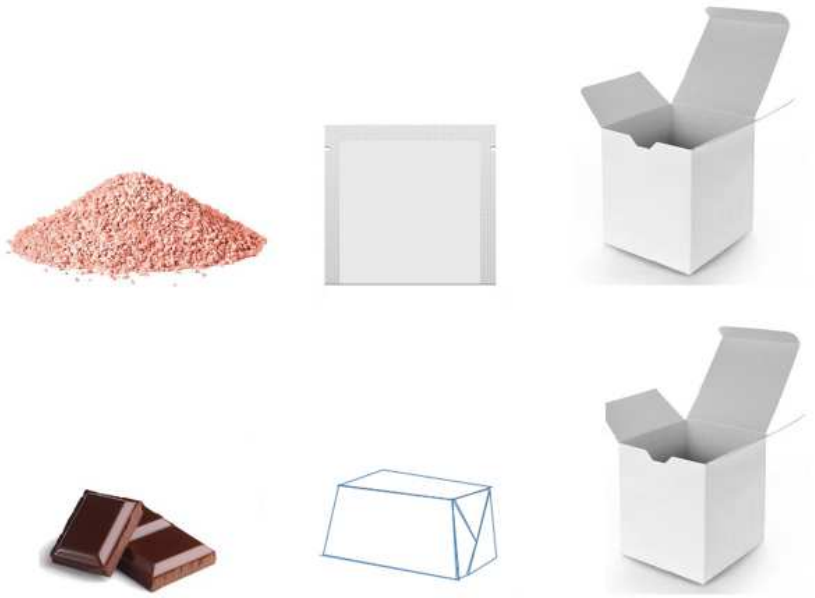


Figure 25 Packaging systems

- The consumer unit is always a folding carton
- For individual contained product, two options have been considered
  - ✓ A sealed aluminum based sachet with a dry powder
  - ✓ An individually wrapped fatty product

In case of a fully sealed aluminum based sachet the barrier assessment leads to the conclusion that both material as well as style can be considered as

sufficiently protected against external influences, in this case any kind of ink can be applied on the substrate.

In case of the individually wrapped product, the executed test procedures helped to outline the root cause of potential leaking areas which have been identified in a small sample size (23/10´000 samples). This is particularly relevant as on those wrappers where a fracture is present, a potential migration through gas phase may occur depending on the formulation of the food product and the functional barrier of the non-aluminum based layer.

From an overall risk management perspective, it is recommended to run an overall migration test to determine the impact of fractures with the potential migrant substances of the ink. Even though both inks claim low migration properties and a mineral oil-free formulation, the safety of the food product needs to be assessed. In parallel, a performance evaluation of the production lines is suggested, focusing on the packing operation. As it was proved in the assessment, the primary packaging material is tended to suffer fractures on the corners, so this potential issue must be controlled in a separate machine evaluation.

In the food industry, the use of virgin fibers is recommended over recycled boards. Board is not a functional barrier (Barnes et al., 2007). In terms of packaging for food product, it is highly recommended the use of a functional barrier between the board and the food product, avoiding direct contact. The kind of barrier would depend on the formulation of the product, ink and environment. As shown in this market screening, it can go from a folded wrapper to an aluminum capsule.

Within the respective test set up internal printing is technically feasible. During the machine run, no critical point in terms of operation window and overall machine efficiency could be observed. However, every food contact ink needs an in-depth assessment, including the final artwork as well.

Based on the respective ink formulation and different type of pigments the visual appearance is different. Following two differences are distinguished.

- Brightness and color saturation are different

- Colors show different hues, particularly dark colors

The overall inside-printing visual differences perceived can be explained by comparing the CIELab* measurements of Food contact intended ink on the inside against the Low migration ink applied on the inside:

	Food contact intended ink on the Inside			Low migration ink on the Inside			ΔE* calculation
	L*	a*	b*	L*	a*	b*	
Y	85,03	-5,3	36,75	86,6	-1,9	56,12	*19,72870498*
C	84,6	-11,93	1,7	73,32	-20,26	-13,93	*20,99819516*
M	68,98	19,08	8,69	66,18	32,42	-2,71	*17,76951322*
K	68,78	-4,09	4,32	56,84	-0,19	5,96	*12,667407*

Table 11 ΔE* calculation results

The scale of ΔE^* states that:

- A value below 1 means there is not perceptible difference by human eyes.
- A value from 1 to 2 means there is a perceptible difference through close observation.
- A value above 3 means a perceptible difference at a glance exists.

To have the same visual perception in internal printing, a ΔE^* value must be below 3. The high ΔE^* values mean that the colors have a very different tone and brightness, mainly depending on the substrate and ink properties. This does not mean an application is wrong or right, the intention of this test was to quantify the difference. For instance, one ink could be perceived different on the internal uncoated side of the board and on the external coated side of the board. This methodology proves to be effective to standardize the color

perception, it can be used for every other ink application comparison regarding internal printing, so it is good to be kept in mind for further research.

Considering the calculated values from Table 9, the ΔE^* between the black color on the outside and the inside is significantly high: the difference in tone and lightness is easily perceptible. This difference is important to be taken into consideration because affects the general tone of dark color. It would be interesting to test what is needed to get a real dark tone on an internal printing or at least what is needed to reach the similar CIELab value for a black color.

Overall interaction between internal ink and crease lines did not show an initial issue, however have been mentioned as a critical point to consider. According to the expert´s advice, crease lines are the main concern for internal printing because inks may present cracking or a layer loosening, for instance, dark colors appearance may lose effectiveness, therefore, it is recommended that text and dark tones not to be on crease lines. This issue needs to be considered when inner side artworks are designed, because the level of definition may be lost on crease lines. This topic can get a deeper research, where different inks are applied on different substrates, or changing the force applied during folding.

Robinson test value was reported under 1, meaning that the ink odor transfer is below the perceptible threshold. This means that, as a first approach, the printing ink fulfills the low migration requirement. However, a more extent panel along with a sensory panel is recommended to guarantee that the organoleptic properties of food products will not change. No matter what kind of substrate, ink or material is being used in the packaging system, the organoleptic properties of the product must remain unalterable (EuPIA, 2008).

These technical insights were obtained under some predefined conditions, for instance:

- Offset printing was chosen as the only printing technology to assess, as all current packs are using this print technology and this would be the first viable change. More research time is needed to run more

possibilities. The same methodology used through this thesis can be used as baseline.

- Ink supplier has been selected based on the novelty of solution offered, as direct food contact inks for sheetfed offset have been a recent development.
- For comparison reasons one board type has been selected to compare conventional ink for food contact material with a novel direct food contact ink.

The results from the survey ran for this thesis brought relevant insights about the consumer perception based on the artwork defined by technical parameters, for instance:

- The positive reaction towards internal printed packs is consistent across regions (UK qualitative study/ Mexico quantitative study)
- During the top-three question, the unprinted concept (a.k.a. *Plain*) showed lower scores than options with internal printing. This means internal printing influences consumer perception.
- This reaction changes per the concept evaluated. Even a very basic print as in the concept *Call to Action*, with a basic text received a higher score than unprinted.
- The top-three question also helps to understand the reaction on consumer perception to an artwork concept with three or more inks applied. A fully printed surface is preferred over a simple or one-ink artwork concept. The crease lines constraint mentioned before needs to be considered, as previously mentioned.
- If an artwork is to be designed with more than three inks, it is recommended to avoid text and images on crease lines and the use of dark tones on it.

This assessment put on the table the first consumer insights from a specific target market. Consumer perception changes around the world, so a similar assessment is recommended to be applied in different markets. As it was shown, firstly the technical feasibility and consumer safety insights are required to run a complete consumer perception assessment, adapted to the food category, product and consumers.

6. Conclusion

The conclusions and recommendations for further work are shown in this last Chapter. Internal printing for a food packaging application was evaluated from three lenses: consumer safety, technical feasibility and consumer perception, in this way the purpose for this thesis could be achieved.

Firstly, the technologies were mapped and the food safety requirements set. Secondly, the initial technical feasibility assessed under defined conditions and materials for the specified food product range. Finally, technical concepts were developed and used on a consumer perception survey, bringing insights from a specific market about internal printing. With all this collected data, recommendations are offered to Unilever for future work.

The findings from the market screening showed that internal printing exists in the food industry. The packaging system containing internal printing always consisted of a consumer unit with one or multiple individual unit(s), every individual unit contains the food product. Different artwork designs were found and clustered to be used as benchmark for further activities. It was observed that direct contact between food product and substrate does not exist. This initial observation worked as the first benchmark prior the primary research as captured in chapter 4 of this thesis.

The literature research collected the necessary data to start answering the research questions. To answer the question *what legal/ regulations apply?* it could be shown that there are specific regulatory details which varies depending on the region and country were the final good is to be sold, however, the basis to achieve safe food products for consumption is the same all around the world. There are overall legislation bodies recognized at a regional level, such as FDA or the Council of Europe, hence there might be a need to cluster regions from this perspective prior progressing future work. Additionally, it is important to mention that regulations around the world

may have modifications from time to time, therefore, they need to be monitored through the development of a product.

The theoretical framework was used to solve the question *how to ensure consumer safety of the product?* The research both from literature as well from the expert interviews clearly outlined that there is not one standard answer, however that the final use needs to be considered in the assessment. This means each execution needs to have an in-depth assessment including an overall migration test once the final artwork(s) is developed. This ensures, in the best possible way, offering to consumer safe and differentiated product into the market. As discussed in the section before, the integrity of the primary pack needs to be ensured in cases a direct food contact has been identified as a consumer safety risk.

Some questions were answered through the literature research and the experts´ interviews as a first approach, this was the case for the question: *what are the technical options?* The Packaging Industry is wide, so it was necessary to narrow down the technologies and suppliers. This thesis only considered the offset printing technology and a technical assessment for a direct food contact intended ink and a low migration ink for food products, both printed on the same board.

The initial assessments of the mentioned scenarios are quite promising. In the next steps, it is recommended to Unilever to deepen the assessment of the both described executions and to evaluate other printing technologies, suppliers and the application of other direct intended food contact suitable inks.

Regarding technical feasibility, the thesis showed that internal printing is achievable under the current specifications of the packaging materials. Thanks to the experts´ interviews and technologies scouting, it has been verified that convertors and ink suppliers are used to work with internal printing in the food packaging industry.

The answer to the question *What is feasible for the required application?* can only be provided in a specific project context taking the final artwork, the

food product, its manufacturing process and primary pack quality into account. At the same time, a clear approach and steps on how to assess this on a case by case basis has been outlined and is available. Internal printing is nowadays feasible and safe, thanks to the application of available low migration inks, this thesis discussed the application of a direct intended food contact ink for two product options where the individual packaging is contained in a sealed sachet or folded wrapper.

Thanks to the insights obtained by using the research process, a more robust answer could be offered to the question *what influences consumers´ perception?* It was outlined that inside print does help to have a differentiation and that there are multiple ways to delight consumers when comes to internal printing. This assumption was firstly presented during the qualitative study done by Unilever, where consumers showed a preference for a fully printed folding carton over an unprinted one. This thesis provided a confirmation to that study through the survey results. The technical developed concepts pointed out that consumers are more likely to have an internally printed folding carton, specially a fully multicolored printing.

This first information is crucial and can be used to inform further research. It is important to note that the artwork itself has only been used to assess if different technical constraints have a strong influence and based on the consumer feedback this cannot be substantiated with the research result. This allows future work a large degree of freedom and needs to be considered as a key enabler – as there is not a constraint to a specific ink type. For future research, it is advisable to focus if reaction to graphics are:

- Specific to consumption habit of a food product in a market
- Influenced over time
- Specific to a certain consumer segment.

The final research question, *what is their reaction for an initial graphic concept designed through technical and safety considerations?* was successfully answered at the end of the thesis. Collecting the first insights and gathering all the collected data from the previous activities and assessments was tough, but at the end, it was worthy. Thanks to the innovation tools used for the artworks concepts creation, the survey was

useful to achieve the purpose of the thesis and even more, a robust set of recommendations were offered to Unilever for further discussions.

The discussion part contains the insights learnt from the survey, at the end it is fair to conclude that internal printing has an impact in consumer perception and it is preferred over internally unprinted packaging. Internal packaging is an interesting feature that can be used to increase the consumer experience during the consumption.

There is evidence to say internal printing is achievable, as there are available options on the market. At the same time this does not allow the conclusion to state that internal printing is achievable for all applications and hence every internal printing scenario needs to go through a similar evaluation one case at a time.

For every approval, a list of conditions needs to be mapped and evaluated, for instance, legal framework, food product formulation, primary packaging material properties, secondary packaging properties, type of contact, printing ink properties, etc. As seen, a considerable number of variables must be analyzed before the product goes into the market. Therefore, the recommendation for the food industry is to analyze the internal printing case by case and one step at a time.

This thesis only considered a specific series of conditions over the vast world of possibilities and solutions the Packaging Industry offers. As one expert commented during one interview, five years ago, internal printing was limited to some technologies (e.g. inkjet) on some substrate and was not available for every food category, for instance, it could only be found on cereal boxes containing a serial number. Nowadays, internal printing is frequently used in the food industry, this allows a conclusion: there is value of creating an enhanced experience through inside printing which is relevant to the printing ink industry, who is working on safe solutions, to brand owners, who invest into internal printing while ensuring consumer safety and the consumer, valuing the enhanced experience by repeatedly purchasing those products and/ or willing to pay a higher price.

References

Agência Nacional de Vigilância Sanitária (2017), *Resolução DOU DE 30/06/2016 Regulamento técnico sobre materiais, embalagens e equipamentos celulósicos destinados a entrar em contato com alimentos e dá outras providências,* Optionline Editora EIRELI. Consulted on: 08/03/2017.

Agência Nacional de Vigilância Sanitária (2017), *Resolução DOU DE 20/05/1999 Regulamento Técnicos: Disposições Gerais para Embalagens e Equipamentos Plásticos em contato com Alimentos,* Optionline Editora EIRELI. Consulted on: 08/03/2017.

Ampuero, O., Vila, N. (2006). *Consumer perceptions of product packaging*, Journal of Consumer Marketing, Vol. 23, No. 2.

ASTM International (2013), *Standard test method for burst testing of flexible package seals using internal air pressurization within restraining plates,* ASTM International.

Barnes, K., Sinclair, R., Watson, D.H. (2007) *Chemical migration and food contact materials*, Woodhead Publishing Limited, pg 302-319.

Begley, T.H., Hsu, W., Noonan, G., Diachenko, G. (2008). *Migration of fluorochemical paper additives from food-contact paper into foods and food simulants,* Food Additives and Contaminants, Vol. 25, No. 3.

Bewerton, P., Millward, L. (2001). *Methods of data collection*, Organizational Research Methods, SAGE, Ch 6.

Council of Europe (2007). *Committee of Experts on Material coming into contact with food, Policy statement concerning packaging inks applied to the non-food contact surface of food packaging*. From [www.coe.int]

Epple Druckfarben AG (2017) *BoFood Organic Product Information*, Version 03/2017. From: [www.epple-druckfarben.de]

European Parliament and Council Directive (2006). *EC 2023/2006 Council Directive on good manufacturing practice for materials and articles intended*

to come into contact with food. Journal of European Community No. L 2384/75.

European Parliament and Council Directive (2004). *EC 1935/2004 Council Directive on materials and articles intended to come into contact with food*. Journal of European Community No. L 338/4.

European Parliament and Council Directive (1982). *EU 82/711/EEC Council Directive laying down the basic rules necessary for testing migration of constituents of plastics materials and articles intended to come into contact with foodstuffs*. Journal of European Community No. L 297/26.

European Parliament and Council Directive (1985). *EU 85/572/EEC Council Directive laying down the list of simulants to be used for testing migration of constituents of plastics materials and articles intended to come into contact with foodstuffs*. Journal of European Community No. L 372/14.

European Printing Ink Association (2015). *EuPIA Customer Information Note regarding the use of sheetfed offset printing inks/ varnishes and water-based coatings for the manufacture of food packaging made from paper and board*, version 3. From: [www.eupia.com].

European Printing Ink Association (2008). *EuPIA guideline on Printing Inks applied to the non-food contact surfaces of food packaging materials and articles*. From: [www.eupia.com].

Ewender, J., Franz, R., Welle, F. (2012). *Permeation of mineral oil components from cardboard packaging material through polymer films*. Packaging Technology and Science. Vol. 26, No. 7.

Flick, U. (2009). *An introduction to qualitative research*, Sage Publications Ltd., London.

FlintGroup. *Food packaging: A guide to best practices for print*. Consulted on 10/03/2017. Requested on: [www.flintgrp.com].

FoodWatch (2015). *Mineral Oil in Food*, Berlin: Thilo Bode.

Gärtner, S., Balski, M., Koch, M., Nehls, I. (2009). *Analysis and migration of phthlates in infant food packed in recycled paperboard*, Journal of Agricultural and Food Chemistry. Vol. 5.

Germany Trade & Invest (2017). *Market Reach*. Consulted on 17/05/2017. From: [www.gtai.de]

Gettis, M. F. (1995). *Direct Food Contact Printing Inks & Coatings*, Zeitschriftenaufsätze, Colorcon Limited.

Golafshani, N. (2003). *Understanding reliability and validity in qualitative research*, The Qualitative Report. Consulted on 05/05/2017. From: [http://www.nova.edu/ssss/QR8/golafshani.pdf]

Gude, T. (2014). *Report 2012L46876*, Swiss Quality Testing Services.

Heckman, J. H. (2001). *Fathoming Food Packaging Regulation Revisited*, Packaging Law, Keller and Heckman LLP. From: [http://www.packaginglaw.com/special-focus/fathoming-food-packaging-regulation-revisited#_ftn17]

Inocue, C., Leerink, A., Blijdenstein, T. (2016). *Risk Assessment shelf-life test of CwGP*, Science and Technology Report, Unilever.

Jickells, S., Castle, L. (1993). *Combined compositional analysis and threshold of regulation as a possible control measure for microwaves susceptors*. Food Additives and Contamination, Vol. 10.

Konica Minolta Sensing (2017). *Color & Appearance Measurement*, Konica Minolta. From: [http://sensing.konicaminolta.us]

Löfgren, M., Witell, L. (2005). *Kano´s theory of attractive quality and packaging*, The Quality Management Journal, Vol. 12, No. 3.

Majeed, K., Sharif, U. (2012). *Fracture toughness analysis of aluminum foil and its adhesion with LDPE for packaging industry*, Blekinge Institute of Technology.

Matissek, R. (2014). *Mineral oil transfers to food*, Food Lab International, No. 1.

Mininni, T. (2009). *Packaging that delivers at the second moment of truth*, The Dieline. Consulted on 10/05/2017. From: [http://www.thedieline.com/blog/2009/5/7/packaging-that-delivers-at-the-second-moment-of-truth.html]

Mittal, M. (2013). *The evolution of packaging*, Digital packaging Experience. Consulted on 18/05/2017. From [https://medium.com/digital-packaging-experiences/the-evolution-of-packaging-57259054792d]

MetsäBoard (2015). *Simcote Product Sheet*. Consulted on 13/04/2017. From: [www.metsaboard.com]

Murray, L. (2005). *The impact of foil pinholes and flex cracks on the moisture and oxygen barrier of flexible packaging*, Neenah Technical Center.

Oetjen, S. (2015). *Lab* 101: An introduction to Lab* Color Space*, Label & Narrow web, Rodman Publishing.

Olsson, A., Larsson, A. (2010). *Value creation in PSS design through product and packaging innovation processes*, Ch 5.

Pedersen, G., Carlson, E., Ekroth, S., Kostamo, P. (2015). *Food contact materials and articles: Printing inks.* TemaNord.

Richter, T., Gude, T., Simat, T. (2009). *Migration of novel offset printing inks from cardboard packaging into food*, Food Additives and Contaminants. Vol. 26, No. 12.

Safeguards (2017). *Switzerland strengthens regulation on food contact materials and articles*, No 015/17. Consulted on 07/05/17. From: [http://www.sgs.com/en/news/2017/02/safeguards-01517-switzerland-strengthens-regulation-on-food-contact-materials-and-articles]

Secretaria de Salud (2012). *Salud ambiental. Juguetes y artículos escolares. Límites de biodisponibilidad de metales pesados. Especificaciones químicas y métodos de prueba*, Norma Oficial Mexicana NOM-252-SSA1-2011. Diario Oficial de la Federación.

Siegwerk Druckfarben (2015). *Know How. Customer Guidance: Printing Inks for Food Packaging*, Siegwerk Druckfarben AG & Co.

Skillington, P. (2014). *Migration of Chemicals through coated paperboards for food contact packaging*, Cape Peninsula University of Technology.

Stallard, P. (2014). *The new science of product* development, Marketing Week.

Suárez, S. (2016). Técnica para generar ideas: análisis morfológico. From: [https://mprende.es/2014/06/18/tecnica-para-generar-ideas-analisis-morfologico]

Summerfield, W., Cooper, I. (2001). *Investigation of migration from paper and board into food-development of methods for rapid testing*. Food Additives and Contaminants Vol. 18, No. 1.

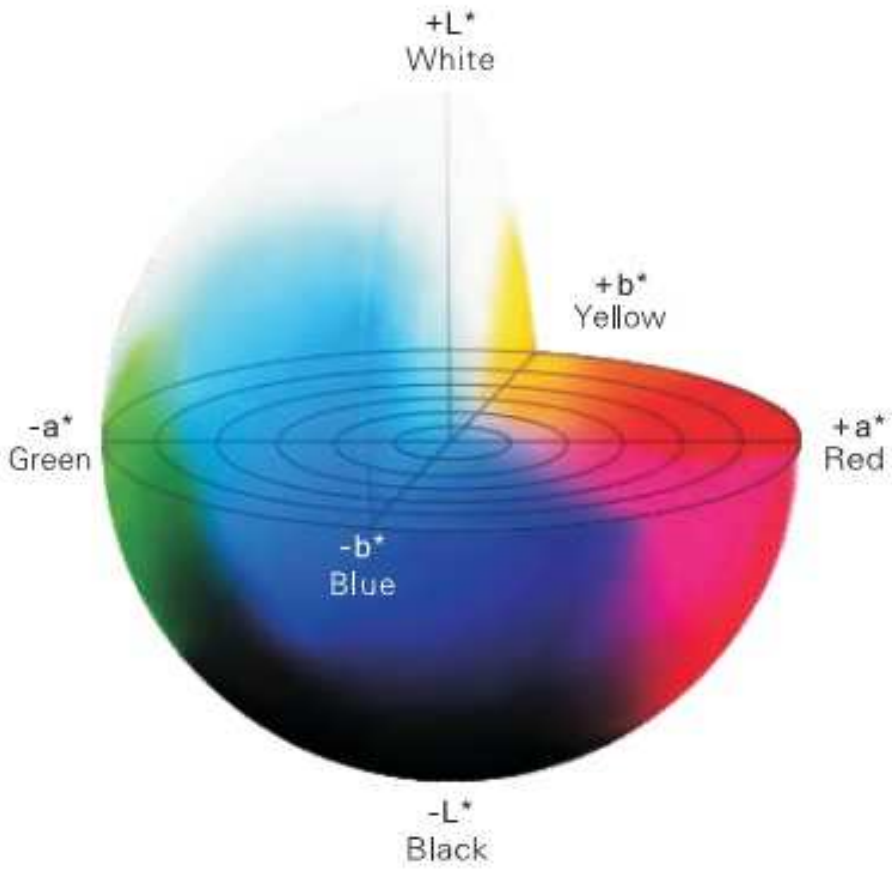
Vanham, P. (2015). *Top 10 things to know about the Mexican economy*, World Economic Forum. Consulted on 06/05/2017. From: [www.weforum.org]

Wordpress (2014). *Evolución histórica del marketing: Coca-Cola*. Consulted 19/05/2017. From: [https://www.wordpress.comevolucion-historica-del-marketing-coca-cola]

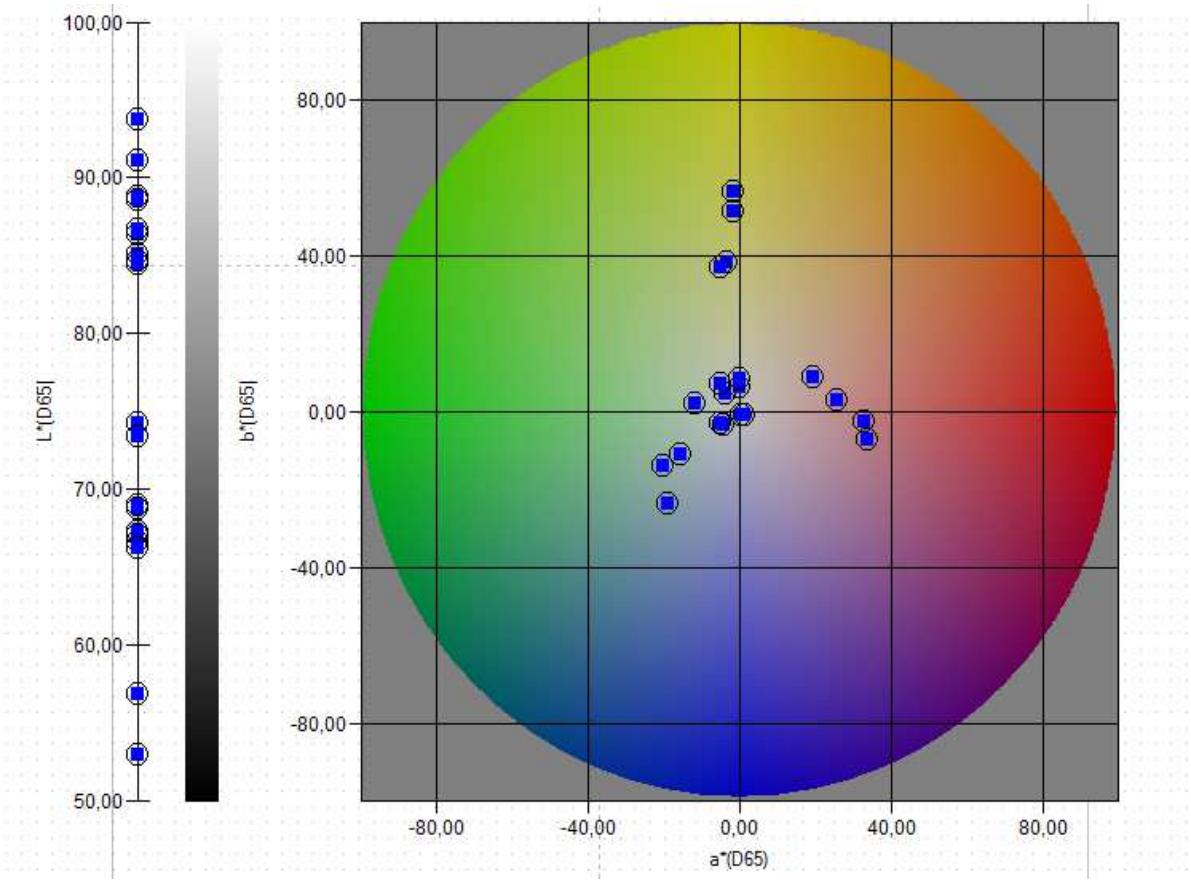
Zeithaml, V. (1988). *Consumer perceptions of price, quality and value: a means-end model and synthesis of evidence*, Journal of Marketing, Vol. 52, pg 2-22.

Appendices

A. Lab* color space diagram



B. Detailed Color Space plot: A* b* chromaticity program



C. Online Survey

Questionnaire

1 Standard page

Selecciona tu edad

Menos de 20 años | 21- 30 años | 31- 40 años | 41- 50 años | 51- 60 años | Más de 71 años

Por favor, selecciona tu género

Femenino | Masculino

Por favor, escribe tu ciudad de residencia

¿Con qué frecuencia cocinas?

Más de 7 veces por semana | Hasta 6 veces por semana | Menos de 2 veces por semana

Cuando cocinas, ¿para quién lo haces?

Familia, amigos, pareja, etc. | Sólo para mi | Nunca cocino

De los siguientes empaques, ¿cuál encuentras más atractivo?

Por favor, comenta brevemente por qué

De los siguientes empaques, ¿cuál encuentras más atractivo?

De los siguientes empaques, ¿cuál encuentras más atractivo?

Evalúa

	Nada	Poco	Regular	Mucho	totalmente
Atractivo	○	○	○	○	○
Moderno	○	○	○	○	○
Confianza	○	○	○	○	○

Evalúa

	Nada	Poco	Regular	Mucho	totalmente
Atractivo	○	○	○	○	○
Moderno	○	○	○	○	○
Confianza	○	○	○	○	○

Evalúa

	Nada	Poco	Regular	Mucho	totalmente
Atractivo	○	○	○	○	○
Moderno	○	○	○	○	○
Confianza	○	○	○	○	○

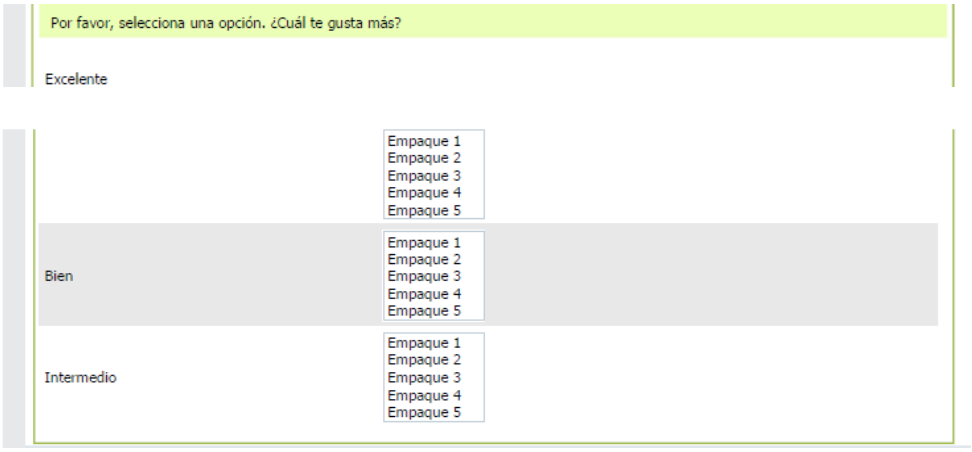
Evalúa

	Nada	Poco	Regular	Mucho	totalmente
Atractivo	○	○	○	○	○
Moderno	○	○	○	○	○
Confianza	○	○	○	○	○

Evalúa

	Nada	Poco	Regular	Mucho	totalmente
Atractivo	○	○	○	○	○
Moderno	○	○	○	○	○
Confianza	○	○	○	○	○

Final


Por favor, selecciona una opción. ¿Cuál te gusta más?
Excelente
Empaque 1
Empaque 2
Empaque 3
Empaque 4
Empaque 5
Bien
Empaque 1
Empaque 2
Empaque 3
Empaque 4
Empaque 5
Intermedio
Empaque 1
Empaque 2
Empaque 3
Empaque 4
Empaque 5