Packaging solutions to reduce discoloration in spices due to light exposure.

A study of 5 spice varieties with different packaging materials and light sources

CASTANEDA, Monica

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MASTER THESIS

PAULIG GROUP
Exploring Great Taste

Santa Maria

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AD VTRVMQVE

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MÓNICA PATRICIA CASTAÑEDA VILLALOBOS

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Abstract

Title:	Packaging solutions to reduce discoloration in spices due to light exposure.
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Goal:	To understand which studied packaging material provided sufficient protection to reduce the pigment discoloration process in the most relevant spices, selected by the company Santa Maria: Paprika, Basil, Cayenne Pepper, Parsley and Grillkrydda (a blend of spices). Different scenarios were considered in the form of 3 different arrangements representing controlled conditions and a simulation of the retail environment.
Delimitations	The study was limited to the perceived visual changes in the selected spices. Also water activity was measured when spices were stored without packages. The changes in the molecules present in the spices whereas how the flavor and taste might be affected were not considered in this study.
Methodology	This study was conducted using a mixed methods strategy consisting of a qualitative phase, formed by semi-structured interviews and observations; and a quantitative phase including 3 different set ups, representing the conditions under which spices are stored: without packaging in Arrangement 1 and under 5 different light sources; Arrangement 2, representing packaging protection against light and reproducing a controlled scenario; and finally Arrangement 3, representing the most similar conditions to

the retailer environment, where spices were stored with different packaging materials in a shelf display.

Findings Only the opaque materials presented a sufficient barrier against the detrimental effects of lighting. The combination of packaging materials (PET + glass) presented an improved effect, but not in the same amount as the opaque packaging materials. In the case of the studied spices, the red spices (Paprika, Cayenne Peppar and Gryllkrydda) bleached faster and in a more visually detectable way than green spices. (Basil and Parsley).

Keywords: Spices, Color Bleaching, Packaging, Light effect, Shelf display, Retailer's arrangements, glass, PET, LED lights effect on foodstuffs.

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Thanks to the personnel from Packaging Logistics, Kemicentrum, Ergonomics and Aerosol Technology and the Department of Architecture and Built Environment in Lund University. y academic supervisors, Märit Beckeman and Karla Marie Paredes. Specially when they supported and encouraged me when I had trouble finding my way out and they were smart enough to hook me out on a lifeline, which helped me to succeed in this task. I want to thank Christina Skjöldebrand for her patience and accessibility to have connections with relevant sources for the research. To Annika Olsson my examiner for her support and critics.

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Thanks to Hillevi Hemphäla that despite her busy schedule, she kindly triggered my interest to light and its universe and provided substantial contribution to the contents of this document, and as well allowed me to use the facilities of Ljus Lab. My gratitude goes also to Robert Backe for his clear attention to my subject, his patience and availability made a very significant contribution every single time I needed, that was also transformed in a friendship. Thanks to Johannes for the electrical installation in the Ljus Lab boxes, that made possible the exposure of the samples.

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As mentioned by Primo Angeli, recognized by its international reputation in the field of graphic communication, in his book “Making people respond”, where he accurately describes the creative process followed in this Master thesis research and also common when developing a product:

“In a partnership between marketing, design and manufacturing, authorship and the creative process are shared so that ideas might flow freely. Professional pleasure comes from playing in a cooperative atmosphere that engenders openness, constructive criticism, and a contagious desire to assist each other in making motivational pictures. It is this attitude that makes anything possible.”

I am proud to show you the results of this journey, which conveys the integration of all those interactions from the academia and the industry, as mentioned by Primo Angeli (1997). So, please take a look at the content and browse as much as much as you wish.

Finally, I would like express my thanks to my family and friends for everything they have done for me, every concern you expressed, helped me to keep my spirits up. Santika, Genyia, Dani, you were very close this last year, and many others, Ivi, Andrés, Mario, Gaby, Ivonne, Fernanda, Moni, Jessica, Jessica M., Denisse, Esther, Thomas, Caro, Hazel, Hannah, Annya, Gayathry, Karishma, and the list can keep going. Thanks for your patience mostly when it seemed I stopped my contact with you, because I entered in an isolation mode, but I now I am finished with my work and I recognize how important you are.

Mónica Patricia Castañeda Villalobos

Lund, Sweden , 10th June 2016

Executive Summary

Santa Maria Co. has encountered issues in their spices assortment; light causes color bleaching in some spices due to light exposure. This phenomenon often happens when the spices are displayed in the retailer's facilities and after the products leave the manufacturing facilities, meaning the Company has no longer the control under the handling of the products.

The company sponsored this study in order to screen available and robust solutions for the current problem. The starting point was setting the basis to understand the behavior of the 5 selected spices (Paprika, Cayennepeppar (Cayenne Pepper), Grillkrydda (Blend of spices), Persilja (Parsley) and Basilika (Basil)), under different scenarios. Different packaging materials were studied and tested conducting experiments under the exposure of different light sources. The efficiency of the barrier presented by the packaging solutions was evaluated comparing the color of the just opened spices against the final color they presented after 7 or 8 weeks of 24 hours of continuous exposure per day.

Once the comparison was made, a suggestion could be given considering a more effective packaging solution as the one in use actually. In order to match the operating principles, the new solution could not be developed without considering a holistic view of the supply chain. The ideal package would be such that it can be effective and applied to as much items with the same presentation as possible. Considering only one packaging solution will avoid additional supply chain complexity or changing the actual conditions of the supply chain. However, it was demonstrated that keeping the same packaging solution is not always possible or suitable, but that the recommended solution must always lead to an increased consumer satisfaction and that trade-offs should be considered when it comes to guaranteeing an effective and appealing display in the retailer's facilities.

Another important reason to undertake this study is that despite the lack of uniformity in light sources in the retailer's facilities, the European (EuP) Directive 2005/32/EC, which took effect in 2016, promotes the use of more LED bulbs due to its lower environmental impact. This fact represents an increased deteriorative effect for the studied products, as demonstrated by the performed tests, where the color bleaching in red spices was increased under the exposure to such light sources.

Taking into account these conditions, there is a reason why a modification in the packaging solution is recommended. If the actual characteristics of the supply chain, and the results of the tests conducted in this research are taken into consideration; it can be concluded that the addition of an opaque plastic sleeve will block part of the light spectrum that deteriorates and bleaches the products.

This packaging solution was considered as the most suitable, because this material presents characteristics that match with those that represent attractiveness the consumer. For instance the PET material presents a good contraction and

adequate shine, enhancing the premium features of the brand. The design of this plastic sleeve can also allow presenting a window, or a transparent area, that will allow the consumers to keep seeing what is contained inside the package.

Finally, additional features of this packaging solution can offer temper evident function, replacing the actual transparent seal. And in terms of materials this option also allows to remove the paper label and glue from the actual supply chain. The plastic sleeve can be easily removed from the packaging when it comes to recycle. It is recommended for the complete development of this packaging solution, to continue with a process where the interactions with consumers are considered. This will allow to understand their needs and to perfectly fit the characteristics of the packaging to their daily life habitudes.

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List of acronyms and abbreviations

a_w	Water Activity
B	Basil
C	Cayenne Pepper
CIE	Commission Internationale de l'Eclairage/International Commission on Illumination
CFLs	Compact fluorescent lamp
CCT	Colour Rendering Temperature
G	Grillkrydda (Blend of spices by Santa Maria)
IKDC	Ingvar Kamprad Designcentrum
lm	Lumen
PET	Polyethylene Terephthalate
P1	Packaging material 1, Glass jar 81 mL (Current packaging material)
P2	Packaging material 2, Glass jar 81 mL+ plastic sleeve
P3	Packaging material 3, Transparent PET Plastic 440 ml (Current packaging material)
P4	Packaging material 4, Plastic lids used to expose samples directly to light
P4b	Packaging material 4b, Glass jar 135 ml (Current packaging material)
P5	Packaging material 5, Amber Coloured Glass Jar 75 ml
P6	Packaging material 6, Amber Coloured PET Plastic 85 ml
P7	Packaging material 7, Transparent PET Plastic 85 ml
P	Paprika
Pa	Parsley

1. Introduction

This chapter is dedicated to introduce the context of the situation encountered by Santa Maria in which the research is based. In order to introduce how the research was conducted a description of the problem, research objective, its delimitations and the research question are presented. A short presentation of the company is given.

1.1. Background

Light is one of the agents of change of many processes that occur in organic substances; however, it is distinct among other agents in the case of foodstuffs, as there is a need for product display in the retailers.

Conservation of the products and exposure are directly in conflict. In the retail display, the visual appearance of the product is a major consideration for the consumers when choosing a product. For most foodstuffs the ideal environment for conservation is complete darkness, as studies presented for cooked meat products (Larsen et at, 2006) and tomato pulps (Biancs & Wissgott, 1997).

Moreover within the retailer's facilities the architectural and spatial organization follows no regulations, regarding light sources, its distribution and characteristics.

Spices, the object of this study, are subject to different levels of light which depend on different factors, such as the product turnover, how often the shelves are refilled, how shelves levels are arranged and the brand sources used in the retailer's facilities.

Despite the lack of uniformity in light sources, the European (EuP) Directive 2005/32/EC, which took effect in 2016, promotes the use of more LED bulbs due to its lower environmental impact, and specifies that only products classified as class A and B when it comes to energy consumption will be allowed for sale. As little research concerning those light sources and its effects on foodstuffs has been carried out, there is a need to propel this study.

Santa Maria initiated this research, as they are the major spice producer in the Swedish market, provides tailored shelves for the retailers in which their products are sold in order to display their assortment of spices. This marketing activity, known as part of the strategy to reinforce how the brand image is perceived in the eye of consumers or the perception they hold in memory, best know as "*brand knowledge*" as described by Keller (1993), is meant to create brand differentiation and identification.

Additionally Santa Maria wants to include new equipment (LED lights) designed to be placed in their existing shelves to increase the appeal consumers have for the products or as described by Sorensen, H. (2009), "*to contribute to better shape and design stores*." Nevertheless, this concept could entail added effects to the current effects of light.

In the case of Santa Maria products, light causes color bleaching in some spices due to exposure to light when displayed after leaving the control of Santa Maria. The company wants to screen available robust solutions for the current problem, analyzing its feasibility and its efficiency in the mentioned conditions. In order to match the operating principles, the new solution should not be addressed without considering a holistic view of the supply chain.

The ideal would be to have as much products as possible with only one packaging solution, to avoid additional supply chain complexity. However, this is not always possible or suitable, but the recommended solution must lead to an increased consumer satisfaction.

When breaking down the supply chain from the filling of spices in their respective packages until the storage in the consumer's home, the stages where greater discoloration occurs identified are during product exposure in the retailer's shelves and storage at home. A complex and dynamic environment in the retailer's stores promotes constant changes seeking to follow trends, designing the best store for their customers and products (Sorensen, H. 2009), where supermarket aisles could be presented in a more appealing way to shoppers, focusing on the most profitable area that takes advantage of the knowledge of shopper.

In the case of the packaging material, the transparency of the glass jars is perceived as an important feature for the consumers to see through the packaging and to provide a quality reference when purchasing, being an important factor in the first moment of truth (Löfgren & Witell, 2005).

1.1.1. Problem description

The problem of light exposure that causes discoloration in some of the spices from Santa Maria was identified mostly because the retailers have communicated the issue to the company, before the shelf life was over earlier. An example of the latter can be seen in Figure 1.

Figure 1:**Color bleaching in Santa Maria spices. Paprika on the left and Gryllkrydda on the right**

The product to the left, in the first image and the product to the right in the second image represent the original color of the spices, the others represent different products that have been displayed in the retailer's shelves, with a localized loss of color or homogeneous bleach.

The packaging system must ensure that the visual characteristics of the spices are maintained after they leave the manufacturing facilities. The characteristics of the packaging design are expected to allow spices to resist the different handling conditions throughout the whole product shelf life.

Up to now, studies have focused separately on the spices; light sources, the packaging materials or the light arrangements in the retail design itself. Consequently, there is still a need for more precise knowledge about the changes that occur in a packaged product under the exposure of different commercial light sources commonly present in the retailer's facilities or in the households, and if the effects causing the loss of color can be reduced.

1.1.2. Company Presentation

Santa Maria sponsored the spices used in this study. The company is today part of the Finnish food group called Paulig, being a part of the World Foods & Flavouring division. Paulig Group is an international enterprise in the food industry; founded in 1876 and noted for high-quality products in key sectors such as Coffee, World Foods & Flavouring and Naturally Healthy Food.

The group has almost 2,000 employees in 13 countries. Santa Maria is Northern Europe's leading flavoring company. Their products are sold in more than 25 countries and the production plants are in Sweden (Landskrona and Göteborg), Estonia, and the United Kingdom. Their business concept is to develop and operate food trends in two areas: Retail and Foodservice. Under the brand name of Santa

Maria is the commodity groups Spices, Tex Mex, Asia and BBQ. More information can be found in the company website: http://www.santamariaworld.com/se

1.2. Objective

This study overall aims to understand which packaging materials 8or a combination of them) will minimize or reduce the discoloration process in spices. A selection of the most relevant spices for the company (a group formed: Paprika, Basil, Cayenne Pepper, Parsley and Grillkrydda (Blend of spices) was considered in this study. The same functionality of the packaging lines and its processes must be considered; ideally packaging solutions must be applicable in glass jars, they shall keep in mind the company requirements and the feasibility of its application throughout the supply chain. The following sub-objectives were also considered.

1. To suggest good practices regarding the display of the spices on the shelves.
2. To determine under which type of light conditions and packaging solutions, the selected spices are less susceptible to present discoloration.
3. To provide Santa Maria with insights to make an informed decision when implementing an innovative packaging solution, designing shelves, as well as how to conduct the evaluation of the tests dedicated to analyze packaging functionality.

1.2.1. Research question

How can the packaging systems used to contain the selected spices diminish color bleaching, and in what extent do they affect it, considering only visual color loss, or perceived photobleaching?.

1.3. Delimitations

The study was limited to the perceived visual changes in the selected spices. The changes in the molecules present in the spices, whereas how the flavor and taste might be affected will not be considered in the scope of this study. The spices considered are present in Figure 2, in the following order from left to right: Paprika, Cayennepeppar (Cayenne Pepper), Gryllkrydda(Blend of spices), Persilja(Parsley) and Basilika(Basil).

Figure 2: **Spices considered in the study. Paprika, Cayennepeppar, Gryllkrydda, Persilja and Basilika** (order from left to right).

Regarding the packaging boundaries the package must remain, if possible, a glass jar due to the level of automation in lines, which were tailored to this material. The study was limited to the available packaging materials to which the company-purchasing department had access; such materials were selected based on relevance considerations for the company. Storage conditions similar to the ones presented in retailer's facilities were considered when conducting the test regarding packaging materials performance. The available resources were the ones present in Santa Maria facilities and in Lund University, the latter were composed by the equipment in Ljus Lab (In IKDC) and in Kemicentrum, departments of research in Lund University, where other food related studies were carried out in parallel with the same equipment, restricting its availability and access.

Additionally it is important to consider that the brand identity throughout different stores will be maintained in terms of the packaging, so that consumers keep recognizing and locating their products regardless of the shopping environment. The suggestion to implement a new packaging solution should be coherent with the brand image and should not compromise the design, branding, marketing, and merchandising added value of packaging. And finally the packaging solution needed to fit the shelf-displays, which provide an effect of auto re-filling, when the consumer takes one jar, and empty front face on the shelves is avoided.

2. Theoretical Framework

This chapter is dedicated to present the relevant findings of the related literature research, and it represents the 4 different pillars that support this research. The first touches the main components of the spices used, and how color is influenced by them; the second, how to perform accurate color measurements; the third; the common light sources available in the different scenarios where spices travel throughout its shelf-life, with a special focus on lights applications in retail environments; and the last one, the properties of the materials used for the tests.

2.1. Color in spices, substances of relevance.

Surface color is an important quality attribute of herbal products; which is why numerous studies have been conducted to investigate color changes or degradation during various processes such as blanching, drying, or heat-treatment. As an example of the relevance of color in spices, Spanish colonizers found that Aztecs had developed dozens of pod-type chili peppers. Today, its name *chile* or *chilli pepper* is derived from the Nahuatl language, "chilli" meaning red (Raghavan, 2000).

Studies conducted by Shepherd, (2012), show that an image or color can activate activity in other areas in our brains like in the brain olfactory cortex, which explain the importance of color when we are assessing flavors and preferences. Vision is the first sense we use to evaluate a food product, and how it looks play an important role on the perception of its characteristics. Consumers first assess the freshness and quality of food by its appearance, which makes pigments a vital characteristic for the initial acceptance of a product (Chen & Resenthal, 2015 & Giusti & Wallace, 2009). Bright colors have a big effect, especially on a later flavor perception, associating them with a pleasant sensation. (Sheperd, 2012; Eastaugh et al., 2008).

One of the reactions by which color diminishes or changes is by photochemical action or photolysis, a process by which a molecule, such as carotenoids or chlorophyll, undergoes a chemical reaction; those molecules are found in greater proportion in the selected spices. The activation energy to this reaction comes from the absorption of a photon, it is absorbed by molecules and/or passed on to other(s), allowing degradation to take place. (Ahsan, 2011). Unless an object is totally non-responsive to exposure to light, any exposure to light, room light or sunlight risks having changes and damages depending on the nature of the colorants. The appearance of fading, darkening, lightening or yellowish tones are common effects caused by light exposure, which are usually irreversible. (Cuttle, 1995)

2.1.1. Carotenoids

Carotenoids are vitamin A precursors, and the most widespread of all naturally occurring pigment groups; they are fat-soluble and responsible of the yellow to red colors in foods. They posses a coloring potential and an antioxidant capacity; such structural characteristic make this pigments susceptible to degradation by external agents. Oxidation is the major cause of carotenoid loss and it is dependent on oxygen; it can be stimulated by heat and light exposure, (Ötles & Çagindi, 2008) as well as in extremes pHs (Xianquan et al., 2005). Typical carotenoid structures found in vegetables are presented in Figure 3.

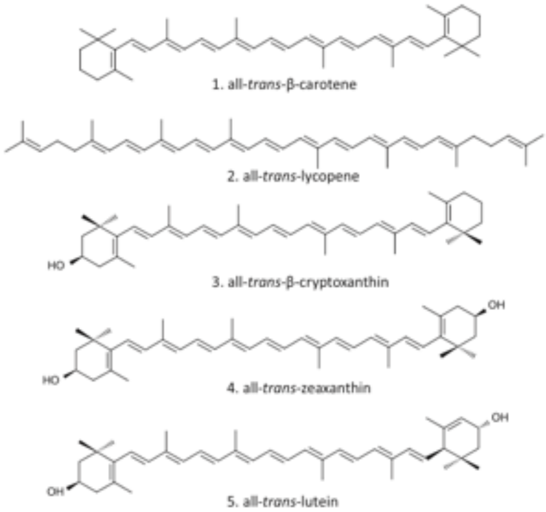


Figure 3: **Main carotenoids in vegetables. (**Adapted from: Murador et al., (2014)).

The degradation of carotenoids leads to color changes as a result of a rearrangement or a formation of cisisomers, epoxides, short chain products and, in some cases, volatile compounds. (Mortesen, 2006).

In the case of lipoxygenase-1, this enzyme is capable of bleaching carotene and chlorophyll under anaerobic conditions and it was proved by Klein et al. (1984) that carotenoids were bleached faster than chlorophylls. The formation of an enzyme fatty acid radical, that reacts with the plant pigments appears to be a requirement for bleaching (Gross, Jeana, 1991)

2.1.2. Chlorophylls

These pigments are the source of the green color in living organisms that capture light energy for photosynthesis. They have a phytol group that confers a hydrophobic characteristic; also a metal bound with magnesium present. This bound is responsible for absorbing light in the visible spectrum region of red (peak at 670-680 nm) and blue (peak at 435-455 nm). The reflection and/or transmittance of the unabsorbed green light (intermediate wavelengths between the mentioned), gives the characteristic green color to plants and chlorophyll solutions.

Most of the plants only have chlorophylls as photosynthetic green pigments when alive. Once they are harvested, protein denaturation occurs (Lafeuille et al., 2014). Figure 4 shows the structure of chlorophyll a and chlorophyll b, varying with the radicals R = CH3 and R = CHO, respectively.

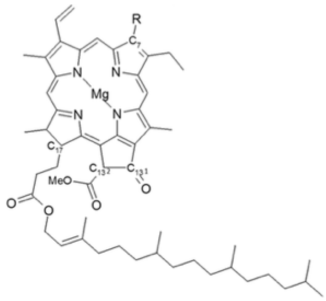


Figure 4: **Structure of chlorophyll a and b** (Adapted from Lafeuille et al., (2014))

The chemical changes in chlorophylls follow multiple breakdown processes during processing conditions resulting in color changes. (Marquez & Sinnecker, 2008). Chemical reactions involve magnesium replacement from the center of the ring and can occur by an acidic substitution, heat treatment; which involves the loss of the carboxymethoxy group at (C13); or after the action of Mg dechelatase, and leads to form derivatives (pheophytins). Enzymatic actions represent the most frequent degradation of chlorophylls, giving the product abrownish-greying surface color pigmentation. Acid conditions promote this loss and low water activity ranges from 0.3 to 0.55 significantly reduce the effect of these enzymatic reactions. (Shermer & Levitan, 2014)

Chlorophyll degradation produces chlorophyllides, that are colored intermediary derivatives before turning to discolored products caused by the enzyme chlorophyllase,which removes the phytol group (C17, Figure 4) and by photoxydation. Enzymes also naturally present in plant leaves are: dioxigenase, oxidase, peroxidase and lipoxygenase. (Gawlik-Dziki, U., 2012)

A way to deactivate those enzymes is by dipping fastly the plant in boiling water, known as a high-temperature blanching pretreatment. Processes used to dry herbs must be used carefully to preserve the aroma and the color of the fresh raw materials. As described by Shermer & Levitan, (2014) the most widely used methods are freeze-dying classified as the one with the lowest impact on color, around 10 % loss; oven-drying, classified as a low impact method leaving 65% to 90% of the initial color; and sun drying, with an important impacts in the herb color leaving only 35 % of the original color.

Regarding the effects on color, consumers consider more as pleasant the bright green color of chlorophylls than the brownish-greying color from its degradation. Studies from Koca et al. (2006), give guidelines to take into account the CIELAB parameter a*, referred below in Figure 5,which is related to the greenish color of food and to reflect the chlorophylls degradation in a reduction of such parameter.

2.2. Color measurement

Different methods attempt to provide a way of expressing colors in a numerical way, one widely known is the CIELAB color space which consists of three axes, L*, a*, and b* (Plataniotis and Venesanopoulos 2000), developed by the CIE (Commission Internationale de l'Eclairage). The L* value represents the lightness, which ranges from 0 (dark) to 100 (bright).The a* and b* values represent the colors indicated along the red to green and yellow to blue axes, respectively. Both a* and b* values range from –60 to 60, depending on the blue or green direction, or on the red or yellow direction respectively. The representation of the CIELAB color space can be seen in Figure 5.

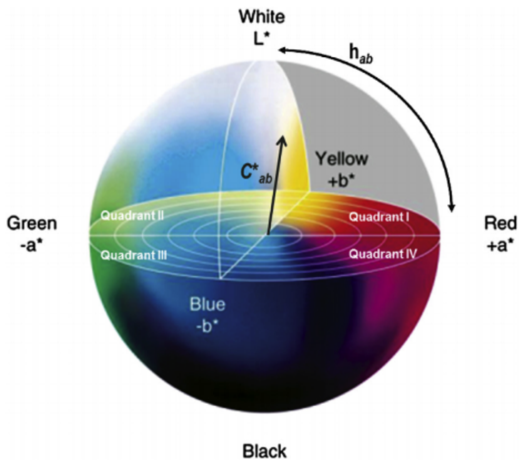


Figure 5:**Representation of the color solid for L*a*B* color space (CIELAB)**

The total color difference (ΔE*) is an important parameter when evaluating the relationship between the visual and the numerical analyses, numerical values show easier the difference; it is calculated as the distance between two points in a three-dimensional space defined by L*, a* and b*. It can be expressed as a single numerical value, but not in which direction colors are different, and it is defined by Eq-1.

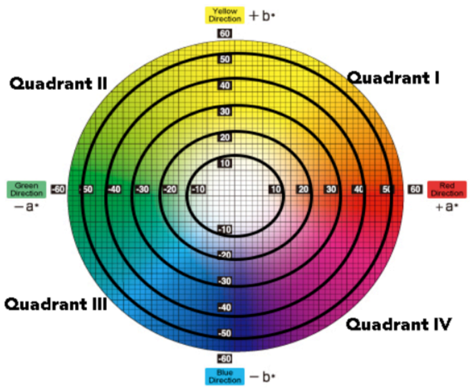
$$\Delta E^* = \sqrt{(L_0^* - L^{*ref})^2 + (a_0^* - a^{*ref})^2 + (b_0^* - b^{*ref})^2}$$

(Eq-1)

Researchers referenced by Da-Wen Sun (2012), presented that resulting values of 1 or less were regarded as satisfactory, while values greater than 3 were considered as unsatisfactory and very easy to appreciate by sight as an effect of a large chromatic difference.

As described by Sant'Anna et al. (2013), the Chroma (C^*_{ab}), represents the vividness of a color and the hue (h_{ab}), represents how colors can be classified as reddish, orange, yellowish; both provide the quantitative and qualitative attributes of color, respectively. The results of these studies suggest that color instrumentation may be an efficient and practical technique to indirectly estimate the presence of bioactive components such as carotenoids and chlorophylls.

The hue corresponds to the three-dimensional color diagram (i.e: 0 for red, 90 for yellow, 180 for green and 270 for blue) observed by the human eye (CIE) and the quadrant should be compensated for the quadrant in which the data appear (Figure 6). The Eq-2 represents how the Chroma is calculated and the Equations Eq-3, Eq-4 and Eq-5 represent the adjustments that must be done according to each quadrant.



Eq-2 $C^*_{ab} = \sqrt{a^{*2} + b^{*2}}$

When +a* and +b* quadrant I

Eq-3 $h_{ab} = \arctan(b^*/a^*)$

When -a* and +b* quadrant II -a* & -b*quadrant III.

Eq-4 $h_{ab} = 180 + \arctan(b^*/a^*)$

When +a* and -b* quadrant IV

Eq-5 $h_{ab} = 360 + \arctan(b^*/a^*)$

Figure 6: **Representation of the chromaticity diagram with the different quadrants and respective equations.**

2.2.1. Colorimeters:

Color meters or colorimeters are devices used to perform the measurements and base its functionality on the fact that part of the light coming from a light source is absorbed by an object and other part is reflected. These differences between absorbance and reflectance make colors different and allow a spectrophotometer to provide detailed information about the nature of a color.

An important parameter for its correct functionality is the calibration, which involves the establishment of known starting conditions in order to proceed with a process of characterization or the process of making a profile for the colorimetric response. Finally comes the conversion, as in devices like Color Detector X-Rite CAPSURE, where the responses are converted to a determined color space in order to match the colors for its application to software e.g., Adobe® Photoshop.

Typically the LAB values are converted into an appropriate CMYK (cyan, magenta, yellow, and black) or to RGB (red, green, blue). These steps are hierarchical, which means that every step is dependent on the preceding. Thus the characterization will be valid according to the calibration condition as referred by X-rite CAPSURE in its user's manual.

2.3. The effect of light.

Surfaces and colors provide us attributes to recognize and identify objects. There are three things that affect the way a color is perceived: light (the characteristics of the illumination), the object, and vision (including the interpretation of this information in the eye/brain system), which is necessary for human observers to perceive specific wavelengths as colors. (Lukac & Plataniotis 2006).

The visible region of the light spectrum is from approximately 380 to 780 nm, as those specific wavelengths stimulate our retinas (Boyce, 2003). Violet-blue color, corresponds to absorbance values between 380 and 480 nm; green corresponds to 480-560 nm; yellow, to 560-590 nm; orange, to 590.630 nm; and red, to 630-750 nm (Sant'Anna et al. 2013). Moreover, light is defined by Konica Minolta (1998) as:

"Light: radiation which stimulates the retina of the eye and makes vision possible"

Visual perception and ambient illumination interacts enabling our perceptual process. For visual stimuli, the lighting is essential and it is a combination of light sources, luminance levels, colors and light fixtures and fittings. Indoor lighting can avoid the appearance of gloom, and lead to instant recognition of appearances, surfaces, object attributes, and discrimination of details. Different light sources will make colors look different; the CIE (1978) defines color-rendering temperature (CCT) as:

" The effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant".

Light sources with CCT values around 4000K are commonly described as 'white' light sources and are commonly present in households, lower color temperature light sources are perceived to be yellowish-white and are said to appear 'warm', and higher color temperature sources are perceived to be bluish-white and are said to appear 'cool'. *(*Boyce, P. R.,2003). More specifications about the color appreciated from each lamp by human eye, and how such colors are associated to each temperature range can be seen in the Figure 7. The LED lamps can be classified according to the color mixing technique used.

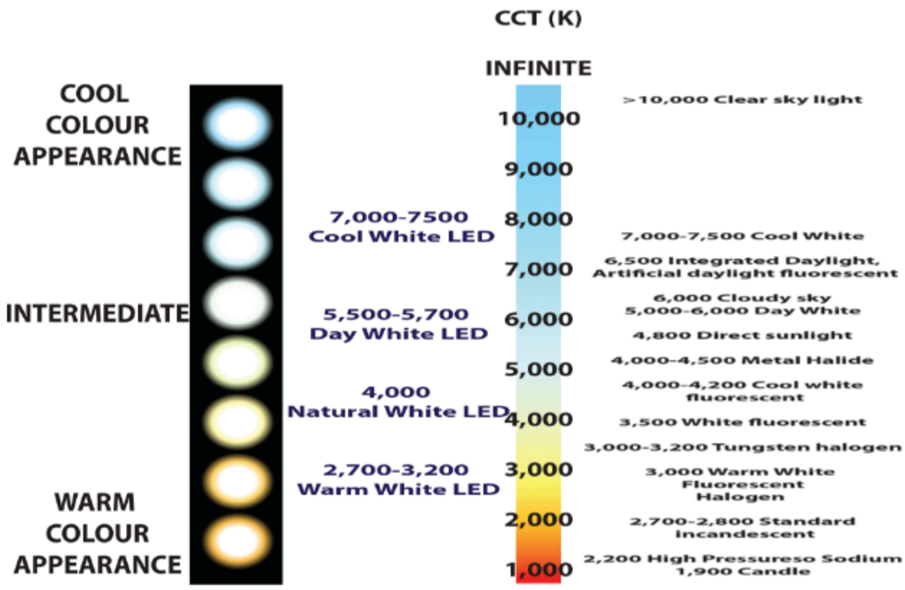


Figure 7:**Typical assessment of color appearance and CCT's of some familiar light sources**

(Adapted from Cuttle, 2015 and Seesmartled.com)

2.3.1. Common light sources

2.3.1.1. Incandescent halogen light

In 1950'sThomas Alva Edison created a system of integrated system of electric lighting. The electric current runs through a wire filament and heats the filament until it starts to glow: Its normal lifetime is about 1000 hours or less. (Energy Star, 2016) Halogen bulbs are technically incandescent light bulbs, illumination is produced in both when a tungsten filament is heated sufficiently to emit light or "incandescence", after it evaporates and deposits metal on the cooler glass envelope (Kistsinelis, S., 2015). The difference between the two is in the composition of the glass envelope and the gas inside the envelope. A standard incandescent bulb has a heat sensitive glass envelope that contains an inert gas mixture, usually nitrogen-argon. (Burter, D., 2010)

2.3.1.2. High-pressure sodium lamps

High-pressure sodium lamps are one of the most important electric light sources thanks to the excited sodium atoms emitting the sodium D lines (589 nm/589.6 nm), which are close to the peak of the eye photonic response (555 nm). This is what gives this lamp its characteristic color and its high luminous efficacy of about 40–50% of the total net radiant power. (Kistsinelis, S., 2010). The normal lifetime of this luminaires is of about 24,000 hours.

2.3.1.3. *Compact Fluorescent Lights-Lamps (CFLs)*

The electric current in these lamps is driven through a tube containing argon and mercury vapor. Such gases emit light on the ultra violet section of the spectrum that excites a fluorescent coating of phosphor located inside the tube and consequently emitting visible light (Kistsinelis, S., 2010). The first time the CFLs are turned on they request more energy than incandescent bulbs, but once the electricity starts flowing, they use 70% less energy than incandescent bulbs and they have a normal lifetime from 6,000 to 20,000 hours and in CFLs spectral distribution has nothing to do with temperature.

2.3.1.4. Light Emitting Diodes (LED)

LEDs are recognized light sources because it is considered that they possess light energy saving potential. LEDs represent an ecologically sustainable alternative to conventional lighting, thanks to their long lifetime (up to 100,000 hours, according to ECOS Consulting LED Report, 2016), which reduces maintenance costs and lowers the replacements in comparison with other light sources. LED lights consist of thin layers of semiconducting materials that emit light when voltage is applied (Kistsinelis, S., 2015). This technology has more similarities with a microchip than other current light sources. However, they provide ultra violet (UV) rays that may have deteriorating effects on products such as foodstuffs. LEDs produce colored light, and in order to get white light, color mixing techniques are used to create it.

Studies conducted by Johansson & Laike (2012), confirm that the knowledge of how this light source is perceived and its possible effects over time, is limited, consequently also its impact on social sustainability. On the other hand Johansson & Laike (2012), reports such as the ECOS Consulting LED (2016), confirm that perceived brightness of the LED lighting increases the perception of accessibility in relation to the obtained photometric measures and that LED lights can contribute to the wellbeing, positively influencing people's vitality, concentration and alertness.

The correct CCT is highly important in spaces such as museums, galleries, operating rooms and retail environment, in order to allow the correct perception of color.

2.3.2. Light applications in retail environments

Lighting is an important tool in designing retailer's facilities due to the need to tempt consumers to visit the store and to facilitate the purchases. Retailer's design can be influenced by guidelines, such as guidelines proposed by IES (International Lighting Design) guidelines for retailers. The adequate design promotes that customers will spend more time inside the facilities, increasing the opportunities to sell merchandise.

Lighting can be seen as the single element which is the most able to give a store an attractive atmosphere. Spatial recognition of the store environment encourages navigation and product browsing and promotes that customers stay inside stores for longer periods. Adequate lighting engages them to take merchandise, to make a purchase and to create a pleasant experience that will influence them either consciously or subconsciously to come back to the store repeatedly (Custers et al. 2010).

Retail architecture tries to set appealing surroundings in chain stores, grocery stores and supermarkets, which are very sparse in both design and lighting compared to lighting in department stores. Therefore retail applications have been often underestimated although retail architecture is important in creating a bond between the customer and the store (Quartier, K., 2011).

The basic problem with designing lighting for industry and displays to be shown inside the retailer's facilities is the wide variability in the amount and nature of lighting requirements to activities related to purchase goods. In every single retailer facility there are different levels of necessary visual requirements which occur under very different environmental conditions as different store arrangements differ even if the chain of the retailer remain the same. In addition the same location might suffer rearrangements due to seasonal changes.

Nevertheless, none of these conditions might pose insuperable problems, given that the extreme conditions could be simulated, and clear idea of the selected light effects could be observed. Customer's mood and behavior in retail environment can be influenced by the selection of lights, cool white lights make the store seem more spacious, while warm white light provides the customers a feeling of safety related to the ambience of familiarity.

However, constraints may be present when it comes to replicating the exact same real conditions or physical situation in which the product exposition to light takes place, like the number of lights and distance to the display. Every store design implies the tailoring of the industrial lighting to each situation. The visual requirements for industrial work can vary greatly, but studies conducted by Park and Farr (2007) demonstrated that younger and older adults in laboratory environment with small displays preferred a CCT of 4100K. The usual solution is to provide general lighting appropriate for the average level of tasks, where work or human activities are concentrated localizing the light sources where they can deliver illuminance in the right place of the whole area, considering as well the directions from which the light comes (Boyce, 2003).

2.3.3. Illuminance and luminance

Illuminance is the amount of light, coming from light sources, which falls on a surface divided by the area of that surface. It is measured in lux, and it is generally referred as 'light levels'. A common office might have an illuminance of 300 to 500. Surfaces as colors/materials of the walls, flooring, ceilings and so on, absorb light, this phenomenon is described as luminance: or amount of light that reaches our eye and that we see (Figure 8), and it is measured in candela per square meter. Lighting has no visible effect in space. We can only see light when it hits a surface. Sometimes it seems like we can see light, but that is only when it is dispersed by small particles such as mist or smoke (Quartier, K., 2011).

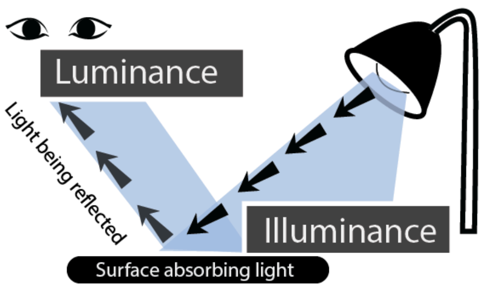


Figure 8: **Difference between Illuminance and Luminance (by the author)**

The light falling on shelves must be expressed in illuminance (lux), and the amount of light that reaches our eye, after falling on the shelf, being partly absorbed and thus reflected, in luminance (Flesch, P., 2006). The illuminance is dependent on the distance and type of the light sources; meanwhile the luminance is also dependent on the surroundings. (Cuttle, 2015)

2.4. Packaging as a barrier

Packaging has the purpose of satisfying the requirements of: containment, preservation and to transport of make available products. In the case of food packaging systems there should be a synergy as described by (Jönson G., 2000), between the marketing, logistical, and environmental functions.

Functionality is one of the challenges and more appreciated qualities of packaging, the ability to create synergies between the food and the packaging system. However, there is no functionality without communication packages function as a tool to sell the product, allowing the product to be easily recognized on the shelves. The protection against the environmental factors varies from product to product but a package is expected normally to preserve packaged foods against thermal leaps, environmental moisture, and mechanical damages as its main functional requirements.

2.4.1. Plastic

Plastics are formed by polymers, what means long chains of many atoms mainly C, H, O, N, they can come from fossil or natural raw materials. Properties of each polymer such as impact, optical, mechanical and electrical characteristics, depend on (1) the monomer chemistry they possess, (2) the length of the chains, as they can be from 2000 to 40 000 monomers, (3) the amorphous or semi crystalline organization state they are in, and (4), the mechanical stress to which they are subjected.

According to Brydson, (1999), some advantages of polymers against other materials are its low density, they request less energy to be transformed in comparison polymers requires temperatures around 200°C against glass that requests around 1200°C. Each polymer has different states and transitions, depending if they can crystallize they can be classified in the families of amorphous polymer or in semi-crystalline polymers as PET that can only turn into a crystalline configuration if its thermal history allows it.

The cooling process affects the crystallization because molecules can move during thermoforming causing an elongation of the molecule. Low cooling speed leaves no residual stress and allows crystallization; a mid-cooling speed leads to an amorphous phase without residual stress; and a high cooling speed leaves residual stress. (Brydson, J.,1999)

2.4.1.1. PET: Polyethylene Terephthalate

Polyethylene terephthalate is polyester issued from a polycondensation reaction called esterification and it consists of a reaction of an acid molecule with an alcohol molecule.

The monomers used for its production are Terephthalic acid and Ethylene glycol, coming from petroleum and renewable resources respectively. Some important characteristics of PET are its high purity when producing it, it is a very transparent material, it can withstand high pressures and it can be dropped without bursting, thus presents good resistance. It also possesses excellent barrier properties for gas. Bottles of this material present a rate of crystallinity of around 20-25%, according to suppliers and referred by Brody (1997).

The technology used to produce it is Injection Stretch Blow Moulding *(*ISBM) or thermoforming, which is a processing technique in which the combination of pressure and heat is used to stretch plastic into or onto a mould to take on a desired shape. This process is considered a secondary process, as a sheet of the polymer must be produced before thermoforming can occur, thermoforming is a more complicated process (Aissa et al., 2010).

2.4.1.2. HDPE: High density Polyethylene:

The characteristics of this polymer are a mid resistance properties, high impact, a good water vapour barrier. It is used normally for closures and caps.

Common technologies used to produce it are Injection Moulding and Extrusion Blow Molding *(*EBM). Injection Moulding is based on feeding material granules via a hopper into a heated barrel, melted using heater bands and a frictional action. The plastic is then injection through a nozzle into a mould cavity where it cools and hardens to acquire the configuration of the cavity. EBM is based on a standard extruder and screw assembly to plasticise the polymer, once melted it is led through a die to emerge as a circular hollow shape called parison. When it has reached a sufficient length a hollow mould is placed and closed around it. The parison is cut at the top by a knife before the mould is moved to a second position where air is blown into the parison to inflate it to acquire the shape of the mould. After comes a cooling period followed the opening of the mould to finally eject the formed plastic. (Aissa et al., 2010).

2.4.1.3. PVC: Polyvinyl Chloride

This polymer is manufactured from two materials:

- 57% of the molecular weight derived from common salt
- 43% derived from hydrocarbon feedstocks but also ethylene from sugar crops is being used for PVC production as an alternative.

PVC is a glossy and transparent materials, but also allows to have an opaque finish that are commonly used in plastic sleeves that are a good and economical shrink film for packaging, such as external sleeves of batteries, because they can be shrinked to the shape or any bottle or container. Actual technologies allow to have a good quality printing with high definition graphics and adjustable design without wrinkles when temperatures in the shrinking process are properly adjusted. Also the colors present resistance to water, giving a high quality appearance to the finished product according to the supplier

2.4.2. Glass

This material presents many advantages when it comes to packaging like its transparency, impermeability and it is an inert material; therefore, it is odorless and tasteless when in contact with food. It also comes from and abundant supply of raw materials.

The container shape and color can be adjusted to appeal customers, but both are limited by the manufacturing, strength and marketing of the finished container. Several glass manufacturers can supply to large-volume fillers, a specific product can have different capacities according to specified shapes and dimension. Another scenario is when the supplier has a catalog of different shapes, colors and volumes available, where the client can choose from or if the manufacturer can produce according to a shape specially designed for a client. Higher volumes lower the manufacturing costs of containers, a principle that is also applicable to other raw materials.

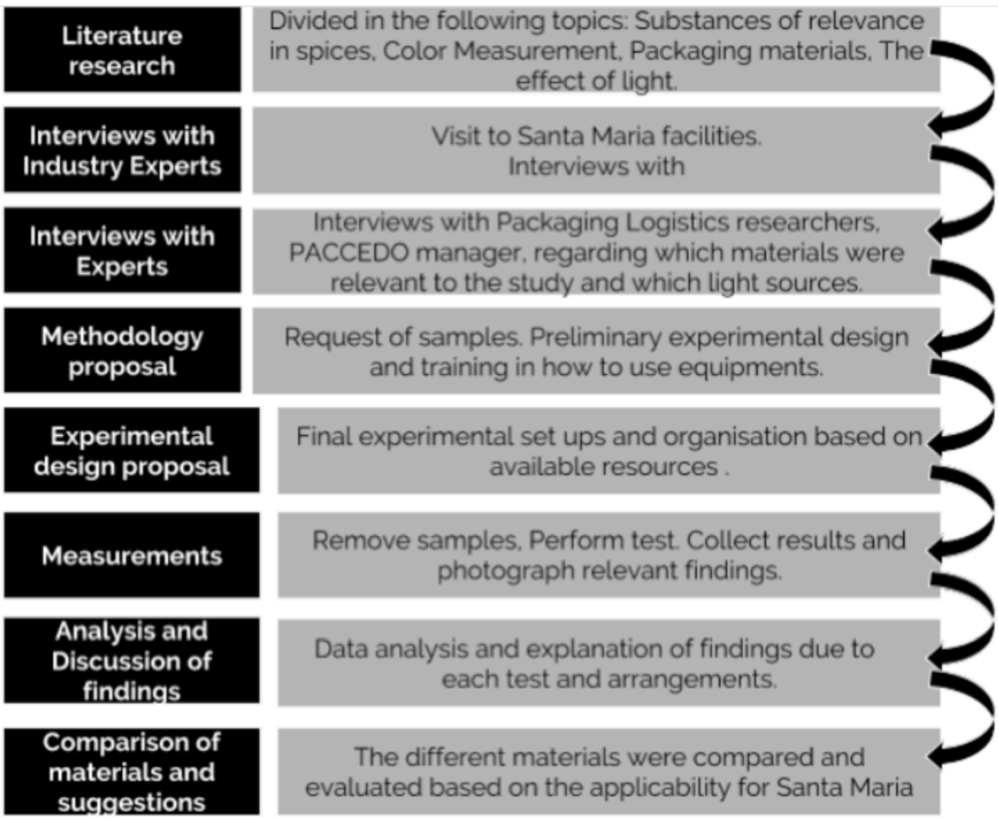
3. Methodology

The aim of this chapter is to describe the data collection methods used to conduct the research in 2 different phases and the basis of selecting this mixed methods strategy. It also explains the characteristics of the different arrangements used and the methodology for the analysis of each section. Also based on the findings from the qualitative phase a preliminary assumption was established, in order to be validated after by the quantitative research.

3.1. General strategy

In order to answer the research question, see Figure 8z, a general process outline was considered as the strategy and was established in the beginning of the work and can be found graphically in Figure 8 as the experimental design proposal. The process of the primary and secondary data collection was performed in parallel and adapted according to the timing in the company.

Figure 9: **Experimental design proposal for the thesis research.**



3.1.1. Selection of method

The preliminary considerations were based on the recommendations of Bell, J. 2010, about including in the methodology section the presentation of materials, the design of the study, its reliability and validity; methods of selection; how to analyze interviews and how criticize of the sources. The literature analysis set the basis for the packaging materials properties framework and provided in-depth understanding of how to design the experiments.

The research was carried out using a mixed methods overall research strategy (Creswell & Plano Clark, 2011) because this structure was the one that best fit the strategy to answer the research questions, it allowed multiple forms of data. This diagram is based on the scientific method, where observations and experimentations are conducted in order to answer a question, following the process of doing background research, construct a hypothesis, to test the hypothesis by doing experiments, analyze the data from the experimentation in order to draw conclusions (Sarasola, 2015).

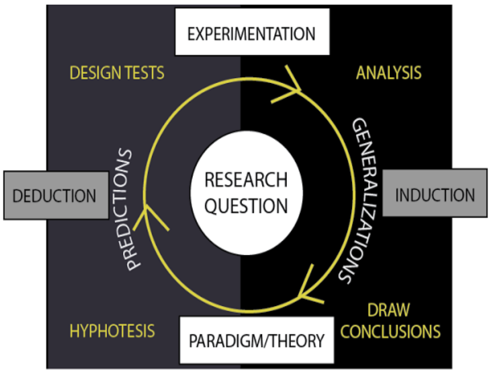


Figure 10:**The scientific method and the alternating cycle of induction and deduction. Adapted from Creswell & Plano Clark, 2011.**

Consequently the process in which the thesis research was conducted was divided in two phases: Phase 1 or Qualitative data collection, and Phase 2 or Quantitative data collection. Below a general diagram of both phases exemplify better the considerations based on the research question. The main questions led to developed sub-question, see Figure 10, in order to understand how to control the conditions when designing the tests in Ljus Lab during the Phase 2.

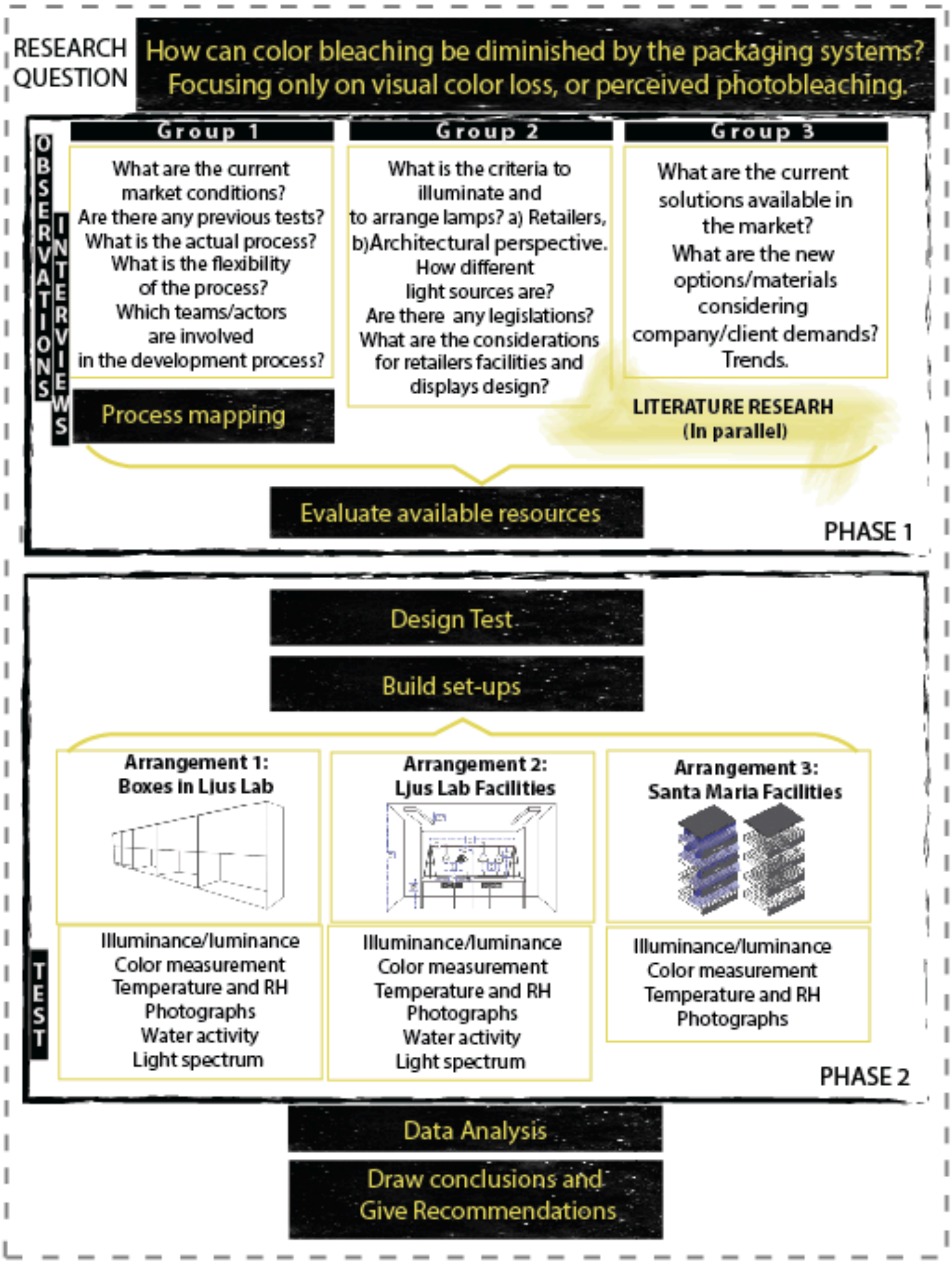


Figure 11: **Description of the 2 phases for conducting the thesis research**

3.1.2. Hypothesis

Based on the initial screening the following hypothesis was made:

A combination of packaging materials would increase the protection against the light, without modifying greatly the manufacturing process and the actual supply chain.

3.2. Phase 1: Qualitative data collection

The qualitative data was collected by primary data collection methods, via semi-structured interviews, where the description of the groups interviewed are present in Table 1. Direct observation of the conditions of the retailer's facilities and consumer's households was also done. The secondary data collection was performed in the form of literature review, based on the general principles about the packaging materials and its properties using online publications, e-books and books as sources of information, and is presented in the Chapter 2: Theoretical Framework. Both processes were conducted simultaneously.

Table 1:**Description of the groups considered in primary data collection**

Group Number	*In order to understand*	*Composed by*
Group 1	Conditions of the market and the company's approach	Santa Maria´s working professionals from the following multidisciplinary teams: Marketing, Purchases, R&D, Packaging development, Project Management, Production and Suppliers.
Group 2	Light conditions arrangements and retailers choice.	Researcher in Ergonomics and Aerosol Technology (Academia), Swedish Working Environment Authority (SWEA) and Retailer Managers.
Group 3	External perspective and future scenarios	Packaging Material Expert from Packbridge & Researchers from the Packaging Logistics Department in Lund University (Academia).

The second group provided better understanding of the complexity of light influence present in the retailer's facilities, 3 different managers from supermarkets in Sweden were interviewed, ICA, LIDL and Willy's. The semi-structured interviews to the third group provided insights from experts in the Packaging Area about packaging materials properties, its current commercialization, its availability in the market compared to the level that can cover the industry requests as Santa Maria's demand.

3.2.1. Data analysis of qualitative study.

Due to the time limitations of this research a complete consideration of all the supermarkets and retailers' conditions available in Sweden could not be analyzed. Consequently the interviews with the industry professionals and their experience in the field provided explanations of the trends and strategies used nowadays in the market derived from their personal insights and knowledge.

The recordings of the interviews were reviewed and analyzed looking for information with considerable relevance to the study. A summary of the observations notes and insights provided valuable information for the next phase of the study and to make an accurate analysis. Together with the considerations obtained after the analysis of the protection against light in phase 2, the most relevant criteria obtained from the phase 1 will be used to analyze in Chapter 5. The evaluation criteria will be set based on a 5 point scale and the different rankings will be determined based on the relevance to the company.

3.2.1.1. Reliability

It is considered that the replicability of research findings and whether or not they would be repeated if another study, using the same or similar methods, was undertaken. The extent to which replication can occur the performed qualitative research has been questioned due to the different time frames and the changing conditions of the market, it can be useful as a screening of the market but authors like Holstein and Gubrium, (1997) argue that a qualitative research is dynamic and can only be conducted effectively in a responsive manner and that studies can never be, nor should be, repeated as 'a somewhat unrealistic demand'.

Features of the qualitative phase might be expected to be consistent and dependable because the structures used on the data by the researcher have been consistently obtained and derived from an analysis, based on the following

- The interpretation is well supported by the evidence.
- The design allows equal opportunity for all perspectives.
- The fieldwork carried out consistently to cover relevant issues.

Thus the reliability of the findings depends on the likely recurrence of the original data and the way they are interpreted, and the findings in this research answer the research question as an outcome of the data. Yin (2009) states that a correct analysis demonstrates the use of as much evidence as possible.

3.2.1.2. Validity

The validity of findings or data is referred as the 'correctness' or 'precision' of a research, concerned with the 'investigation of what you are claiming to be investigating' (Arksey and Knight, 1999); and with the extent to which the structures are applicable to other groups. (LeCompte & Goetz,1982).

Additionally the following points were considered when conducting the research

• Sample coverage: The structure of the open interviews reduced the possibility of bias; providing a comfortable environment for the participants to express freely their opinions.

• Capture of the phenomena: The environment and the quality of the questions that were conducted for the research allowed the participants to explore their points of view.

• Identification or labeling: The bleaching or spices and color loss were mentioned in order to identify the phenomena, reflecting the issue in terms understandable by all the participants.
• Interpretation: The participants have been exposed to the phenomena and they can recognize it after referring it in the interviews.
• Display: The findings portray in a way that can be found in real conditions in the retailer's facilities, allowing to analyze and to draw conclusions.
Finally there is a strong link between the validity of qualitative data and the extent to which generalization can occur.

3.2.2. Insights that lead to the design of the quantitative tests.

Working together with Santa Maria's Marketing Department and Business Intelligence and Marketing it was possible to take into consideration the actual conditions of the market and the variables affecting the display of the products in the retailer's facilities. Based on deep understanding of the manufacturing process, a process mapping (present in the section 4.1.1) and activities was carried out as an initial phase to limit the field of study and to focus only on the most important factors that lead to a loss of color in spices packed in the glass jars.

3.3. Credibility of the study

The data generated from the qualitative phase will be presented in a narrative form, but only presenting the most relevant ideas in order to construct comprehensive, interrelated ideas and interpretations of the actual conditions of the market by the use of the inferential generalization as mentioned by Ritchie J, Lewis J (2007) which lead to assertions which are context-free, and their value lies in their ability to achieve prediction. There will always be factors that make a particular setting unique but that considering these judgments about transfer to other settings can be made.

3.4. Phase 2: Quantitative data collection

This phase was formed by 3 different arrangements of experiments, the first in Santa Maria's Facilities, and the second and third in Ljus lab, a recently built area in IKDC building. The arrangements were designed based on recommendations of experts that installed the electrical installations, available structures to support the luminaries, space constraints and equipment availability for exposing samples to different light sources.

Table 2 presents all the packaging materials used to test in the experiments with a code assigned for each, those codes will be mentioned throughout the document.

Table 2: **Codes assigned to packaging materials used.**

Code	*Description*	*Image*	*Code*	*Description*	*Image*	*Code*	*Description*	*Image*
1	Glass jar 81 ml *The actual containers had a paper label.		4	Samples without packaging placed in Santa Maria´s lid		6	Plastic PET COLOURED 85 ml	
2	Glass jar 81 ml+ plastic sleeve *The actual container had a paper label.		4b	Glass jar 135 ml *The actual containers had a paper label.		7	Plastic PET small 85 ml	
3	Plastic PET 440 ml *The actual containers had a paper label.		5	Glass jar COLOURED 75 ml				

In the case of the packaging material code 2 (Glass jar 81 ml + plastic sleeve), the samples were the same as the code 1, the difference is that a plastic sleeve was cut according the measurements of the package (10 cm), leaving enough space for allowing a correct shrinking (12.5 cm) and placed and shrinked manually with and industrial AEG Heat Gun, see Figure 12.

Figure 12: **Process of placing the plastic sleeve manually.**

The packaging materials with the codes 4,5,6 & 7 were filled manually in Santa Maria´s facilities with a bigger presentation of the selected spices from a plastic container, in the experimental kitchen designed for the development of new recipes.

3.4.1. Generalities about the tests

The exposure of the samples in arrangement 1 and 2 was carried out in with a length of 8 weeks each and of 7 weeks in the case of arrangement 3. There was a consecutive sample exposure to light of 24 hours, with no extra humidity or temperature controls but the ones already present in the rooms dedicated to perform the tests. The arrangements, equipment used and measurements performed in each experiment will be described per experiment. The exact number of total measurements performed per arrangement can be found in Appendix 9.2 for more details; in the case of the color meter triplicates were taken and for the water activity measurements were done in duplicates.

Additionally, to match the color with parameters used to display on screens and design software a colorimeter (Color Detector X-Rite CAPSURE), was used to register the initial color of the samples and controls.

In the case of the arrangements with controlled parameters, the measurements of the set-ups were considered as very important in order to ensure a similar exposure to light of all the samples used during the study according to each arrangement; therefore the standardization of lights expects to provide comparable results between the arrangements when it comes to drawing conclusions and to proposing recommendations.

This research studied the lighting via manageable arrangements and the overall set-up of the arrangements is the result of the author's perspective and the attempt to make the most of the available resources in the different locations.

The sample removal will be defined depending on the arrangement characteristics. In the case of arrangement 1 every removal a sample from each spice was removed from the boxes and stored in a different area once the measurements were performed, the following weeks the procedure was the same until ending with the samples.

In the case of arrangement 2, the spices contained in the P1, P2 followed the same process, but in the case of P3 and P7, the samples were measured and after placed back to the arrangement in the same position and in the same day due to space constraints. In the case of P5 and P6, the samples were only removed after the period of 8 weeks was finished, due to the fact that containers needed to be emptied and also due to space constraints.

In the case of arrangement 3, P1, P2, P3, P4, P5, P6 and P7 were removed each 2 weeks until a total period of 8 weeks, which means 4 removals, and the procedure was the same as in arrangement 1, the samples were not placed back to the arrangement after measurements were performed.

The procedures used to measure color can be found in Appendix 2, and the following Table 3 describes in a general way all the test performed per arrangement. Also the reasons why these specific tests were conducted in each arrangement are explained, in the case where the test was not carried out in certain arrangement it was due to availability constraints i.e., the equipments used to measure were located in a specific facility without the possibility of moving the equipment out of it.

For all the images from certain arrangement the camera parameters were set the same, ensuring the colors portrayed were the same for all the sets of pictures.

Table 3:**Description of the arrangements and test considered for quantitative analysis**

Arrangement Number	***In order to understand***	***Conducted tests and explanation***
Controls	***Closed Box:*** Actual conditions inside Santa Maria warehouse ***Cold storage:*** **A different process to store spices.**	**Color measurement:** In order to answer objective 1 and 2, to define with process had more harmful effects on spices color, to quantify changes in color against a reference after each removal. To understand if the storage conditions are maintained before display, if the spices maintain as well their color.
1. Ljus Lab Boxes	Behavior of spices when they do not present any protection from packaging, understand expected changes in the selected spices to be able to correlate with the other arrangements results. Controlled parameters for distance of samples from the light sources to have controlled illuminance.	**Illuminance and Luminance:** To measure light coming in contact with package, light absorbed and light reflected by the spices. Verify principle of distance is affecting illuminance as referred by Cuttle, (2015), to ensure strong basis to answer sub-objective 2. **Color measurement:** In order to answer objective 1 and 2, best display conditions and light sources with more harmful effects on spices color, to quantify changes in color in a numerical way. **Temperature and Relative Humidity**: To understand environmental conditions and if there are any changes throughout the full length of the tests. **Light spectrum going inside the packages:** To understand which material is letting pass which amount of light in order to answer sub-objective 3. **Water activity:** To link if color changes are related to changes in aW, when the spices are open and to correlate expected results in other arrangements. **Photographs:** Visual representation of results.
2. Ljus Lab	If changes in color are appearing and which material is performing the best, under very controlled conditions.	**Illuminance and Luminance:** To quantify differences against other arrangements, and considering differences based on the available resources. **Color measurement:** Same as arrangement 1 **Temperature and Relative Humidity**: To understand environmental conditions affecting the test. **Light spectrum going inside the packages:** To

		understand which material is letting pass which amount of light in order to answer sub-objective 3, if the behavior remains the same under different conditions. **Photographs:** Visual representation of results.
3. Santa Maria Warehouse	The effect on spices of the new trend to create an ambiance on retailer's displays.	**Illuminance and Luminance:** Same as arrangement 2. **Color measurement:** Same as arrangement 1 **Temperature and Relative Humidity**: To understand environmental conditions in a real environment. **Photographs:** Visual representation of results.

3.4.2. Set-ups design: Arrangements

3.4.2.1. Arrangement 1: Boxes in Ljus Lab Facilities in IKDC Lund University

This experimentation was carried out in IKDC facilities inside the Ljus Lab, where spices were exposed to 5 different light sources inside a structure designed specially for running tests in parallel. With a limited capacity this set-up used to understand the effect of each light in the color bleaching process in the selected spices. The spices were placed in containers provided by Santa Maria (Packaging material code 4) in the order shown in Figure 13. Those containers had a height of less than 0.5 cm.

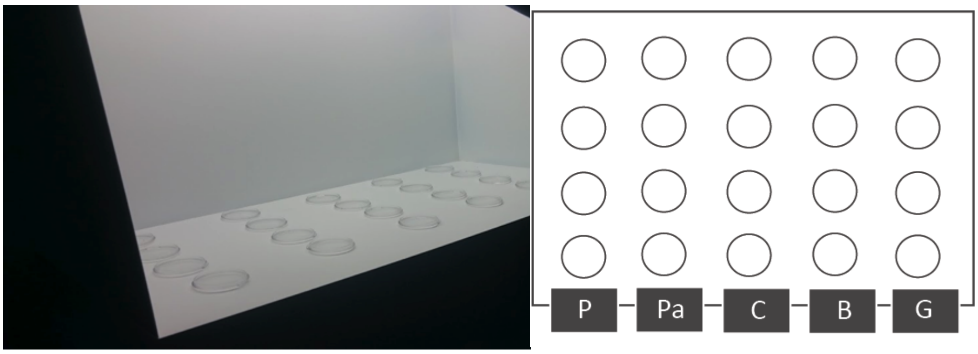
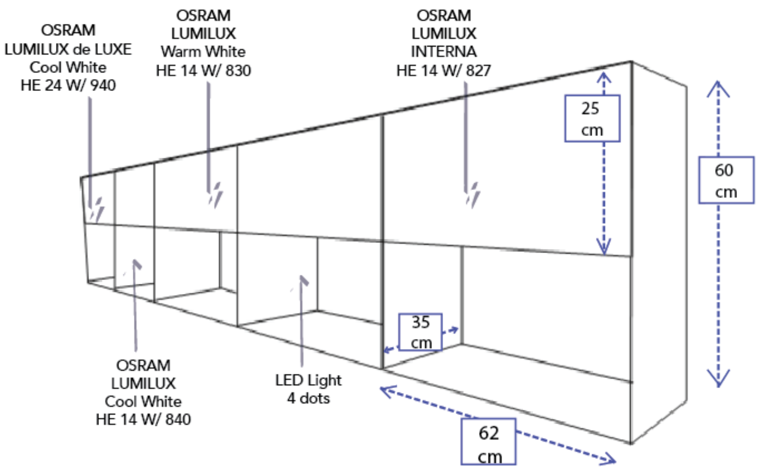


Figure 13: **Empty containers provided by Santa Maria and the arrangement inside each box.**

After placing the samples a thick fabric was used to cover the boxes in order to prevent sunlight from coming inside the boxes, due to the fact that the boxes were facing a window. Figure 14 shows how the boxes were before and after being covered by the fabric, guaranteeing no sunlight was going through to the boxes.

Figure 14: **Boxes in Ljus lab and the designed cover.**

Moreover, all the spices were arranged following the same order inside, the number of samples per box and the number of total samples in the arrangements are presented in Figure 15.



Quantity	Description
5	Boxes with different light source
5	Spices variety per box
4	Samples per spice inside each box
20	Total samples per box
100	**Total samples in total boxes.**

Figure 15:**Measurement of the boxes in Ljus lab and its characteristics**

As in the previous arrangements the following tests were conducted in the samples exposed to light in Arrangement 3, the summary can be seen in Table 4:

Table 4:**Measurements performed In Arrangement 1: Ljus Lab boxes**

Test No.	***Test***	***Frequency of the measurement***	***Equipment***
1	Illuminance and Luminance*	Once, when the set-up was totally built	Hagner Universal photomete r Model S2
2	Color Measurement**	Dark and frozen conditions: Once in each. (The same for all arrangements) Samples exposed to light: Every 2 weeks in a total period of 8 weeks.	Color meter CR-400/410
3	Temperature and Relative Humidity***	Throughout the whole exposure period	EL-USB-2-LCD
4	Photographs	When visual changes were appreciated	NIKON Coolpix PS500
5	Light spectrum going inside packages	Once, when the set-up was totally built	AvaSpec-2048-USB2
6	Water activity****	Control: At the beginning of the experiment. Samples exposed to light: Every 2 weeks in a total period of 6 weeks.	AquaLab Series 3

*Illuminance and Luminance: As in the previous arrangement, lm were measured for the illuminance and luminance, but following a pattern of 3 points inside each box, the distribution can be seen in the results section.
**Color Measurement: One sample per spice variety was removed in week 1,3,5,7. The samples were placed in a closed box with supports to be transported to the facilities in Kemicentrum, and 3 replicates were made per sample to analyze the color.
***Temperature and RH: Same as previous arrangement.
****Water activity: After measuring the color of each sample with the Chroma Meter, samples were placed in the plate designed for the AquaLab Series 3, the samples were analyzed per duplicate due to the equipment availability constraints in Kemicentrum.

3.4.2.2. Arrangement 2: Ljus Lab facilities in IKDC Lund University

An arrangement of 50 spices per side under the exposure of 2 different light sources (400 and 1000 lm) was placed to understand the color change under both light arrangements comparing the spices of interest. The arrangement and the measurements can be observed in Figure 16 and Table 5 respectively, the distribution of the samples was organized in a way to allow having an equal exposure to the light in the designed are inside the cardboards, the lamps hanged on the roof were also taken into consideration. The samples are represented in the diagram below the lamps and the measurements of the cardboard in which the samples were positioned (77.5 cm), are also equal in both sides.

Additionally the resources available allowed to use the same brand bulbs, but 2 lamps were the same and 2 lamps were different, lamps that were equal were positioned in opposite direction to cover in an equal way the light from the luminaries from the roof, its localization can be seen in the drawings with the same drawing, and those different from each other are represented by a black and a white lamp, in the 400 lm and 1000 lm section, respectively in Figure 16.

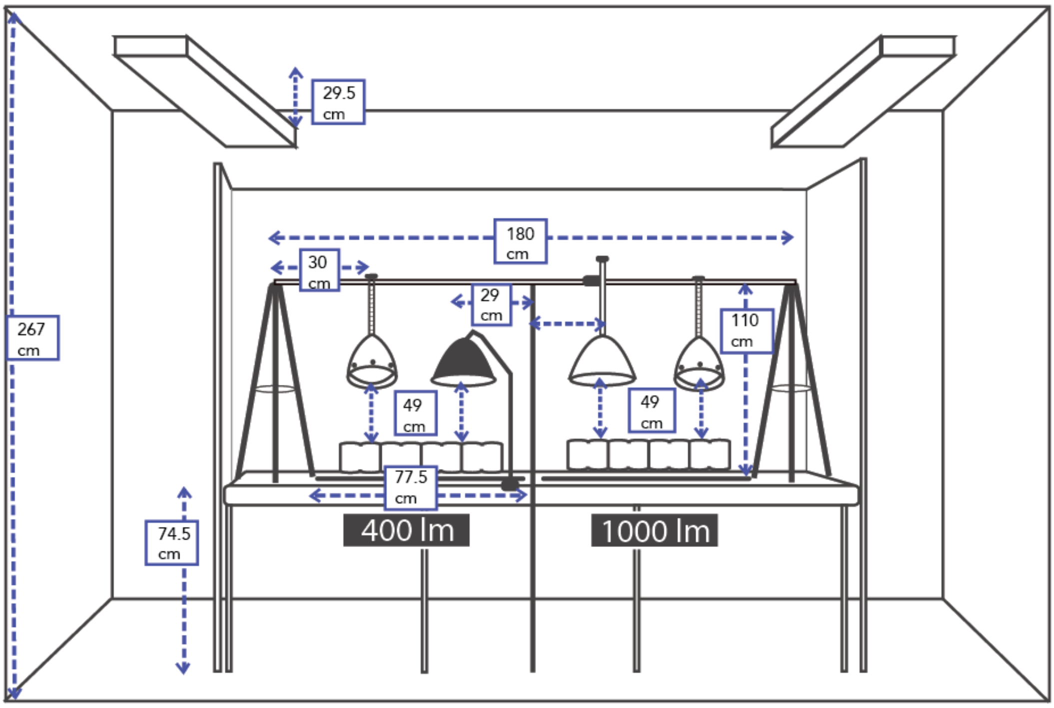


Figure 16: **Ljus lab organization for arrangement 2.**

The total number of samples can be seen in Appendix 2 and the distribution of the packaging materials in the cardboards are presented below in Figure 17, from an upper view, but representing the distribution previously shown, the surface is presented with different patterns to exemplify where the samples were placed.

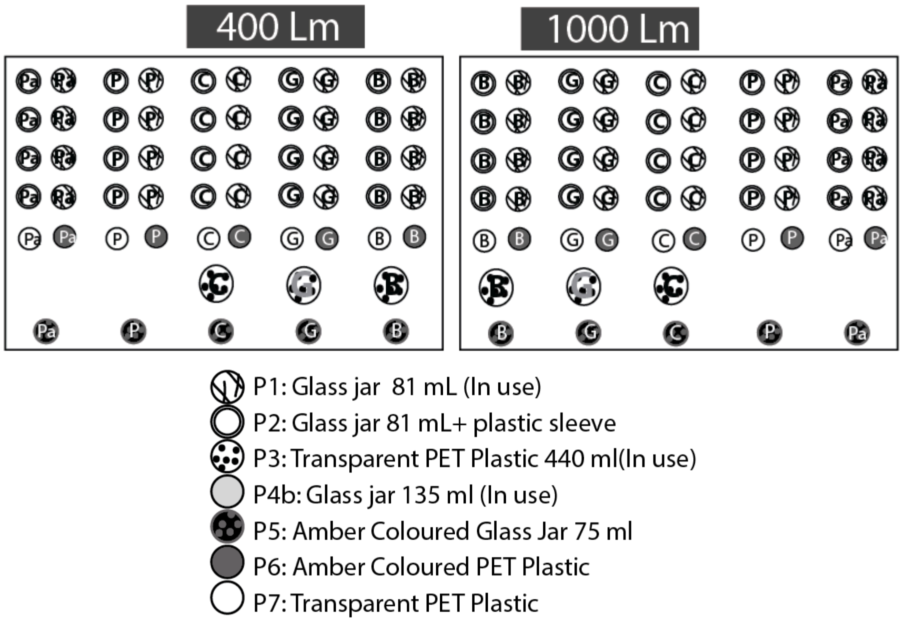


Figure 17:**Arrangement 2: Ljus Lab Facilities, the patterns indicate the position of the different packaging materials. (Top view)**

As in the previous arrangement a variety of tests was carried out. Unlike Arrangement 1 in Arrangement 2, the contact of the researcher with the samples was possible every day, the control of how they were exposed to light was higher, allowing to verify the storage conditions and with a restricted access to the room in where they were stored. The tests are shown in Table 4.

Table 5:**Measurements performed In Arrangement 2: Ljus Lab facilities**

Test No.	***Test***	***Frequency of the measurement***	***Equipment***
1	Illuminance and Luminance*	Once, when the set-up was totally built	Hagner Universal photometer Model S2
2	Color Measurement**	Dark and frozen conditions: Once in each. (same for all arrangements) Samples exposed to light: Every 2 weeks in a total period of 8 weeks.	Color meter CR-400/410
3	Temperature and Relative Humidity***	Throughout the whole exposure period	EL-USB-2-LCD
4	Photographs	When visual changes were appreciated	NIKON Coolpix PS500
5	Light spectrum going inside packages****	Once, when the set-up was totally built	AvaSpec-2048-USB2

*Illuminance and Luminance: As in the previous arrangement the lumens were measured for the illuminance and luminance following the next pattern of 9 dots in each arrangement. The number of points where measurement was performed, was decided based on whether any of the dots from the center presented a change in value and having in mind the biggest area coverage, see Figure 18. The high of the sensor were the measurements were taken, was always the same using as a reference the height of an empty 81 ml glass that was used as a support.

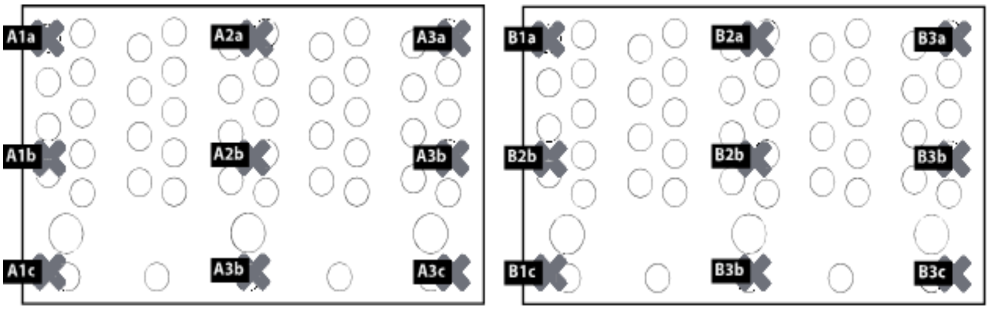


Figure 18:**Points of Illuminance and Luminance measurements in Arrangement 2: Ljus Lab.**

9 points in each side, where measurements were performed under 400 lm (A) and 1000 lm(B). Top view

**Color Measurement. One of the 4 available containers per spice variety was removed each week in order to perform the color measurements in the laboratory at Kemicentrum without being reintroduced to the arrangement. In the case of P5, P6, the samples were measured at the beginning and at the end of the research, because measurements could not be performed without pouring all the content in the packages, introducing variability on the distribution of the samples inside the containers. P3 and P7 were moved for the measurements and positioned back to light exposure in the arrangement due to space constraints.

***The recording of temperature and relative humidity parameters was performed in intervals of 30 minutes, during the first week in order to verify if conditions were similar as those registered by other devices used in Ljus Lab, due to parallel use of the equipment. Once the parameters were analyzed an assumption was made, the parameters were very similar and measurement in the other rooms of the lab were considered, after the data was transferred to excel and plotted.

****Light spectrum going inside packages: The 6 empty packaging materials distributed as in Figure 16, and referred with the codes 1,2,3,5,6 & 7 were evaluated under the 2 lamps present with bulbs of 400 lm and the 2 lamps with bulbs of 1000 lm, using the same high, from the table to the lamps, in the same position and considering a height of 2 inches from the bottom of each packaging material, previously marked, see Figure 19.

Figure 19: **Light spectrum measurement inside the packaging materials showing the area where the sensor was located and the distance from the table.**

3.4.2.3. Arrangement 3:Santa Maria's facilities

As part of the experimentation to determine when and under which conditions the color bleaching is occurring, the samples of the selected products contained in the different packaging systems mentioned previously. Samples were distributed in the different set-ups to understand how light affects the products regarding if they are placed in the actual conditions or in the display with added magnetic LED lights.

Santa Maria's facilities were used to analyze the spices under a scenario with the most similar conditions in comparison to real shelf ready displays present in the retailer's facilities. An experimental setup based on the common conditions used in the retailer's stores was proposed, carried out inside Santa Maria's facilities, dedicated for the evaluation of the appearance of the finished products at the shelves, adapted with conditions similar to those present in the retail stores.

The shelf levels can be altered according to the demand and to fit the needs of the retailer store. Two equal arrangements of 4 levels each with and without LED lights were used to compare the effect of using LED lights against the actual arrangement in retail stores, see Figure 20.

Figure 20:**Final Santa Maria facilities arrangement**

The arrangement of levels, the spaces per level and magnetic LED lights added to the shelves versus the shelves without lights can be seen in Figure 21, where the location and quantity of lights is also represented.

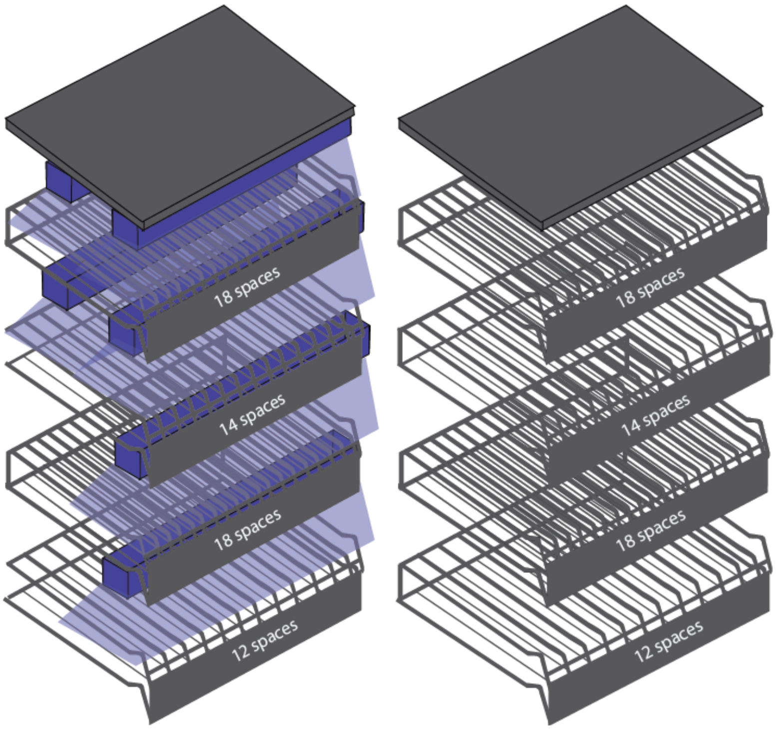


Figure 21:**LED lights quantity and arrangement vs Actual arrangement.**

The following figure 22 represents the arrangement and total of samples of each packaging material, with their distribution in each level of the shelves, naming level 1 the level at the top and so on.

The codes of the spices present in the diagram are linked to those in the acronyms list, and as each level contained different packaging materials the figures have a different references to a packaging material according to the color scale present at the bottom of the diagram, the materials that include the legend "in use" mean that are actually being used as packaging materials in Santa Maria's assortment. Also this diagram makes reference to the Figure 19. The levels 2 and 4 with 14 and 12 spaces respectively, were only filled with P & C and C, G & B respectively, because those are the only varieties available in the used presentations. The top level was distributed as evenly as possible in order to fit the samples due to the lack of more shelves.

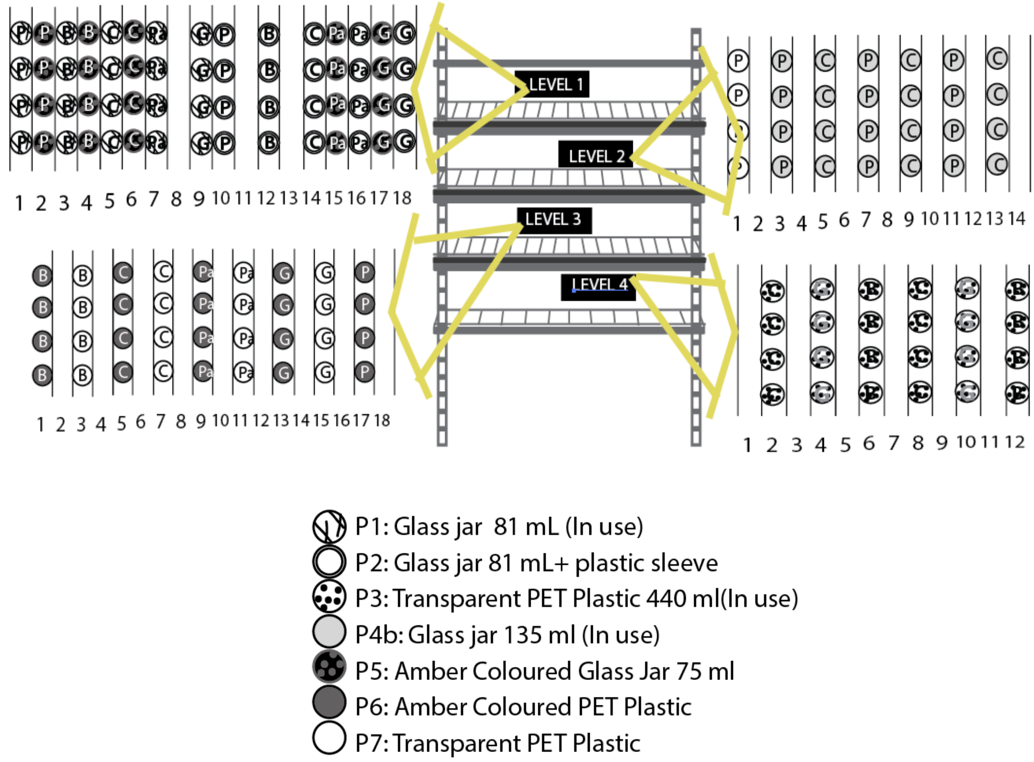


Figure 22: **Sample arrangements in each level, from top to bottom.**

The total number of measurements is referenced in Appendix 2, under the column LED SM (Shelf arranged with LED lamps) and SM (Shelf arranged in actual conditions in retailer's facilities), and the summary of the tests conducted on the samples in Arrangement 2 are shown in Table 6.

Table 6: **Measurements performed in Arrangement 3: Santa Maria's facilities**

Test No.	Test	Frequency of the measurement	Equipment
1	Illuminance and Luminance*	Once, when the set-up was totally built	Hagner Universal photometer Model S2
2	Color Measurement	Dark and frozen conditions: Once in each.(same for all arrangements) Samples exposed to light: Every 2 weeks in a total period of 8 weeks.	Color meter CR-400/410
3	Temperature and Relative Humidity**	Throughout the whole exposure period	Thermometer
4	Photographs	When visual changes were appreciated	NIKON Coolpix PS500

*The illuminance and luminance were measured in different sections of the shelves arrangements, based on the most relevant points in the structures. Measurements were carried out according to the sections present in Figure 24.
**In order to measure the temperature and the humidity a device was located in the warehouse of Santa Maria, such thermometer measures the temperature parameters inside the warehouse facilities. However this device is located just outside the door of the room used for store the LED and current displays, if the temperature inside the room was increased due to the added lights, the thermometer was not detecting these conditions, due to the fact that it is fixed to the wall.

3.4.2.4. Data analysis

In the case of the test 2, color measurement, all the values were collected by triplicate, and the average and standard deviation was calculated. Based on those average values of each removal, depending on the arrangement, the data was organized to present the changes in a chronological order. Once the values were organized, ΔL*, Δa*, Δb* could be calculated. The values were calculated considering the difference between each removal, subtracting the most recent week from the previous one, and finally the ΔE* was calculated based on the values from the control against the last sample removal after the whole period of exposure.

Moreover C ab* was calculated applying Eq-2 and based on the ΔL*, Δa*, Δb* found between each sample removal (4 removals per arrangement); h ab* was calculated using only Eq-3 or Eq-4 depending on the quadrants in which the values a* and b* were located (See Figure 6). The red spices were only located in the quadrant I, and samples from Basil or Paprika were present whether in the quadrant I or II. The values and quadrants of each sample will be specified in the results section.

Once the Equations were applied the samples located in the extremes, more damage by light and less damage by light were identified and compared against the visual results obtained from the observations and referenced to the photographs section of the results of each arrangement.

The values of ΔE* from Arrangement 2 and 3 were considered to be arranged in a way to calculate an analysis of variance, Two way ANOVA, in which the values of ΔE* for each removal were considered. This value was selected to analyze due to the fact that it includes the 3 parameters for color, L*, a*, b*.

A total of 4 ANOVAS was applied, 2 for the Arrangement 2, consisting in one for arrangement with 400lm and other for arrangement with 1000lm; for Arrangement 3, the two-way ANOVA were applied to the set up with actual conditions in the market and other for the set–up with added LED lights. The parameters evaluated were the influence of the package against the effect of the different spice in the color bleaching.

4. Results.

The chapter is dedicated to present the results from the 2 phases of the study. First form the qualitative data collection, the most relevant findings form the observations and the interviews are summarized and later, from the quantitative data collection, also the results of the tests performed to each arrangement.

4.1. Phase 1: Results of qualitative data collection

For the purposes of the study, these interviews were sufficient to address some of the central concerns of the research. Such concerns allowed understanding better the dynamic conditions of the market, the difficulty to generalize about the luminary models and the scarce architectural design in retailer stores, compared to . In order to determine that the costs and the energy efficiency of the lamps were important, a link was commonly found with legislations and costs, because establishments needed to be compliant with regulations. Due to these reasons, the fact of selecting equipment for the retailer's facilities is dependent on budgets and the packaging solution design cannot be designed based on an ideal scenario but to resist the most severe conditions.

The comprehensive findings from each group of interviewees are summarized in Table 7, including the contacts from the interviews and describing the reasons for them to be in the study.

Table 7: **Findings from the qualitative phase of data collection.**

Group number	Group 1
To understand:	Market conditions Actual conditions Previous tests Teams and actors involved in the process
Contact	Peter Blomgren, Expert Strategic and Research Projects (Santa Maria), Staffan Kaldén, Sourcing Category Manager Traded & Packmaterial (Santa Maria), Christopher Westerberg, European Marketing Manager, Spices (Santa Maria), Malin Brodén, European Trade Marketing Manager (Santa Maria), Sofia Wallsten Packaging Development Specialist (Santa Maria), Fredrik Karlsson, Warehouse and Production Responsible (Santa Maria).
Type of contact	Person to person open- interview

Findings	The steps from the reception of the raw materials until the finished product, represented in the process mapping (Figure 23) Insights about how current packaging solution is very adapted to every stage and process in the production lines with high degree of automation and little human contact with the product once it contained in the glass jars or PET bottles. The conditions of the raw materials distribution are well settled; the relationship with suppliers has been built thanks to many years of purchases, adjusting the supply chain and timings to the current suppliers. Modifications in the current package solutions followed a process that leaded to the actual solution, considering as a pillar the recognition in the market by consumers and the characteristic shape of the brand. Glass jar has always been the preferred material for consumers, also due to the density of spices such as parsley that contain less weight per package compared to spices like Grillkrydda or Paprika, to mention some. There are new prospects of strategies in the retailer's facilities, as the shelves that are actually provided by Santa Maria to the retailers. Those shelves allow adapting the distribution and having spare levels to adjust the organization inside the stores. If new parts or new shelves are to be designed and added, they should be easily adapted to the existing ones, . Moreover if lamps are added the effects they will have on Santa Maria spices is not known yet.
Group number	**Group 2**
To understand:	Illumination criteria in retailers facilities How different light sources are Considerations when designing/arranging displays
Contact	ICA Supermarket Manager in Fäladstorget 14, 226 47 Lund, Sweden Lidl Manager in Magistratsvägen 6, 226 43 Lund, Sweden Willy's Manager in Magistratsvägen 22, 226 43 Lund, Sweden Hillevi Hemphälä, Ergonomy and Aerosol Technology Researcher , Lund University Per Nylen , Swedish Work Environment Authority Contact*
Type of contact	Person to person open-interview. * Via e-mail
Findings	Generalizations cannot be established when it comes to lamp characteristics, the architectural design of every store is very varied, the most common lamp (assumed they were similar due to design and visual characteristics) is represented in Appendix 5 with a star on the image. Most of the luminaries are changed based on the needs of the retailers, for instance when one is not working properly or due its normal use and lifetime; it necessary to change it and that is taking place during the hours when the supermarket is closed to public and also shelves are organized and refilled. In the case of ICA supermarket, the aisles presented a wider variety of products and the displays were those supplied by Santa Maria, also it was confirmed that the lights remain on during the whole night. In the case of Willy's the trays were present but not the shelves from Santa Maria, many lights are turned off to save energy. As mentioned by Boyce, (2003), it was verified that the most common arrangement is localizing the light sources where they can deliver illuminance in the right place or in a wider area.

In all the supermarkets it was confirmed that light is an important factor in retail space because it creates an atmosphere and it has proven that it affects consumer preferences as referred by Quartier, K., (2011) and with Custers et al., (2010).

The personnel working in the stores rely on the purchases department in charge of buying supplies for the facilities. Very few products have a specific design for their shelves and normally they are provided by the brand if applicable. It was observed a widespread distribution of CFL's lamps but regarding the use of LED lamps as mentioned by Johansson & Laike (2012), the effects on health are not known by the personnel working in the retailers facilities. Also every manager confirmed a preference for products that are energy efficient and if they provide better illumination inside the supermarket, but they show concern about the change of the electric installations in order to install them in the supermarkets, that it will request a considerable initial investment.

Every lamp is different even though the bulb specifications are the same, every supplier is different and even if the same bulb is used in a different luminary of lamp, the characteristics of the light spectrum will be different. Very few interviewed people understand this principle, only the personal from the academia was aware.
The LED lights were more commonly found in the households, but still not as present as CFLs.

The considerations to have in a working environment are such that the personal safety and job satisfaction can be guaranteed. Recent programs that offer incentives to encourage the use of energy efficient compact fluorescent lamps (CFLs) and Light Emitting Diodes (LED) mark utility planning and costs reduction programs in Europe. A fact that was relevant to the supermarket managers, but that in most occasions they were not the contact to make a decision to select LED against CFLs.

Group Number	Group 3
To understand:	Current solutions available in the market, in order to answer sub-objective 3 New options and materials Commercialization barriers
Contact	Per-Stefan Gersbro. PACCEDO Managing Director, and Ex-Director Packbridge, Packaging Logistics Researchers in Lund University.
Type of contact	Person to person open-interview.
Findings	The transparent materials have always been very attractive to the consumer, due to the fact that they can see what it's inside the package. Barrier issues are also linked to the material selection when designing a new packaging system, trade-offs must be considered to tackle most of the undesired issues due to barrier properties. Mixtures or materials are common to achieve this properties, but constraints as the recyclability might present an issue in countries without the level of development in recycling chains as in Sweden. Aluminum has always been the perfect material to block light, gases and oxygen. New transparent materials with better properties are being developed, and their costs are not as competitive as the other materials and also the commercialization is limited.

Thanks to the interactions with the personnel from Santa Maria the stages in the supply chain were understood and evaluated providing enough information for the following sections.

4.1.1. Process mapping

A diagram presenting the more relevant facts about the supply chain was created and applied to explain interactions between lighting, spices packaging system and possible factors that influence the optimal design for a new packaging solution.

This diagram (see Figure 23) includes the insights from the different stakeholders and will offer an analysis of the simpler way to reduce efforts, energy and environmental impact while guaranteeing consumer satisfaction. The information from the suppliers was limited but due to the fact that the spices were always very bright and colorful when packing and always contained in opaque bags meanwhile waiting to be packed; it was assumed that the opaque packaging in which they are transported was robust enough to protect spices from color bleaching.

Photographs collected during the observations of conditions of how spices are stored and displayed in the retailer's facilities can be seen in Appendix 5. In its majority Santa Maria spices were displayed on the shelves from the brand, in the case of supermarkets' chains known as more affordable, the shelves were more austere or not present at all; here the Santa Maria's trays were commonly found to display products. The distribution of lights was dependent on the design of the facilities, how high the roofs were, and following mostly the sense of travel inside the store and validating the point highlighted by Quartier, K., (2011) were it is mentioned that the architectural design inside the retailer's facilities is commonly sparse.

Also as an interesting comparison, it was observed that some supermarkets in France (e.g. Franprix, Lecrerc and Auchan) are already using magnetic LED lights to create an ambiance to attract consumers. Also some other kinds of lights were found. The lights varied from metal halides with warm lights in order to give the idea of a wine cellar when displaying wines; or in the case of baby food, it was done to make it seem like a baby room, and finally in the display of cosmetics to make the aisle more appealing when the consumers pass near to the products.

These examples can be found in Appendix 9.5.1. It is important to highlight that in all the cases the packaging materials presented an opaque surface and exterior material in contact with light, in the case of wines colored glass bottles in the case of the milk powder an aluminum can and in the cosmetic products. Those opaque materials were polymers or films used to contain the products.

Appendix 9.5 shows the results of the observation of different supermarket chains in Sweden. As it can be observed in Figure 23, the stages of the whole supply chain are exemplified. The stages in which the product is in more contact with light sources are during the display on the shelves inside the supermarkets and when the the consumers store spices at home and meanwhile they empty the contents of the packages after the purchase. The other stages were discarded for the purpose of this study, the first stage coming from the supplier was not observed in detail because of location constraints.

It was assumed that the light conditions under which the spices are packed in the supplier facilities, and after during its transportation to Santa Maria facilities are effective enough in terms of light protection. It was observed that all the spices were very colorful when opened from the cardboard containers (See packaging material from supplier in Figure 23), being such packaging material the ones containing the spices when they entered into the packaging process in Santa Maria.

In the following stages after the manufacture, the packaging system was considered protective enough, because the majority of the secondary packages from Santa Maria present cardboards covering the spices (see Manufacturer of Distribution Center in Figure 23). The part of the surface that was open of the secondary package, was also coinciding with the part of the jar that had the label, not letting light come in into the surface in contact with the spices. Therefore, it was concluded that the stages where the products are under Santa Maria's control, present a good protection against the damaging effects of light.

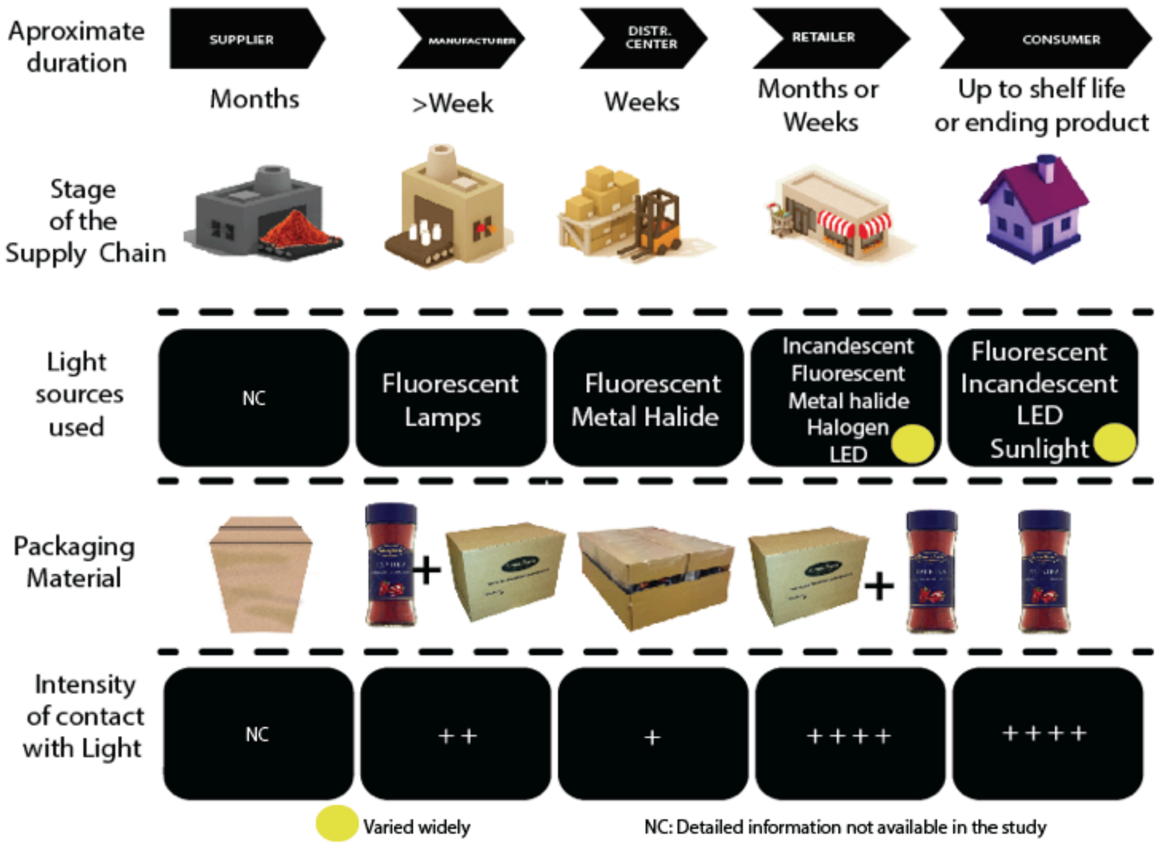


Figure 23: **Process mapping identifying where the contact with light causes more damages to color.**

It was found during the observations that many consumers are not conscious that the light can damage the product, and that the way they store the product can be very relevant to maintain the suggested shelf-life of the product. In Appendix 6, it can be seen that the design of the storage area in the households depends on the architectural choice and on the design of the kitchen. When there is a specific area designated to store containers, such as glass jars and other PET containers like the ones dedicated for oil, it is more common that the consumers store the spices in that area. In this case furniture is commonly designed thinking in the ease of access and aiming for a good organization in the kitchen.

It was also observed that when the consumer was in a rush, the most common place to store spices was near to areas where sunlight was commonly present. Those areas were the tables, areas were they prepare the food, windows frames, and in general areas that increment considerably the contact with light.

Also in the kitchen it was commonly found more LED lights, than other areas of the households. This confirmed what was referenced by Hillevi Hemphälä, who mentioned that the warmer lights are preferred in areas recognized for comfort and creating a feeling of coziness, unlike cooler lights that are commonly located in working areas, as in this case where the food is prepared and precision is needed, like when using a knife and colors and contrasts need to be perceived properly. Thereby when spices are used they are in contact with those LED lamps.

The most relevant criteria to evaluate the performance of the package were set based on the company needs. The following criteria are explained in detail according to the value assigned in appendix 9.12.2, being 5 the highest value and 1 the lowest. The results can be found in Appendix 9.12.1 and the final chart including the evaluations obtained from phase 2 regarding the category "light protection", can be found in section 5.3. The categories determined thanks to the results in phase 1 were the following:

- Cost
- First moment of truth
- Premium finishing
- Second moment of truth
- Supply chain fit
- Sustainability

4.2. Phase 2: Results of quantitative data collection

As a reference for all the samples, 2 different conditions were set for the controls, the first group was stored under cold conditions in an Electrolux freezer present in IKDC were the temperature was verified in the front panel of the freezer, allowing to keep track of the temperature of storage, that was kept at -18 C, the Figure 24, shows the temperature control panel.

Figure 24: **Electrolux freezer present in IKDC.**

The second group of controls was stored inside of one of Santa Maria's boxes inside the room where the arrangement 2 was and the box was located under the samples exposed to light. In both cases the samples remained with no perceptible changes to the human eye, condition that was very obvious with the red spices stored in the arrangements, where they had easily visually detectable changes after the second week of exposure under certain light arrangements.

Only the equal materials can be compared against each other as for example, in the case of the P1: glass jar and P2: glass jar + plastic sleeve, the measurements were carried out removing the part of the plastic sleeve covering the package in order to perform the measurement, and both surfaces in contact with the sample and then with the color meter had the same properties. Other samples only were compared to themselves at the beginning and the end of the tests showing how the CIELAB values increased or decreased.

4.2.1. **Arrangement 1: Ljus Lab Boxes**

This first arrangement considers a more controlled ambiance in Ljus Lab in Lund University facilities with 5 different light sources where the spices were all exposed at the same distance to the bulbs. This arrangement allowed understanding the behavior of the different spices when they do not present a packaging material, in order to verify which spice was more susceptible to which light source or if the other conditions as contact with the air

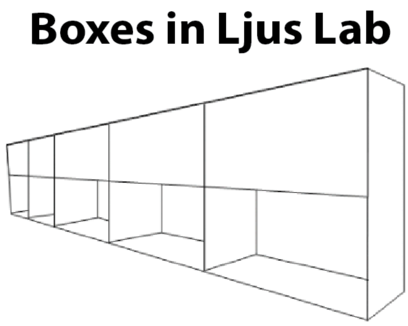


Figure 25: **Arrangement 1**

were also affecting widely the loss of the color.

4.2.1.1. Test 1:Illuminance and Luminance Arrangement 1

Table 8 shows how the different light sources used in the test emit light and how the CCT can be visually appreciated differently depending on the characteristics of the lights and how box 1 and 4 present the best CCT.

Figure 26 represents an extract from Figure 7 and 14, where it can be seen it is consistent with the light temperatures of white fluorescent lamps and as mentioned by Cuttle, (2015), the CCT is better in the Cool White fluorescent lamp, like the one present in Box 1, than the warm fluorescent in Box 5. In the case of Box number 2 the modulator was turned in a way that the light was not emitting its whole intensity but its consistent with the light color in table 7, and all the measurements were done under that intensity. It can be seen in the previous table 8, that this lamp is one of the less intense out of the 5 lamps used compared to the second box in Figure 26, were the lamp is presented with all its intensity.

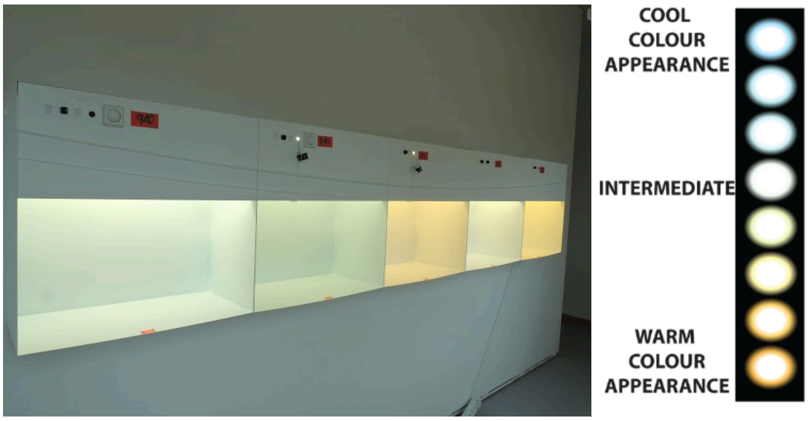


Figure 26: **Color appearance**

The light sources belonged to the category of fluorescent lamps, but every single lamp presented a different temperature, which can be seen in the last three digits of the lamp name. For example "940" makes reference to 4000 ºK of temperature and are classified by OSRAM as: warm (2750K+3000K) middle (4000K) and cold (4800K+5400K) lighting, and it confirms what was stated by Park and Farr (2007), that the light sources with temperatures of around 4000 K present a better appreciation of colors, as the light in Box 1. The reason why consumers prefer this lamp is that the colors are perceived as very bright and intense. In Table 8 the Points 1, 2 and 3 are represented by P1, P2 and P3.

Table 8: **Illuminance and Luminance measurements performed in Arrangement 3:Ljus Lab Boxes.**

Image	Illuminance/Luminance cd/m2	Light Characteristics

	Box 1		
	P1	P2	P3
Illuminance	3700	4000	3600
Luminance	900	800	900

OSRAM LUMILUX de LUXE Cool White HE 24 W/ 940 Fluorescent

	Box 2		
	P1	P2	P3
Illuminance	460	1600	450
Luminance	150	150	150

OSRAM LUMILUX Cool White HE 14 W/ 840 Fluorescent

	Box 3		
	P1	P2	P3
Illuminance	2800	3200	3000
Luminance	580	600	640

OSRAM LUMILUX INTERNA HE 14 W/ 827 Fluorescent

	Box 4		
	P1	P2	P3
Illuminance	3300	3600	3600
Luminance	730	570	850

LED Light 4 dots

	Box 5		
	P1	P2	P3
Illuminance	2900	3100	3100
Luminance	610	620	610

OSRAM LUMILUX Warm White HE 14 W/ 830 Fluorescent

The light sources most commonly found in Sweden are such as the light used in the box 3, with 14 W and 827, which means 2700 K of temperature; in the case of the light from Box 1, it is commonly found in areas where color perception is crucial, as surgery rooms, theaters, some restaurants and hotels. It is also interesting to mention that in countries like Sweden, it is preferred to use warm light in the households to convey a warm and cozy environment inside households, compared to other European countries that have warmer weather and where the light sources tend to be cooler inside the households, to give a feeling of relief against the warmer exterior conditions, as mentioned by the researcher Hillevi Hemphälä in IKDC.

4.2.1.2. Test 2:Color Measurement Arrangement 1

All the samples were measured having triplicates of each and the software from the Color Meter allowed to transfer the data to Excel to plot the values, an average of the values was obtained and the standard deviation was calculated. Most of the values presented standard deviation values of under 0.5.

The spices with more variation were Basil and Paprika, due to the fact that they presented small leaves and opposite to the powders it remains more surface that is not in contact with the packaging material, causing the laser of the equipment to have a tiny layer of air in some sections. Finally the values were divided in L, a* and b* values to make it easier to see the magnitude of the change in each spice. The values can be found in the graphics 1 (L*), 2(a*) and 3 (b*) of Appendix 9.9.1.

In all the cases the Parameter L: Lightness increased but in a more pronounced way in the Grillkryddor, followed by the other two red spices. In the case of Basil and Parsley the changes were not that pronounced in the time period of exposure.

The a* and b* values followed the same trend, they were divided in the group of red spices and in the green spices group. The red spices decreased in both a* and b* values and in the case of the green spices the values augmented, but again not in a pronounced way as in the group of red spices.

Once all those values were obtained the Eq-1 and Eq-2 or Eq-3 (depending the quadrant in which the data was located) were applied and the Table 9 in section 4.2.1.3 shows the values obtained, the ΔE represents how big was the difference between the initial L a*b* values and the values after the 7 weeks of exposure.

The values obtained from Arrangement 1, splitting the measurements per week of removal are present in detail in Appendix 9.9, in the way of graphics and tables with all the numerical values. All the L* values increased in all the spices, but it mas more pronounced in the red spices, being the Grillkryddor the spice that turned brighter after the whole exposure period.

Those values were used to perform the calculations for the ΔE values using Eq-1,(see below) and as based in what was referred by Da-Wen Sun (2012) that values above 3 are highly perceptible by human sight.

$$\Delta E^{*} = \sqrt{(L_0^{*} - L^{*ref})^2 + (a_0^{*} - a^{*ref})^2 + (b_0^{*} - b^{*ref})^2}$$

Eq-1

The spice that presented more changes from the beginning until the end of the 7 weeks light exposure was the Grillkrydor (G), which can be observed under the column of ΔE, with the highest values, with an average of 25.5 units, followed by the Cayenne Peppar with an average of 20.29, after the Paprika with 16.9, the Basil with 5.73 and finally the Parsley with 4.76 units. This means that the carotenoids are being oxidated. This is consistent with Ötles & Çagindi's (2008) statement, that oxidation of carotenoids can be stimulated by light exposure and from Mortesen (2006) that the degradation of carotenoids leads to color changes as a result of a rearrangement or a formation of other compounds. Also it shows the protective effect that packaging provides against the environmental conditions according to Jönson G., (2000).

In the case of the green spices the changes were almost not perceptible even when no packaging was present, giving a reference for the measurements that will be presented afterwards in the arrangement 2 and arrangement 3 sections to understand a preamble of the changes that happened in the spices. In this arrangement only Parsley was classified in the quadrant II.

Table 9: **Values of ΔE, ΔC $_{ab*}$ and Δh $_{ab*}$ in Arrangement 1: Ljus Lab Boxes**

Arrangement 1: Boxes Ljus Lab																				
	Paprika				Basil				Cayenne Peppar				Parsley				GrillKryddor			
# Box	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab
1	19.27	8.32	I	0.33	6.55	3.21	I	0.23	22.51	13.46	I	0.3	3.28	0.78	II	0.03	26.23	21.91	I	0.24
2	14.03	10.56	I	0.11	5.35	1.07	I	0.05	17.24	11.19	I	0.26	3.45	0.45	II	0.07	24.99	20.91	I	0.21
3	11.79	8.95	I	0.1	5.07	0.62	I	0.07	19.25	11.6	I	0.26	5.02	1.36	II	0.1	24.24	20.68	I	0.2
4	18.68	11.34	I	0.24	7.3	1.52	I	0.07	21.42	13.56	I	0.29	5.69	1.85	II	0.00	26.16	21.43	I	0.26
5	20.86	12.85	I	0.25	4.38	0.65	I	0.07	21.02	11.68	I	0.31	6.39	2.61	II	0.05	25.86	21.26	I	0.25

4.2.1.3. Test 3:Temperature and Relative Humidity Arrangement 1

The conditions inside the room were maintained between 21°C ±2.5, which represents the normal storage conditions in a household in Sweden. The relative humidity during the whole period was also measured. The chart from the data logger can be found in the Appendix 7. This logger was also applied to the arrangement 2, after determining that the conditions remained almost the same and due to lack of availability of other equipment. The upper line in the chart represents the temperature and the middle line represents the relative humidity of the rooms, those measurements can be found in detail in Appendix 7.

4.2.1.4. Photographs Arrangement 1

Every week from the initial week or week 0, the samples were placed in the distribution presented in Table 10, to make it easier to appreciate the color changes from week to week, the week 0 represents the original colors of all the spices, from the very moment the spices were poured from the sealed containers into the lids (P4), filling the height of the lid.

The Figure 27 represents the structure used as a support to ensure all the colors were perceived as real as possible, and the parameters of the camera are represented, those parameters were maintained for every session:

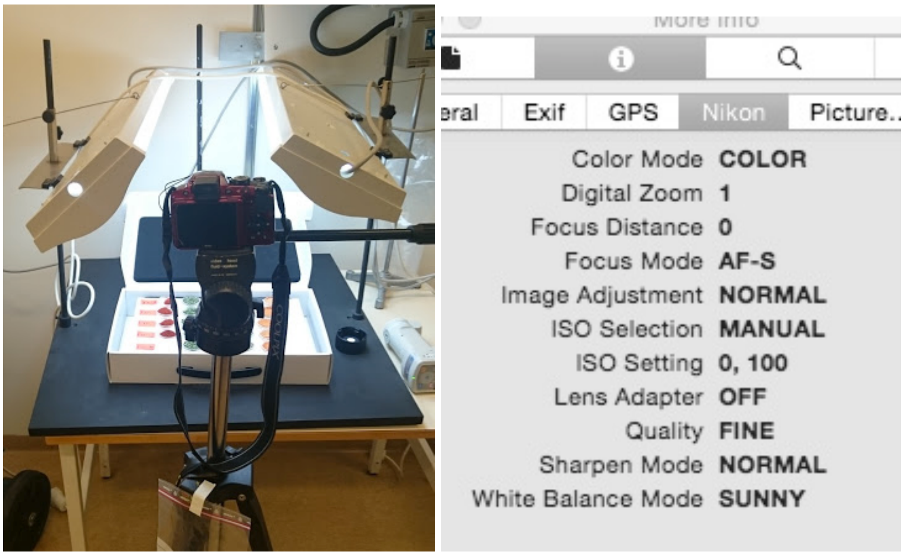


Figure 27: **Structure and lamps used to take photographs.**

Table 10 summarizes the changes found from the original color that spices presented in Week 0 and the final appearance of the samples after being exposed in the respective boxes for a period of 7 weeks. It can be easily observed the changes in color, more changes regarding the differences between each week can be found in Appendix 9.9.

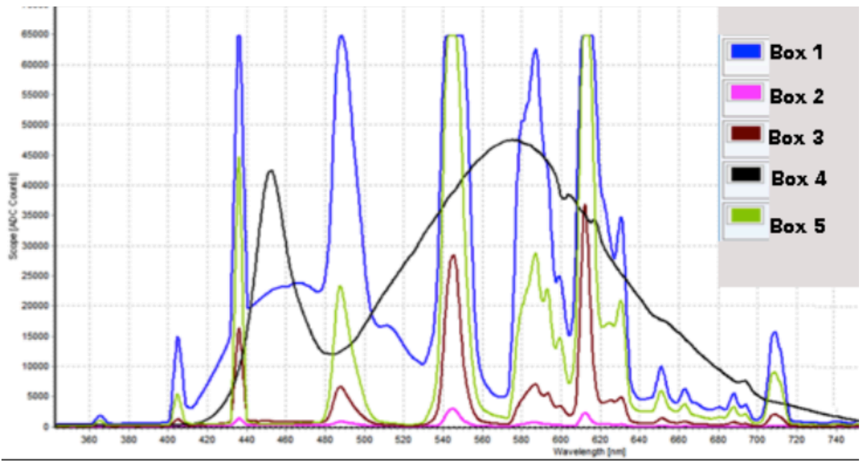
Table 10: **Changes of color per week in samples of Arrangement 1.**

	Week 0
This image represents the original colors of all the spices, from the moment they were poured from closed containers stored in closed boxes with no contact to light. The order from left to right is P, B, C,Pa,G.	
	Week 7/ Removal 4
This final week the samples were organized in the order, P,B,C,Pa & G. All the G samples were totally clear no visual difference was perceived against the different lamps. In the case of the P and C the samples that retained more the color were in Box 2.	

In the final week of exposure, the parsley and the basil were changed in order. All the other spices were placed in the same way allowing seeing how evident were the changes in the red spices

4.2.1.5. Test 5: Light spectrum going inside packages

Thanks to the presence of different light sources arranged in similar conditions it was possible to compare how each packaging material can provide protection under each light source. The following Graphic 1 shows how different are the light spectrums of each of the luminaries are, representing how even the same classification of light in the case of the fluorescent lamps, will emit different spectrums according to the light temperature and consequently how they will have an effect in the sample in question. It can be observed that the LED lamp, presents the higher emission of energy in a more constant way (black line), and that has a very different shape when compared to the other luminaries, that only present around 5 peaks in the same wavelengths, the y axis represents the ADC counts.



Graphic 1: **Different spectrums from each box used in Arrangement 1.**

The following charts represent the protection that each package provides against light, the intensity of the energy provided by each luminary can be appreciated in the "y" axis, the more exterior light represents the light from the luminary without any package present.

After measuring all the materials in all the boxes, a trend was observed, in spite of changes in the characteristics of the light source. The package that provided more protection in terms of not letting the light come through was the P6: plastic amber PET after the following ranking was followed in terms of less light going inside the package, and it prevailed no matter which box was used to measure.

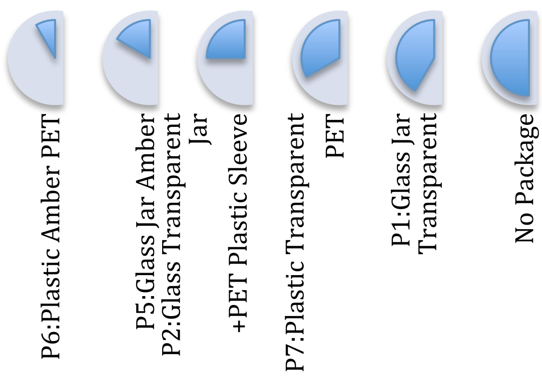
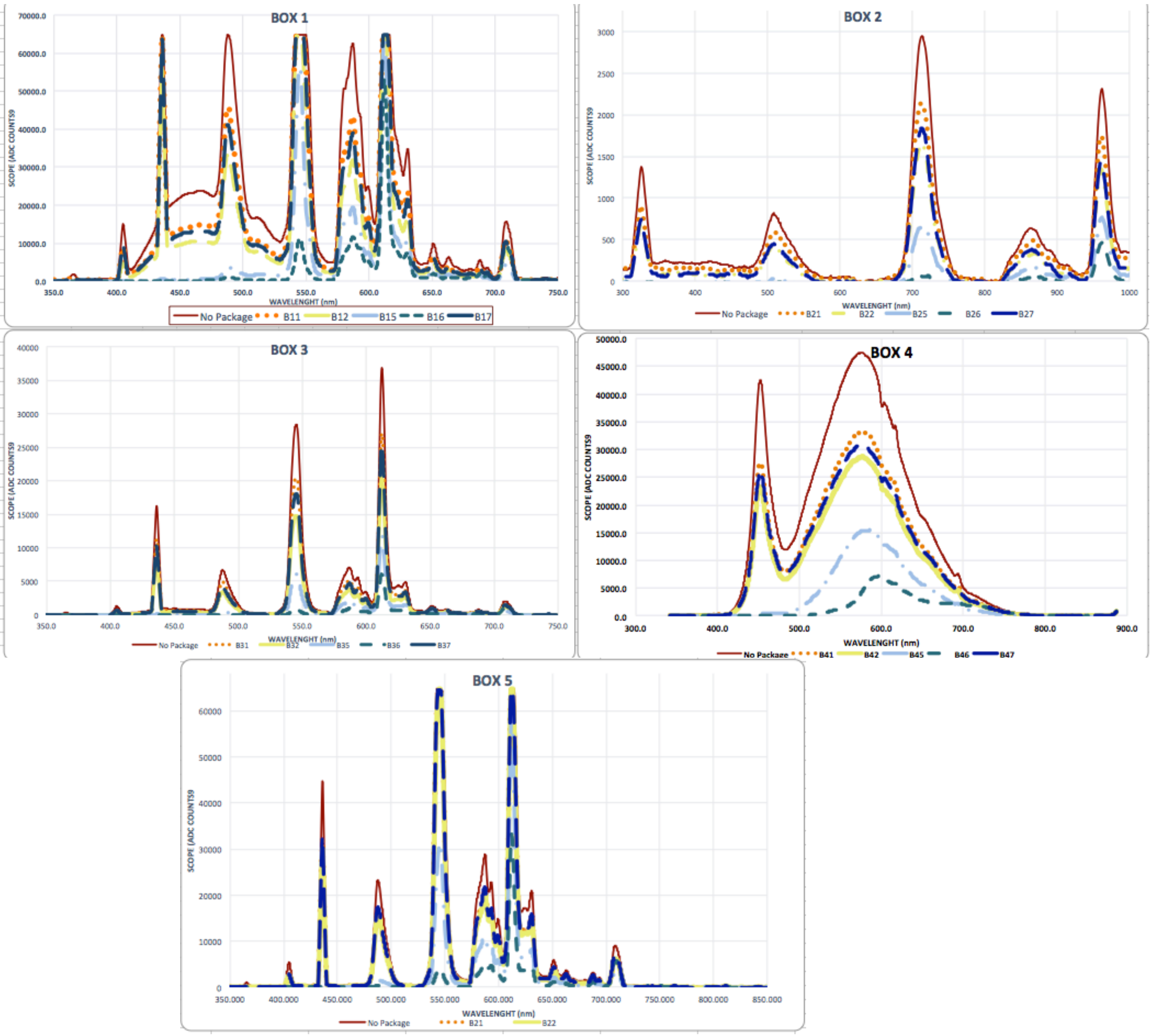


Figure 28: **Trend of how much light was going through the different packaging materials.**

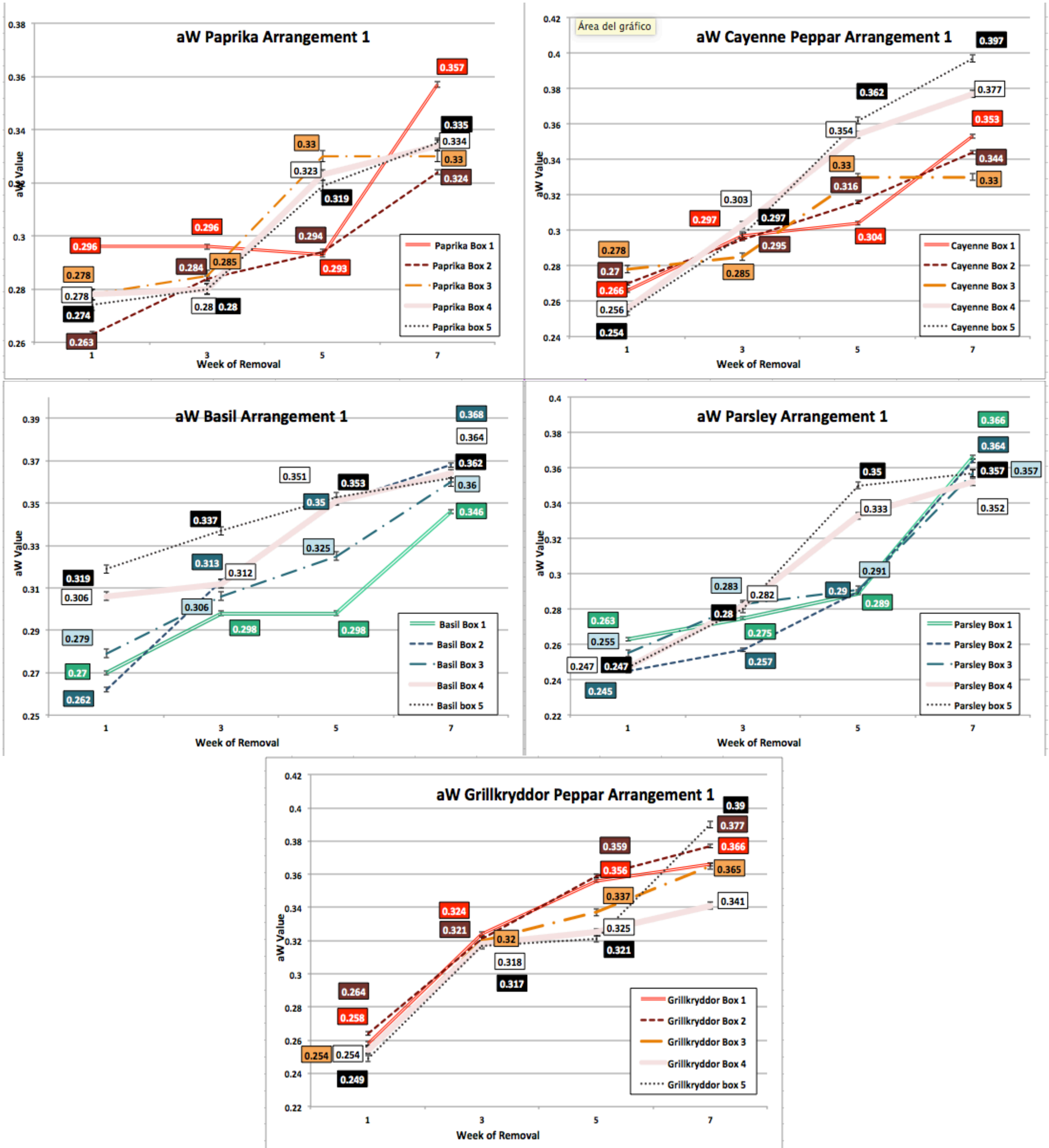
After the test of the characteristic light spectrum from each box was calculated, the different packaging materials were also evaluated inside each box, taking into consideration the height and angle position of the samples, taking care that every package was placed in the same way in the moment of performing the measurement. The following Graphic 2 represents the part of the light spectrum passing through the different packaging materials. In all cases the trend explained in the Figure 26 was maintained with the P6 (plastic amber PET bottle), being this material, the one with the least amount of light going inside the package.



Graphic 2: **Light spectrum of light passing though all the packaging materials per box.**

4.2.1.6. Test 6:Water activity Arrangement 1

In general an increase of the water activity was observed in all the samples exposed to the different light sources. The most probable explanation is that the samples were stored in contact with the ambiance without any packaging acting as a barrier. The following Graphic 3 shows the changes per week in the water activity values.



Graphic 3: **Aw Values for the samples in Arrangement 1: Ljus Lab boxes.**

All the values of Aw increased, but as well the changes were more pronounced in the red spices, Water activity values of around 0.3 from a just opened sealed container increased to values around 0.45, after 7 weeks of exposure to light with the established measures from the boxes in Ljus Lab.

4.2.2. Arrangement 2: Ljus Lab facilities

4.2.2.1. Test 1: Illuminance and luminance Arrangement 2

The following Table 11 shows the different illuminance and luminance measurements according to the established points being the values, the correspondent to the arrangement with bulbs of 400 lms and the B, the arrangement with the bulbs of 1000 lms, “AV” means average of the points located at the same position, whether 1, 2 or 3, and the final row shows how different the values between the 1000 lms and 400 lms bulbs are. As a reference the points in the arrangements are also included below the table.

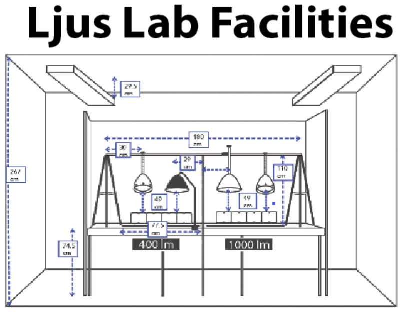
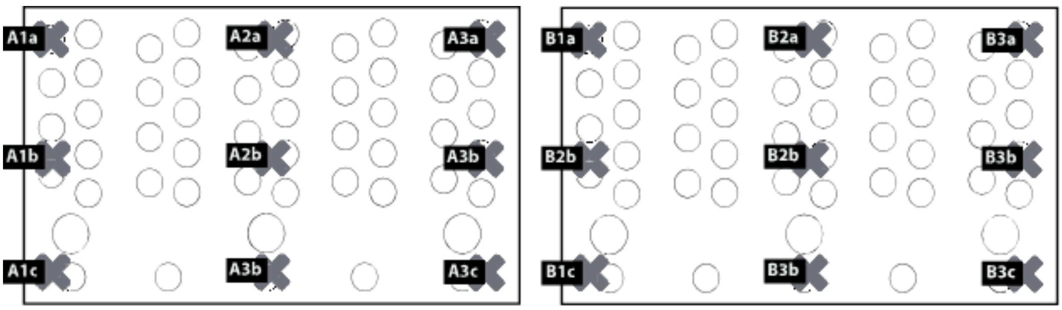


Figure 29: **Arrangement 2**

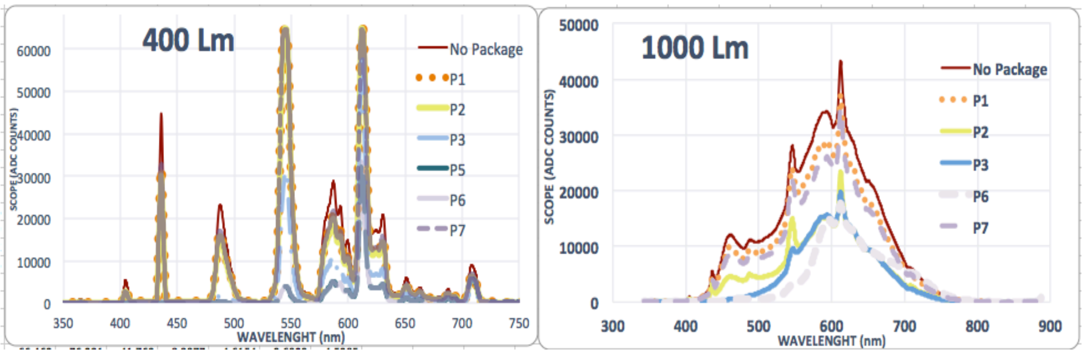
Table 11: ***Test 1, Illuminance and Luminance values in Arrangement 2.***
(I: Iluminance, L:Luminance, AV: average, %<>A vs B: Difference between average in Section A and Section B)

Section A: 400 lm									***Section B: 1000 lm***								
1	***I***	***L***	2	***I***	***L***	3	***I***	***L***	1	***I***	***L***	2	***I***	***L***	3	***I***	***L***
A	1100	60	a	1100	65	A	900	80	A	1500	60	a	2100	160	A	1400	160
B	1250	60	b	1500	75	B	1100	80	B	1800	100	b	2500	160	B	1600	160
C	1200	60	c	1400	75	C	1100	80	C	1600	100	c	2100	160	C	1700	160
AV	1183.3	60.0	AV	1333.3	71.7	AV	1033.3	80	AV	1633.3	86.7	AV	2233.3	160.0	AV	1566.7	160.0
%<>A vs B			%<>A vs B			%<>A vs B											
	27.6	30.8		40.3	55.2		34.0	50									



4.2.2.2. Test 5:Light spectrum going inside packages Arrangement 2

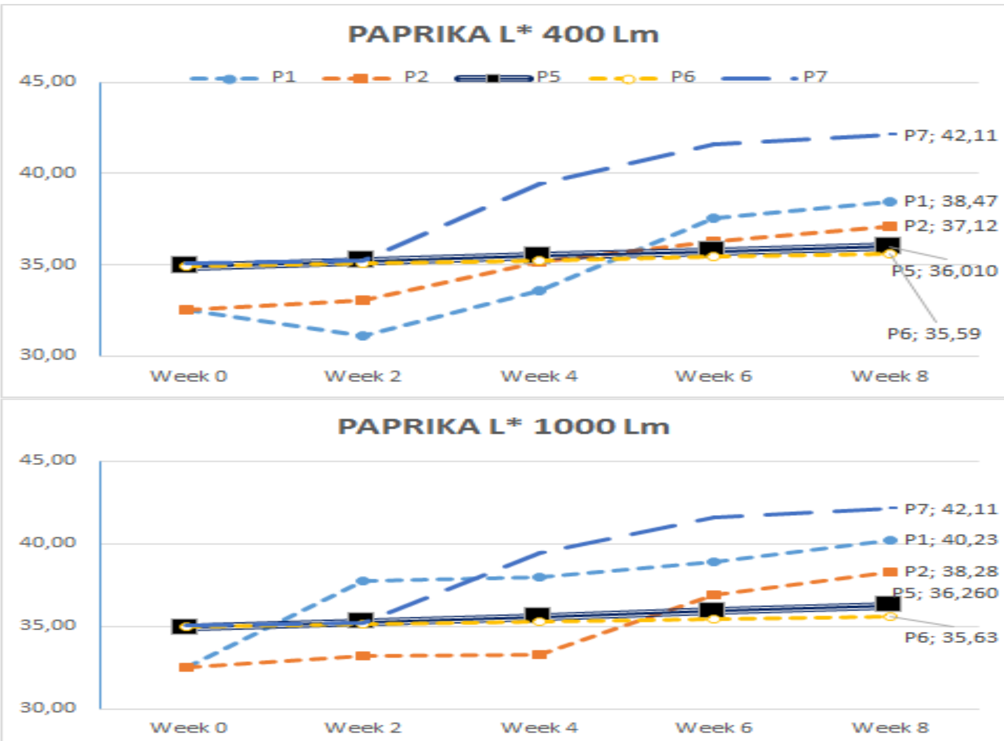
In this case it was also proved that every luminary presents a different spectrum and in the lights from the arrangement of 1000 Lm showed mostly only one peak, meanwhile the set-up with 400 lm several non-continuous peaks as showed in Graphic 4.



Graphic 4: **Light spectrum and protective effects of packaging in Arrangement 2.**

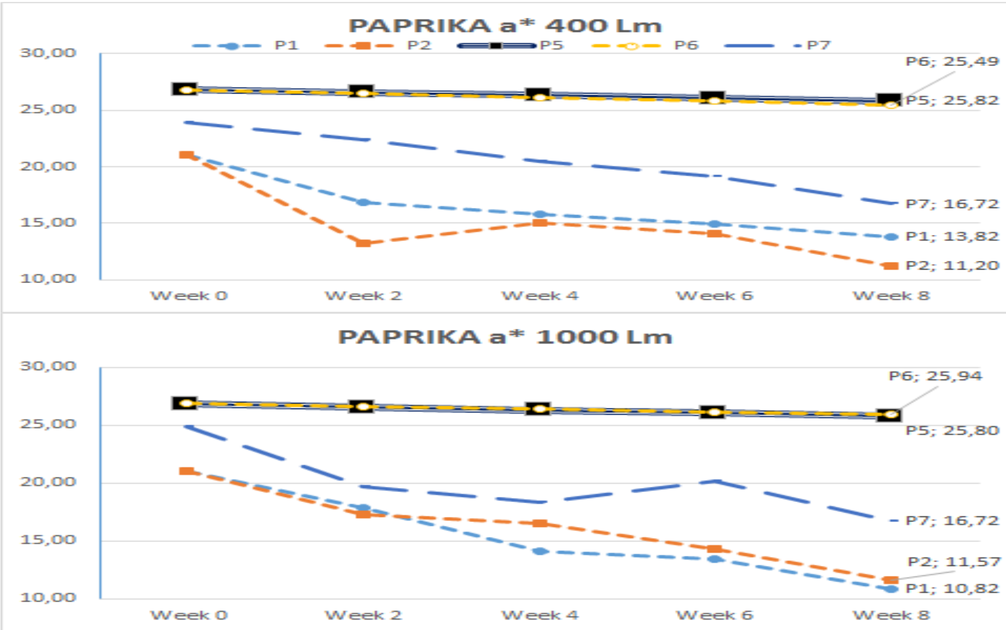
4.2.2.3. Color Measurement Arrangement 2

In all the samples in Arrangement 2, it can be observed that the values of L* increased throughout the time, as in the previous arrangement. In this section, the Paprika was selected to present the values because this spice is the most commonly used spice in Santa Maria. This Graphic 5, presents how the information was organized in Appendix 9.8.2. Here the packaging materials are included in one chart, to show how the packaging materials P5 and P6 gave a protection that allowed the spice contained to maintain almost the same characteristics as the beginning of the test. The set-ups with 400lm and 1000 lm were presented. All the details about the other spices and its tables can be found in the mentioned Appendix 9.8.2 in the form of L*, a*, b*, and they are presented in a separated way per packaging material.

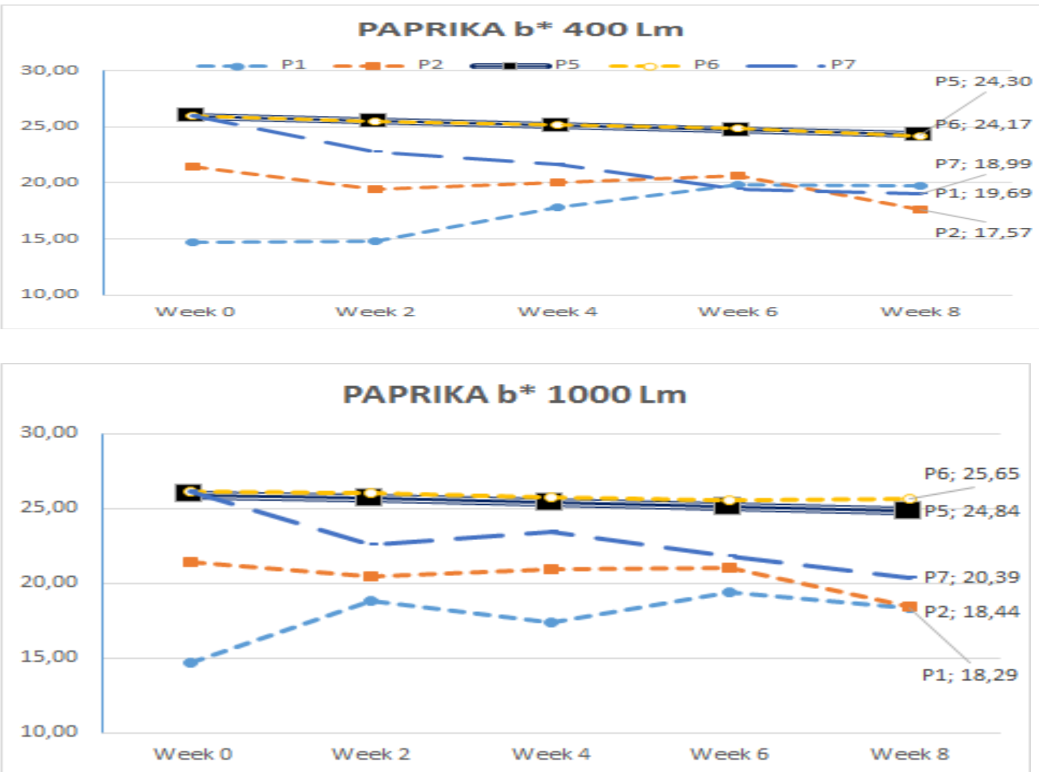


Graphic 5: **Comparison of L* value after the period of light exposure for Paprika in arrangement 2.**

In the case of the L* it can be observed that P1 and P2 were similar at the moment of performing the measurement, in the P1 the changes were more in comparison against a glass jar plus a plastic protection. The material with less changes were P5: amber glass and P6: Amber PET Plastic.



Graphic 6: **Comparison of L* value after the period of light exposure for Paprika in arrangement 2.**

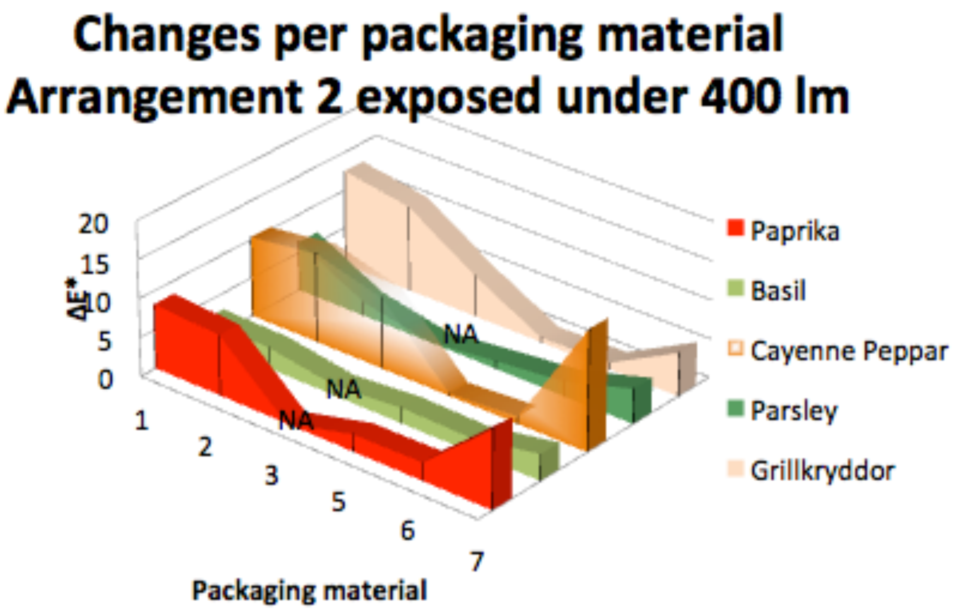


Graphic 7: **Comparison of b* value after the period of light exposure for Paprika in arrangement 2.**

The same procedure was done to each of the spices, the charts and tables with the complete information can be found in Appendix 8. Eq-1 was also applied to analyze the data, where values above 3 are considered as very visually noticeable and regarded as unsatisfactory by humans according to Da-Wen Sun (2012). The following Table 12 presents all the calculation for each spice and the respective packaging materials.

Table 12:**Values of ΔE* obtained per spice and packaging material in Arrangement 2.**

Arrangement 2: Ljus Lab		Paprika				Basil				Cayenne Peppar				Parsley				Grillkryddor			
	PACK	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab
400 LM	1	8.3	7.48	I	0.06	2.9	1.17	II	0.1	10.3	1.36	I	0.2	7.4	4.13	II	0	14.6	10.3	I	0.06
400 LM	2	7.8	3.18	I	0.21	2.7	0.88	II	0.12	11.5	10.26	I	0.01	6.2	1.79		0.04	13.9	10.45	I	0.01
400 LM	3	NA	NA	NA	NA	1.3	1.89	I	0.05	9.2	0.28	I	0.15	NA	NA	NA	NA	5.9	2.43	I	0.05
400 LM	5	2.2	1.86	I	0.01	2	0.91	I	0.01	0.3	0.06	I	0	1	0.24	II	0.04	0.6	0.26	I	0
400 LM	6	2.3	2.18	I	0.01	1.8	1.61	I	0.01	0.4	0.05	I	0.01	1.9	0.16	II	0.1	0.8	0.71	I	0
400 LM	7	10.2	13.66	I	0.02	3.4	1.38	I	0.02	15.6	9.97	I	0.06	8	7.54	II	0.07	13.8	12.2	I	0.17
1000 LM	1	10.4	0.44	I	0.18	3.8	0.37	II	0.08	15.1	6.88	I	0.03	7.8	1.94	II	0.02	11.9	15.87	I	0.16
1000 LM	2	8.5	1.25	I	0.18	1.7	0.08	II	0.06	11	3.05	I	0.18	4.6	1.35	II	0.11	10.6	11.29	I	0.01
1000 LM	3	NA	NA	NA	NA	3.7	2.61	I	0.08	12.7	7.1	I	0.18	NA	NA	NA	NA	6.3	1.83	I	0.11
1000 LM	5	2	1.5	I	0	1.11	0.1	I	0.04	2	0.69	I	0.01	1.1	0.96	II	0.01	1.1	0.52	I	0.01
1000 LM	6	1.6	1.51	I	0	1.1	0.85	I	0.02	0.7	0.39	I	0	0.6	0.44	II	0.01	1.1	1.06	I	0
1000 LM	7	14.7	11.52	I	0.09	2.8	2.98	I	0	11.3	6.16	I	0.07	8.7	9.11	II	0.03	6.3	10.45	I	0.02



Graphic 8: **Comparison of ΔE * value after the period of light exposure per packaging material.**

It can be concluded from the representation of Graphic 8, that in most cases the only materials which presented a satisfactory grade of ΔE* were the ones that were colored and that let pass less light to be in contact with the foodstuff, the values with NA represent the spices that are not commercialized in this packaging volume.

After obtaining all the values of ΔE* per spice and per arrangement the two-way ANOVA was applied, considering an alpha value (α) of 0.05, with H0: that all the packaging materials and all the spices represent the same effect. Represented with the following data:

H_1: P1=P2=P3=P5=P6=P7

H_{1b}: S1=S2=S3=S4=S5

H_1: Not H_0

with α = .05.

And the Table 13 represents the values from the analysis of 100 lm, the other values can be found in Appendix : 9.10.

Table 13: **Two-way ANOVA results for the 1000Lm arrangements.**

ANOVA							
Source of Variation	SS	d.f.	MS	F	p-level	F crit	Omega Sqr.
Factor #1 (PACKAGING)	87.83665	5	17.56733	3.00402	0.01755	2.37098	0.08907
Factor #2 (SPICE)	147.53576	4	36.88394	6.30718	0.00027	2.52791	0.18870
Factor #1 + #2 (PACKAGING x SPICE)	71.64076	20	3.58204	0.61253	0.88758	1.75104	0
Within Groups	345.02800	59	5.84793				
Total	652.04118	88	7.40956				
Omega squared for combined effect	0.20888						

In this analysis the values of p-level for both packaging and spice were smaller than the **α** reference of 0.05.

For factor 1: Packaging p-level = 0.017 < alpha (α) of 0.05

For factor 2: Spice p-level = 0.0002 < alpha (α) of 0.05

Which means that there are significant differences between the packaging materials and as well significant differences between spices; therefore H0 is rejected and there is at least in both the packaging and the spices a condition that represents different effects when it comes to color change.

4.2.2.4. Photographs Arrangement 2

The following picture shows the changes in color of the different spices placed in arrangement 2. The order in which the spices were arranged for this picture is from top to bottom: Grillkryddor, Parsley, Cayenne Peppar, Basil and Paprika. The spices in the left represent the spices from the week 0 or controls, and the 4 last columns represent the spices from the last week of exposure.

They are separated if they belong to the section with 400 lm as light source or 1000lm (showed in the bottom of the image). The first or third column (with the orange band), from left to right, represents the spice with the plastic sleeve applied (which was removed for the photo session and to conduct the measurements) and the 2nd or 4th column (without any band). The spices with the packaging material as it is used actually (placed in the 2nd or 4th columns), bleached in a more intense way, for instance it can be seen that the color of the Grillkryddor, which is located in the first line, is very bleached, (Figure 30).

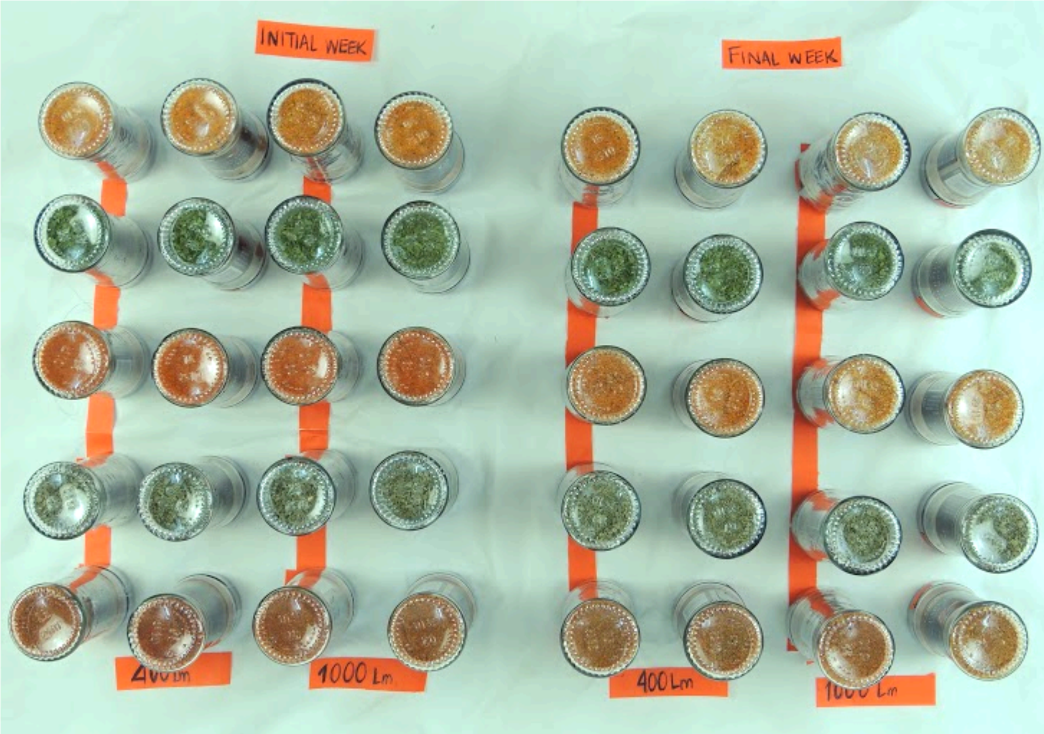


Figure 30: **Comparison between initial and final color of spices exposed to ligh in Arrangement 2**

Figure 31 represents the change in color in the Cayenne Peppar contained in package P7, the photograph was taken in this position to show that the face of the package closer to the light source, received the strongest effect as they were placed upside down in the set-up.

Figure 31: **Comparison of Cayenne Peppar in P7 after exposure under 400lm (left,) and 1000lm(right)**

4.2.3. Arrangement 3:Santa Maria's facilities

This second arrangement was an in-site test performed in Santa Maria facilities with samples contained in the displays normally found in the retailer's stores. It was settled using 2 different arrangements of samples as mentioned before in Figure 20, one shelf was using normal office lights versus the other with added magnetic LED lights suggested by the marketing department, and similar to those found in other retailers as the ones referred in Appendix 5.

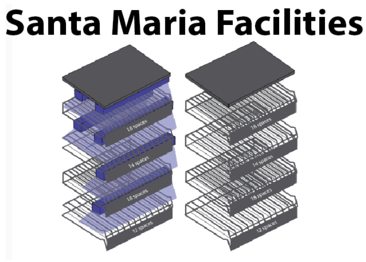


Figure 32**: Arrangement 3**

The products arranged in the setting in Santa Maria's facilities started to present evident difference after 2 weeks of exposure, Grillkryddor had the most pronounced change; the color was very degraded after the second week in the case of shelves with magnetic LED lamps, against the arrangement without these lamps.

4.2.3.1. Test 1: Illuminance and Luminance Arrangement 3

The following Table 14 represent the different illuminances and luminances at the different sections of the shelves, the higher the rack the higher the values due to the fact that also the luminaries from the roof were closer to this section of the shelves and being consistent with Cuttle, (2015). In the case of the LED Lamps it can be seen how the values were considerably higher than those from the section without the LED lamps. Also it was observed, in the areas that were in contact with some light from the magnetic lights of the arrangement with LED, that the values were also higher.

Both sections were measured after turning the lights on, represented in Section 1A and Section 2, and in the case of section 1, also a measurement of the values of illuminance and luminance was conducted, to compare how much those values changed before and after turning the lights on, this is represented in Section I.

The difference between both conditions was considerable, augmenting in values around 90%, as it can be seen in the Figure shown previously in the methodology the display looks very appealing when turning the lights on, but also the exposure to light must be considered when displaying the products.

It was also observed that the lights located at the edges of the set-up, represented by 3A, 3B, 3C and 3D in Figure 24, with the magnetic LED lights, also had an effect on the surroundings, affecting mostly the points located at 1A, 1B, 1C and 1D of the section without added LED lights. It will also be observed in the color values measured on the spices located in that area, presented in section 4.2.3.2.

Table 14:**Values of Illuminance and Luminance in Arrangement 1 with reference to the points in Figure 24.**

		I	L		I	L		I	L		I	L		I	L
1 Section1 without LED	1a	800	20	3a	1100	20	3a	800	15	4a	1100	90	5a	1100	50
	1b	550	25	3b	800	25	3b	550	30	4b	800	20	5b	700	20
	1c	400	10	3c	550	15	3c	400	15	4c	600	90	5c	600	14
	1d	400	10	3d	500	10	3d	400	10	4d	700	28	5d	650	29
		I	L		I	L		I	L		I	L		I	L
1 A Section 1 with LED	1a	**8000**	**170**	3a	**8700**	20	3a	**9000**	**220**	4a	**7000**	**210**	5a	**8400**	**260**
	1b	4600	30	3b	6000	40	3b	5700	30	4b	7800	35	5b	8000	60
	1c	4100	50	3c	5900	60	3c	4600	50	4c	7600	90	5c	9100	60
	1d	4100	30	3d	5500	90	3d	3200	20	4d	7800	80	5d	8500	60
		I	L		I	L		I	L		I	L		I	L
2 Section 2 with LEDs from Section 1 On	1a	1000	240	3a	1100	18	3a	900	59	4a	80	60	5a	80	90
	1b	500	40	3b	800	23	3b	600	25	4b	500	230	5b	550	20
	1c	300	30	3c	600	11	3c	400	10	4c	200	40	5c	400	20
	1d	200	40	3d	700	22	3d	300	12	4d	300	130	5d	400	20
Percentage of illuminace/luminance difference between arrangements															
1 vs 1 A		90%	88%		87%	0%		91%	93%		82%	57%		87%	81%
1 vs 2		88%	-41%		87%	10%		90%	73%		99%	71%		99%	65%

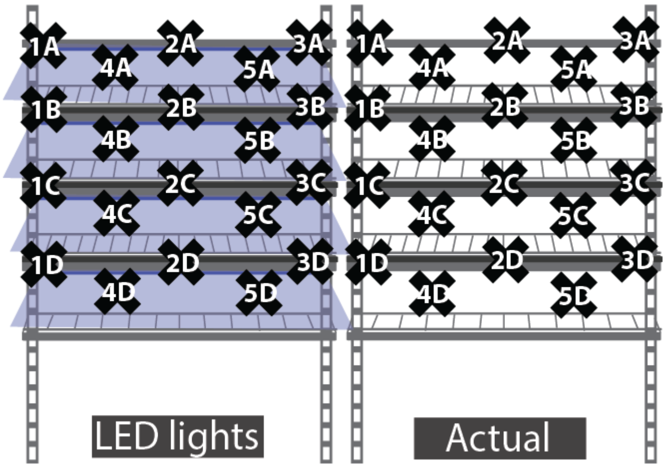


Figure 24: **20 points where measurements per shelf were performed for illuminance in Arrangement 1: Santa Maria warehouse and codes.**

4.2.3.2. Test 3: Color measurement Arrangement 3

The graphs and tables presented in Appendix 9.8.3, were created with the same principles as the previous arrangement, and they represent the changes in the different materials exposed to light in arrangement 3. The packaging material with the best performance was again the P6, Amber PET bottle.

It can be observed when the comparison is made between the packaging materials en the normal arrangement named "SM", that the values of ΔE* are smaller than those of "SM+LED". It can also be observed that the bigger the value of ΔE*, it is linked with the change in chromaticness, in other words according to Sant'Anna et al., (2013) the vividness of the color faded out. In this arrangement it was also evident that the spice with the most severe bleaching was the Grillkryddor.

Table 15: **Values of ΔE* obtained per spice and packaging material in Arrangement 3.**

	Arrangement 3: Santa Maria Facilities																				
	PACK	Paprika				Basil				Cayenne Peppar				Parsley				Grillkryddor			
		ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab	ΔE*	ΔC ab*	Quad	Δh ab
SM	1	4.9	4.28	I	0.01	2.3	1.5	II	0.11	8.9	5.87	I	0.12	5.1	2.94	II	0.2	6.8	6.37	I	0.03
	2	4.7	3.89	I	0.08	2.2	0.14	II	0.06	8.8	7.36	I	0.07	5	3.5	II	0.17	6	4.45	I	0.07
	3	NA	NA	NA	NA	5	3.95	I	0.03	6.5	2.73	I	0.04	NA	NA	NA	NA	5.5	1.12	I	0.06
	4	6.2	5.06	I	0.16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.1	1.98	I	0.11
	5	2.9	2.51	I	0.03	2.2	1.95	I	0.04	2.8	1.93	I	0.01	2.6	1.32	II	0	3.3	2.39	I	0
	6	2.8	1.35	I	0.03	1.9	1.79	I	0.02	2.7	1.04	I	0.02	2.5	1.49	II	0.01	2.9	1.79	I	0.02
	7	2.9	2.4	I	0.02	5.4	0.99	I	0.04	4.6	3.58	I	0.05	5.6	3.8	II	0.03	10.3	9.59	I	0.02
SM + LED	1	5.2	2.45	I	0.03	3.8	0.87	II	0.05	5.3	3.8	I	0.06	4.6	2.66	II	0.02	8	3.29	I	0.1
	2	3.4	2.2	I	0.12	3.7	0.86	II	0.03	5.2	3.76	I	0.02	2.8	1.82	II	0.17	5.1	4.01	I	0.01
	3	NA	NA	NA	NA	2.8	0.76	I	0.03	6.5	2.73	I	0.04	NA	NA	NA	NA	8	3.12	I	0.01
	4	5.2	3.88	I	0.12	NA	0.03	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11.1	9.39	I	0.06
	5	2.8	0.92	I	0.02	2.5	1.93	I	0	3	1.38	I	0.02	2.8	2.39	II	0.07	3	2.29	I	0.01
	6	2.8	1.19	I	0.01	2.6	2.62	I	0.01	3	1.27	I	0.04	2.7	2.29	II	0.06	3	1.95	I	0.01
	7	4.7	3.11	I	0.04	5.1	8.42	I	1.39	4.5	3.76	I	0.83	3	1.07	II	0.21	12.3	10.31	I	0.09

The analysis of ANOVA was also performed for the values of ΔE* obtained between each removal and the following hypothesis was used for the analysis

H0=P1=P2=P3=P4=P5=P6=P7

H0=Spice1= Spice 2= Spice 3= Spice 4= Spice 5

After the analysis it was possible to reject Packaging materials for the spices, because the p-level was less than 0.05 and accepted for the spices, because in the case of the spices the p-level was higher tan 0.05, more details can be found in Appendix 9.10.2

4.2.3.3. Photographs

Figure 33 represents the changes in the different materials exposed to light in arrangement 2, as in the earlier Figure 26 qnd Figure 27. Figure 33 shows that the spice with the higher bleaching was the Grillkrydor, the images are small, but the LED Set-up bleached considerably the color. It was evident that the sections of the package that were closer to the magnetic lamp, presented the strongest loss in color, and being consistent with the statements of Boyce, (2003) & Cuttle, (2015), that say respectively, that the directions from which the light comes, and the distance from where the light comes from, influence the effect of the light source, the closest the lamp, the biggest the effect.

Figure 33: **Gryllkrydor, the spice that presented the most pronounced bleaching.**

The material with the best performance was the P6, the amber PET bottle, and the samples from different spices are shown in Figure 34, where the contents of package P5 and P6 are shown after the exposure period, showing that the changes are not very perceptible to the sight compared to other spices, and that the color was slightly less intense in the samples form P5.

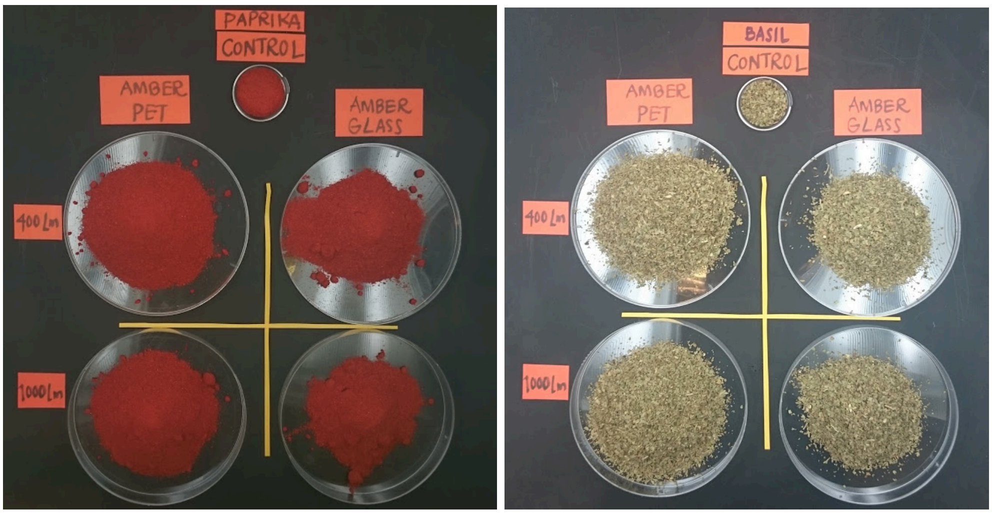


Figure 34: **Contents from packages P5 and P6, Paprika on the left and Basil.on the right.**

The following images show the changes in other packages P3 in Figure 35, and P4 in Figure 36, where it can be seen 2 jars above the label initial week (from left to right). The spice from the first removal from the section without LED lamps, after the first removal of the spice from the section with LED lights added, then above the label final week (From left to right) 2 jars from the last removal from the section without LED lights and other from the section with LED lights, respectively. It can be seen how the Grillkryddor presented very evident changes.

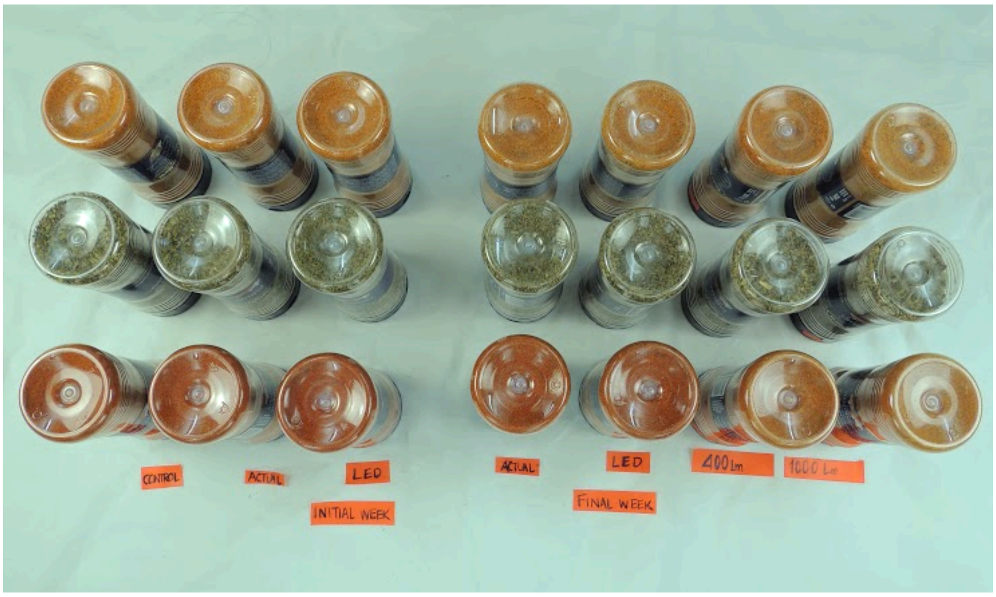


Figure 35: **Comparison between all the arrangements against control in Packaging 3**

Figure 36:**Packaging 4 before and after the exposure in Arrangement 3.**

5. Analysis and discussion.

This chapter presents the generalizations obtained from the findings of both phases of the research, considering each arrangement and later in an integrated way. Thanks to the previous results, possible solutions are proposed and evaluated in this section. Such solutions are presented in the form of recommendations and parameters to consider for the packaging materials, in case of change of the actual packaging solution. The most relevant findings from the methodologies are presented as well.

5.1. Phase 1: Qualitative research

Supermarkets' architectural arrangement of lights is based on customers' circulation. Some buildings have high ceilings, where fluorescent lighting is commonly organized in a homogenous grid, some others are arranged with the aim of maximizing space distribution in accordance with Boyce, (2003,) who discusses the lights distribution in the retailers facilities. In the case where ceilings were very close to the shelf top, amps, were also almost in direct contact with the products, with some centimeters of separation, increasing the exposure to light, as the illuminance absorbed by the surfaces depends only on the distance to the light sources according to by Cuttle, (2015).

In supermarkets like Willy's, where they normally store boxes at the top of the shelves, those cardboards are placed there because they contain products to later refill the shelves. Normally the spices with shelf ready displays referred as trays by Santa Maria, were located at the bottom of the shelves: Those trays are effective when decreasing the handling of the products by human hand, but at the same time the exposure or detectability by the consumer is less, being the reason why implementing a better design for the secondary package will attract easier consumer's attention.

Generally, store distribution of supermarkets consists of long aisles surrounded with shelves where the lighting is perceived or its distribution is arranged as homogenous as possible. Lights are switched on in the whole store area regardless of activity level. The periods during which lights remain turned on are dependent on the retailer's chain. It is common that they remain on for periods of 24 hours, in the case of frozen of refrigerated products, and in the general aisles (in cases such as in ICA) lights remain on as well for 24 hours, increasing the exposure time of products without protective light barriers.

Magnetic LED lights are already in use in other European countries as France, where they are attached to some shelves. Those lights are placed in a way that promotes the consumer attractiveness in order to ease the navigation and to create a more appealing ambiance. The use of those lights is only commonly found for the exposition of cosmetic products or other products that possessed opaque packaging, whether opaque polymers, aluminum or green glass in the case of wines, see Appendix 9.5.1 to consult the images.

In most cases lighting are installed with the principle ‘the more light, the better’, this lead to arrangements with evenly distributed luminaires, or with occasional extra lights added strategically to illuminate areas of difficult access. Some areas such as the ones storing fresh or frozen products are illuminated with spotlights or tubular lights, with the aim of better demonstrating the product. This organization allows the distinction of products placed at the bottom of the shelves, where in some cases, the lights are linked to the operation of refrigerators. Temporary expositions are commonly located at the entrance of supermarkets, also illuminated with spotlights, to attract attention; as a result the areas seem livelier, and the customer gazes frequently towards the focal points where lights are directed.

LED lights produce light using only small amounts of energy, they present a correct color rendering, which is important when perceiving the colors of the spices as natural as possible in retailer’s facilities. In comparison with other light sources, LED lights emit high amounts of energy forming 2 peaks in the UV section of the light spectrum, the first at approximately at 450 to 580 nm, (refer to Graphic 2), giving the basis to understand what promoted deteriorating effects on products or color bleaching, which was observed with more intensity in the red colored spices analyzed in this research during phase 2. The LED lights were perceived by all the managers interviewed as a good solution for saving energy in the supermarkets but they were concerned about the electrical installations and all the changes that will consequently come from changing them.

Mostly the LED lights ware to be found in the households because of the ease of installation and that the expenses or costs were covered by the owner of the house, who sees the installation as an investment, without considering the turnover when purchasing them in the same level as in a retailer’s facility.

5.2. **Phase 2**: Qualitative research

Clear differences between the light conditions in the 3 different arrangements were found, demonstrating that different lighting can indeed have a different effect on the changes in color as encountered by the samples, producing changes in the visual appearance of the products. It was confirmed that the higher the energy emitted by the lamp or the luminary the higher the effect it will have on spices. This was true, especially for the red spices, which were more sensitive to light than the green spices used.

As previously mentioned by Koca et al. (2012), the color green was represented by the a*, which was only present in the quadrant II, whether the sample was Basil or Parsley.

Water activity in the samples stored in the Arrangement 1 increased (on average) 17% in the Paprika samples, 20 % in Basil, 27 % in Cayenne Pepper, 30% in Parsley and 30% in Grillkryddor, which shows that the package provides a barrier against certain environmental factors as described by Jönson G. (2000); even though the actual packages do not represent a good barrier against light, they protect against humidity.

Comparing the available packaging to the past versions available, it is quite evident that the changes have not been very noticeable as described by Gerding et al. (1996) and Louis (1999). Being a good reason for this is that conservative attitudes are present among the consumers and in the manufacturer. Many efforts are lead by consumer preference and such is the case of Santa Maria products. Spices in general are commonly packed in glass jars.

Also it was demonstrated by the observations, that the personnel working in the retailers and the consumers lack knowledge that the light affects the color characteristics of spices. Corroborated by this research, where it was evident in the case of red colored spices. This confirms what Ötles & Çagindi, (2008) mentioned, that carotenoids oxidation is accelerated by light exposure, regarding the changes in temperatures, the studied arrangements presented very similar conditions of around 23°C, suggesting that the light at this temperatures had a stronger effect on oxidation.

Water activity in the opened samples notably increased after the period of exposure. The color changes can be linked when comparing Arrangement 1 and Arrangement 2, were the values representing the changes in color, were higher when the packages were absent. If a comparison is made between Arrangement 1 and 3, the changes in color were more pronounced in the section where the magnetic LED lamps were placed, because samples were in very close contact with those lamps, increasing the effect of light as mentioned by Cuttle. (2015).

Another reason why packaging innovation has not been evolving is the concern for the use of several materials; which increases the cost of the investment and the complexity of the process, as well as increasing the number of actors involved. Another very important consideration is the environmental impact when it comes to recycling the empty containers, that are made of different materials and that are more difficult to recycle: In Sweden when packaging is made of materials that can be easily separated and broken down, the well–developed Swedish recycling system can be properly used.

The proposition of using a new package with more components would have to fit the supply chain including the production lines. And considerations such as time constraints when doing modifications in production lines should be taken into account. Modifying a production line might represent negative effect on overall efficiency and might compromise the fulfillment of consumer's demand; consequently, all the variables of how the processes are carried out nowadays must be evaluated properly in order to implement changes.

The solution needs to take into account the actual product and supply chain demands, and in the case of shelf ready displays, the convenience and appearance for both the consumers and retailers.

The best protection was only such offered by the opaque materials, P5 and P6, and the material P6 (Amber PET), that had the best performance. This was shown in Tables 9,12 & 15, where color degradation, of each spice in each sample material was exhibited in terms ΔE* for each spice. The final colors were compared against the initial measurements of the controls.

The most pronounced changes were found in the spices located under the magnetic LED lights, confirming what Cuttle,(2015), mentioned about the effect of light, that it is determined by the distance, in this case, the foodstuff, or other product to the light source.

The reduced percentage represented by the opaque materials suggest that the color bleaching will be only diminished in an efficient way by a material that blocks the light emitted in the sections of the light spectrum correspondent to the UV lights.

5.3. General analysis

The general objective of this research was to understand which packaging materials or combination of them offer a sufficient light barrier that could reduce the discoloration process in spices. Another aim was, to possibly provide a solution that was effective enough, but using the existing glass jar. It was demonstrated by the obtained results of this study, that the package that only uses glass, does not provide a sufficient barrier against light. The only conditions, in which the packaging performs well, were when it was stored in dark conditions whether in a closed cardboard or refrigerated (also in conditions without contact to light sources), as demonstrated by the controls stored under these characteristics.

Therefore, based on the findings and analysis of this research, the research question and the sub-questions, can be answered. Remembering the research question:

- How can color bleaching be diminished by the packaging systems in the selected spices? *Considering only visual color loss, or perceived photobleaching.

The conditions of handling after the manufacturing of the product cannot be controlled by Santa Maria. Under the represented scenarios, photobleaching was only diminished when the packages have opaque characteristics and let pass only small amounts of energy from the light spectrum, as the cases of packaging P5(Amber Glass Jar) and P6 (Amber PET). The P2 (Glass jar + PET plastic Sleeve) provided an augmented protection, that was equivalent of the glass jar (P1) and the transparent PET (P7) together, thereby suggesting that a correct combination of materials could provide the desired protection against light.

Figure 37: **Gryllkryda with and without plastic sleeve after the exposure period, arrangement 2.**

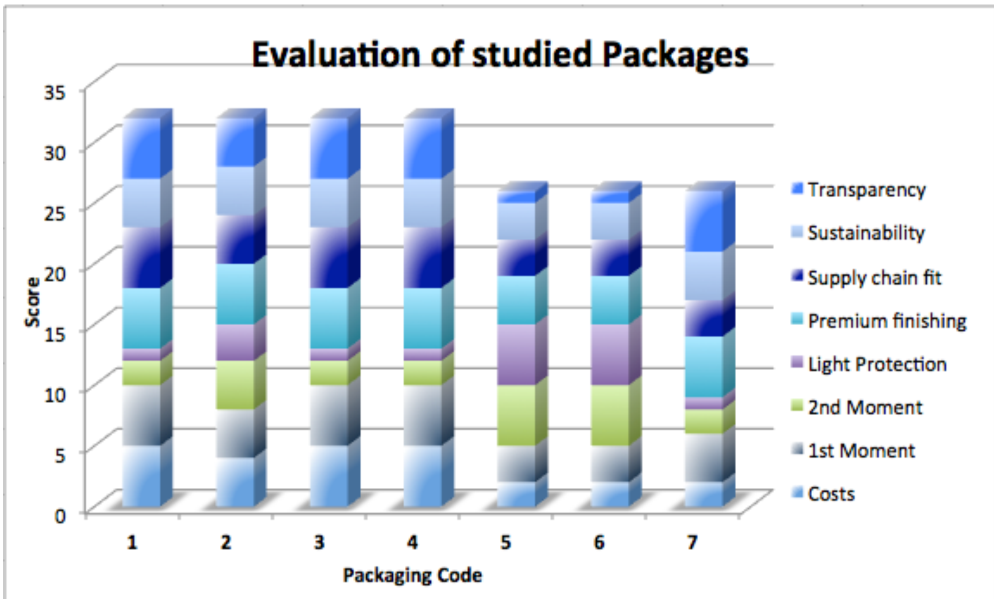
The left jars represent P1 without plastic sleeve under 400lm and 100lm from left to right, and the ones in the right, represent P2, 1000 lm and 400lm from right to left.

Regarding good practices for the display of the spices on the shelves it was found that no message about light sensitivity and storage is present in the actual packages of Santa Maria spices. Even if consumers do not dedicate enough time to read the contents of the text included on the package, it is necessary to include that spices are sensitive to light and that they should be stored in dark and dry conditions. Mostly in the red spices, it was observed that the section of the container that was in contact with a light source was more prone to bleaching, creating a heterogeneous bleaching of the color. This suggests that when the shelves are filled there are, less spaces between the jars that will make them exposed to light.

The light conditions that presented less negative effect on spices were the lights that emitted less energy. This was the case of box 2 with less than 5000 ADC counts, showing that the less light the better it is for the color conservation. Regarding the packaging solution, the packaging material in which the selected spices were less susceptible to present discoloration was also following the same principle, less light, better color conservation.

In order to provide Santa Maria with insights to make an informed decision when implementing an innovative packaging solution, the studied packaging materials were finally evaluated. The parameters considered were deducted from the interviews with the staff (Group 1 of people interviewed) in phase 1. Such evaluation criteria is presented in detail in the Appendix 9.12.2 and assigned with a score form 1 to 5 and they are classified for example in supply chain fit, where the actual conditions of the manufacturing line are compared against how much the actual characteristics will need to change in order to apply a new packaging solution or if a new supplier needs to be included in the supply chain. The following stages after the package filling were considered that could practically remain the same, as they will not be as affected as the previous if modifications to the packaging material are done.

The results of this quick analysis of the performance of each material and its level of protection against light is represented in Graphic 9 below, and can be seen in more detail in Appendix 9.12.1. In this Graphic it can be seen that the existing packaging materials are considered as a good fit, because the manufacturing lines and the suppliers are already established and the relationships are build. But in the case of Packaging 2 it can also be said that the benefits could be even better once a new manufacturing line is established. Also it is considered how complicated it will be to change the actual supply chain in order to provide a protective enough solution against light effect.



P1: Glass jar 81 mL (In use)
P2: Glass jar 81 mL+ plastic sleeve
P3: Transparent PET Plastic 440 ml(In use)
P4b: Glass jar 135 ml (In use)
P5: Amber Coloured Glass Jar 75 ml
P6: Amber Coloured PET Plastic
P7: Transparent PET Plastic

Graphic 9: **General evaluation of all the studied packages**

It was observed that it is important to have temperature controls when conducting the tests dedicated to evaluate packaging functionality. In this case,the temperature was not controlled, but as suggested by Ahsan, (2011), and Cuttle (2015), it can also have effects on the color bleaching accelerating the effects and allowing to see the efficiency of a new package solution. It was also mentioned that the recommended temperature values are around 40°C for general accelerated shelf-life tests, when evaluating product microbiology.

5.4. Recommendations

Light sources that are not LED, emit energy with discontinuous peaks of wavelengths, and represent less deteriorative effects on products; despite not presenting the most intense damage in the spices according to the study, they do not enable perception of defined contrasts and color intensity, which is important when attracting customers (Chen & Resenthal, 2015 & Giusti & Wallace, 2009). Moreover, the lifetime of such lights is becoming unsustainable, because of its higher cost against LED technologies, which are increasing in usage because of European Authorities' recommendation, due to its efficient energy consumption. Nevertheless, LED lights emit higher energy especially in the section of 450 to 580 nm of the light spectrum, the section that represented several damages regarding color bleaching in the red spices.

If the usage of such lights increases, the requirements to develop a package that protects the spices from the light will also increase, otherwise the shelf–life of the products will be even more affected.

Taking into account a scenario with an improved package solution, it is strongly recommended to continue with the stage-gate innovation process (See Figure 26), in which the first stages are being considered and covered greatly with this study. This methodology is suggested as the innovation for the packaging solution is considered to be an incremental innovation, as mentioned by Järrehult, B. (2011), where the best way to reach the final consumers is the objective. In the next stages a business model must be made in the organization based on the inputs from this research.

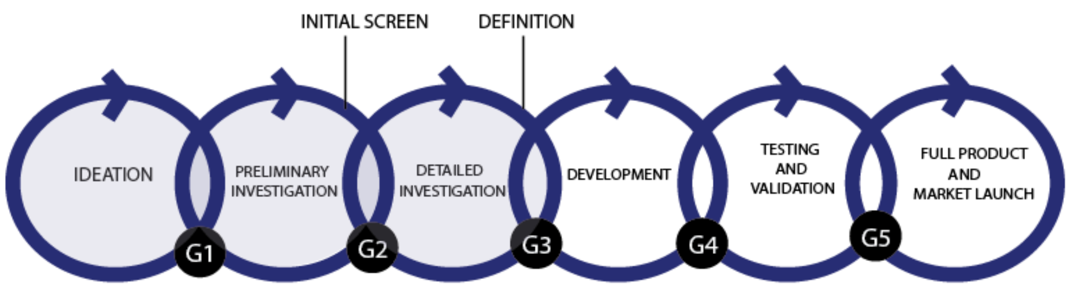


Figure 38: **Stage-gate process and covered stages with this study**

The following steps of this process might ensure the development of a solution that corresponds with the market needs. It is also recommended to conduct:

- A qualitative study based on design sessions working together with consumers, R&D and Marketing. Working hand-in-hand with consumers will anticipate expectations and define stimuli that will appeal to the consumers.

- Create an iterative process of fast prototyping: This will translate consumer expectation on product reality and will create alignment between a brief description of the new packaging solution and the activities performed by the teams. A process of constant feedback allows reworking the idea or solution as much as possible before launching. The materials to include for the packaging solution must consider the protective effect against light as essential, because, as demonstrated by this study the actual packaging solution does not represent an effective barrier against the deteriorative effects of light in the case of red spices. The iteration will allow creating a synergy between protection, product shelf-life stability and with consumer expectations. Considering the feedback from real consumers will reinforce the preference towards the brand Santa Maria.

In the case of Santa Maria where the functionality of the packaging solution is important the iterative development should be done with loyal lead consumers. This iterative way will spare the costs of doing expensive consumer tests, and a useful solution is to have simple messages (Järrehult, B., 2011).

Regarding the recommendations for the materials, the findings of the research demonstrated that the usage of different materials in the packaging increase the protection against light, but the transparent PET plastic sleeve material does not represent enough protection against light, because the original colors from the controls were bleached only % less than the current packaging material.

Many options are available with PET plastic sleeves and PVC established, technologies continue to evolve and accurate objectives could be set if it is determined that the solution is feasible in the market based on consumer information, currently the PET presents a better shrinking quality, a benchmark showed that the options are many (Appendix 9.10). Issues like shrinking angles and the quality of the design may be adjusted by the supplier, as some suppliers propose to work hand-in-hand with companies when it comes to ironing out details such as adjusting plastic sleeves to actual shapes giving a high quality finish.

An important consideration to take into account for the packaging design is the fact, confirmed by this study, that there is a lack of knowledge by the consumer that the light damages the products, and they leave commonly the jars in areas where the product is prone to lose its color; therefore, to include some phrase or infographic on the package that communicates the sensibility of the product is also recommended.

Finally in Figure 33 it is presented a possible solution using the slogan from the brand “No more boring meals” as part of the design of the plastic sleeve. This plastic sleeve will present a barrier against light because of its opaque features, where a window is suggested to be placed in the same area of “no more boring meals", represented by white in the image. That way the image of the brand is maintained and it is aligned with the statement of the brand, giving an innovative use of the window for the plastic sleeve, and consequently having two uses, to enhance the essence of the brand and at the same time to protect the contents inside the jars from light exposure.

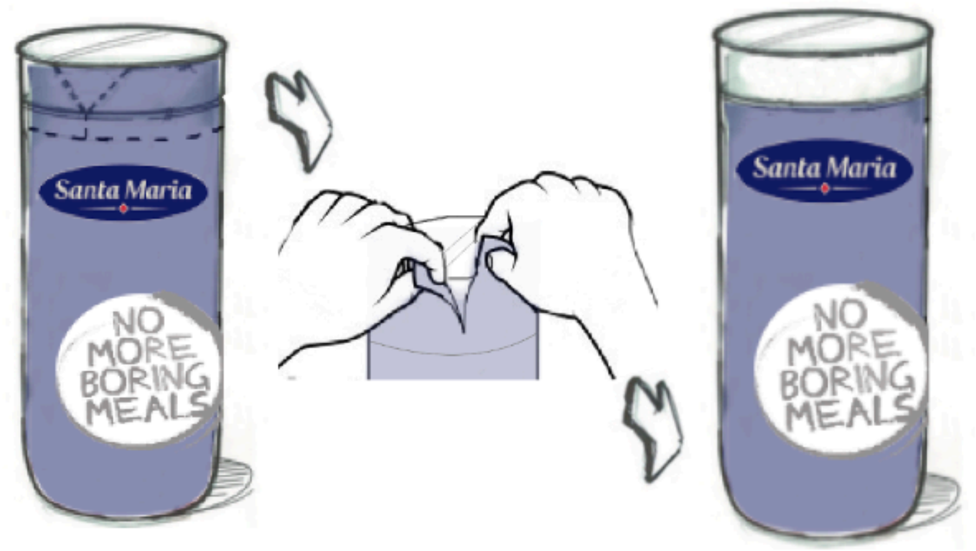


Figure 39: **Recommended solution, A temper evident plastic sleeve protective against UV light.**

6. Conclusion

This chapter presents a summary of the findings concluded throughout the whole research, focusing on the recommendations and solutions for the encountered issue of color bleaching in the selected spices by Santa Maria.

An evaluation of 7 selected packaging solutions was conducted in this Master Thesis research, using 5 different spices and testing them under different conditions of 3 different arrangements.

This research achieved the following conclusions for the sub-objectives:

1. To suggest good practices regarding the display of the spices on the shelves.
   Storage conditions in the retailers and the consumers' households were described leading to parameters that the packing solution must present to present a robust protection.

2. To determine under which type of light conditions and packaging solutions, the selected spices are less susceptible to present discoloration.
   The less light going through the packaging material the best for the spices contained in those packages, demonstrating that a packaging material that provides a UV light barrier will slow down the discoloration in spices.

3. To provide Santa Maria with insights to make an informed decision when implementing an innovative packaging solution.
   The most suitable materials for a packaging solution were proposed. Those recommendations were based on the barrier to light. Also the most susceptible spices were identified in order to use them as a reference for future analysis.

When spices are contained inside the different packaging materials the water activity remains more controlled due to the sealing that closes the jars, reducing the interactions with the environment. On the other hand, if jars are opened an increase in the water activity occurs, as in the households where the consumers store the containers with the spices until they are finished. In the case of samples with no packages the initial water activity values of around 0.3 from a just opened sealed container increased to values around 0.45, after 7 weeks of exposure to light. See Appendix for more information regarding each spice.

When a product is packed with different packaging materials the interactions with light will depend on how much light passes through the packaging material. The opaque materials studied (P5: Amber glass and P6: Amber PET), were the ones that offered a better barrier against light. However, it was also observed that the packaging solution that used a combination of a PET plastic sleeve and a glass jar offered increased protection than either the glass container or the PET container on their own. This was found to be the most suitable to adapt to the existing conditions in the manufacturing facility; because this option would not request major modifications in the actual supply chain and manufacturing lines, such as equipment purchase or new molds design, that will be needed if other solution is to be applied.

The use of an opaque plastic sleeve will not request to adapt a totally different material to the actual manufacturing of spices, because a similar material is already in use to create the temper evident feature for the cap.

The products stored under UV lights with the studied packaging materials, presented an increase of discoloration, proving that those lights are more harmful to the selected spices. It was also proven that the red spices, Grillkryddor, Cayenne Peppar and Paprika were more susceptible to present discoloration, because severe damages were observed in the short exposure period considered in this study. These spices might be considered for packaging evaluations in order to provide meaningful results when applying the packaging solutions to the complete Santa Maria spices assortment.

A plastic sleeve including UV protection, and a transparent window to see through, will provide robust protection and will still satisfying the desire of the consumers to see what they are purchasing. Also the brand identity could be enhanced, if the design is applied properly to match with the slogan of Santa Maria, “No more boring meals”.

The primary package is seen as a key element of consumer experience and should be considered in innovation projects, because packaging can create value a) during the first moment of truth, when the products are displayed on the shelves and the consumer navigates to choose a product and b) during the second moment of truth, when the products are in the kitchens of the households and the brand still visible. A good overall impression of a new image in the packaging solution will be reflected in product superiority conveying the values and drivers of Santa Maria.

7. Future research recommendations

In this section the areas on interest for further research are included, as well some relevant considerations that can add value to this research but due to time constraints they were out of the scope of this thesis, but that will broaden the panorama of the referred issue.

Taking into account the total time dedicated to this research, (which was 20 weeks), objectives were selected based on the relevance for the company. The focus was a screening process of the most relevant spices with the available packaging materials, to understand the effectivity of the protection against light, and to understand how spices behave in the selected scenarios with different illumination.

For future work it would be also interesting to take into consideration breakthrough technologies such as plastics bottles with glass coatings. They were considered for the study initially, but no samples were available within the timeframe of the project. Such options use materials, coming from the field of nano-layers and nanomaterials that form coatings and/or layers, those options present barriers for bottles and cups. Mostly these solutions have not been commercialized yet in a way that will fulfill big demands or are reserved to pharmaceutical uses.

Additionally, if the work with the company is to be continued, it would be relevant to include:

- The research of the chemical changes in the studied spices. Considering factors that were not included in this study, such as the comparison of the changes in water activity of spices when they are stored without packaging material; and to compare them against the water activity of the different spices after being stored with packaging materials. Those measurements were not performed due to lack of equipment availability, equipment that was used only to measure this parameter in the samples from arrangement 1. In order to understand better the changes taking place in the spices, the changes in the pigments and in the substances of relevance should be also included.
-
- An analysis if there exist relevant correlations between the organoleptic changes that might be occurring at the same time that pigments degradate, would be also interesting. If this study is to be conducted, the tests should be carried out with a trained sensory panel acquainted to the spices sensory profile and descriptors, in order to have relevant results.
- As recommended by this study, the actual glass jar could be maintained if an additional material is added, such material must represent a barrier

against light. For this aim, several suppliers could be analyzed; request prototypes so tests could be carried out.

- An evaluation of the shrinking properties when adding the solution to the jar can be carried out. Also a verification of which material represents better visuals for the jar, if the PET, the PVC or the OPS plastic sleeves present a better finish, and if those plastic sleeves match with the recommendations mentioned in the literature.

Moreover it should be noted that when deciding the most feasible recommendation and when considering different suppliers of plastic sleeves, it is important to consider the investment required to install ovens or shrinking equipment in order to completely account for total costs, total investment, and requested modification of the actual production line, or generally speaking a technology evaluation.

Last but not the least, once the new packaging solution is to be launched with the consumers a final feedback session with fast prototypes will determine if such a solution is aligned with what is perceived to be accepted in the Swedish market and if the investment is justified. This can be linked to the analysis of the plastic sleeves and where the window could be placed. Consumer analysis can provide richer inputs from what would be preferred from a consumer perspective, based on experiential tests with the users and prototypes to avoid bias.

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9. Appendices and enclosures

9.1. Appendix 1: Timetable

	Location	December	January	February	March	April	May	June	July	August	September
Supervisor and examinor assignation	Lund (Märit and Annika)										
Thesis Draft presentation	Lund University IKDC	16/12/2015									
Meeting with R&D Manager	Lund University IKDC	17/12/2015									
Literature research			7-15/01/2016								
Photo Studio Session	Lund University IKDC		7/1/2016								
Company Insights and Specific requirements	Sta. Maria Gothenburg		14/01/2016								
Christopher Westerberg, Marketing manager for Spices			14/01/2016								
Torbjörn Lilliebjelke, Team manager R&D Spices			14/01/2016								
Staffan Kaldén, Sourcing Manager (Packaging/traded goods)			14/01/2016								
Meeting with supervisors	Lund University IKDC		18/01/2016								
Photo Studio Session	Photo Studio, IKDC		19/01/2016								
Literature research summary			18-22/01/2016								
Logbook											
Contact with university staff											
General overview of suggested methodologies			18-22/01/2016								
Identification of laboratories/ areas to perform tests											
Specific technologies for color measurement											
Insights from Company Production Facility											
Process mapping	Sta. Maria, Gothenburg		25/01/2016								
Data collection of Company strategies regarding developmen											
Methodology proposal, Parameters/ Areas assigned in facility											
Meeting with supervisors				5/2/2016							
Methodology analysis											
Sample delivery											
Powders				08-12/2/2016							
Packaging materials											
Experimentation validation											
Sample definition analysis (if they will provide relevance)											
Analysis of suggested time frames				11-19/2/2016							
Color meter											
Photograpy session	Lund University IKDC										
Sample definition for following experiments											
Meeting with supervisors											
Discussion with Company				22-26/02/2016							
Marketing Insights					1-4/03/2016						
Contact with suppliers											
Experimentation					1-17/03/2016						
Data collection											
Meeting with supervisors											
Making of presentation					15/03/2016						
Preliminary results presentation	Lund University IKDC				17/03/2015						
Analysis of results					18-31/03/2016						
Analysis of feasibility											
Summary of requested process/suppliers changes						4/1/2016					
Cost of alternative options											
Meeting with supervisors											
Thesis document							02-28/05/2016				
Draft							02-15/05/2016				
Revisions							02-28/05/2016				
Final document							15-28/05/2016				
Final thesis presentation	Lund University							3/6/2016			
Poster hand-in											
Poster feed-back								14/06/16			
Thesis pitch/poster presentation	Paris, France										1st week

9.2. Appendix 2: Total number of measurements

TEST 1: Illuminance/Luminance										
#	Description	LED SM	N SM	400lm	1000lm	Box 1	Box 2	Box 3	Box 4	Box 5
ARR:1	Illuminance	20	20							
	Luminance	20	20							
ARR:2	Illuminance			9	9					
	Luminance			9	9					
ARR:3	Illuminance					4	4	4	4	4
	Luminance					4	4	4	4	4

TEST 2: Color Measurement		LED SM					N SM					400lm					1000lm					Boxes					
CODE	Description	P	B	C	Pa	G	P	B	C	Pa	G	P	B	C	Pa	G	P	B	C	Pa	G	P	B	C	Pa	G	TOTAL
1	Glass jar 81 ml	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	NA	NA	NA	NA	NA	**80**
2	Glass jar 81 ml+ plastic sleeve	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	NA	NA	NA	NA	NA	**80**
3	Plastic PET 440 ml	NA	4	4	NA	4	NA	4	4	NA	4	NA	4	4	NA	4	NA	4	4	NA	4	NA	NA	NA	NA	NA	**48**
4	BOXES	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	20	20	20	20	20	**100**
4b	Glass jar 135 ml	3	NA	3	NA	NA	3	NA	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**12**
5	Glass jar COLOURED	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	NA	NA	NA	NA	NA	**50**
6	Plastic PET COLOURED	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	NA	NA	NA	NA	NA	**50**
7	Plastic PET small	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	NA	NA	NA	NA	NA	**80**

TEST 3: Temperature and Relative Humidity	FREQUENCY	TEMP	RH
CONTROL FRIDGE	STATIC LOGGER	X	
ARRANGEMENT:1	STATIC LOGGER	X	
ARRANGEMENT:2	STATIC LOGGER	X	X
ARRANGEMENT:3	STATIC LOGGER	X	X

TEST 5: Light spectrum going inside packages		LED SM	N SM	400lm	1000lm	Boxes
1	Glass jar 81 ml	NA	NA	2	2	5
2	Glass jar 81 ml+ plastic sleeve	NA	NA	2	2	5
3	Plastic PET 440 ml	NA	NA	2	2	5
4	BOXES	NA	NA	NA	NA	5
4b	Glass jar 135 ml	NA	NA	NA	NA	NA
5	Glass jar COLOURED	NA	NA	2	2	5
6	Plastic PET COLOURED	NA	NA	2	2	5
7	Plastic PET small	NA	NA	2	2	5

		LED SM					N SM					400lm					1000lm					Boxes				
CODE	TEST 6: Water activity	P	B	C	Pa	G	P	B	C	Pa	G	P	B	C	Pa	G	P	B	C	Pa	G	P	B	C	Pa	G
1	Glass jar 81 ml	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2	2	NA	NA	NA	NA	NA
2	Glass jar 81 ml+ plastic sleeve	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2	2	NA	NA	NA	NA	NA
3	Plastic PET 440 ml	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2	NA	2	NA	2	2	NA	2	NA	NA	NA	NA	NA
4	BOXES	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	20	20	20	20	20
4b	Glass jar 135 ml	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Glass jar COLOURED	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2*	2*	2*	2*	2*	2*	2*	2*	2*	2*	NA	NA	NA	NA	NA
6	Plastic PET COLOURED	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2*	2*	2*	2*	2*	2*	2*	2*	2*	2*	NA	NA	NA	NA	NA
7	Plastic PET small	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2*	2*	2*	2*	2*	2*	2*	2*	2*	2*	NA	NA	NA	NA	NA

9.3. Appendix 3:Measurement procedures

The procedures of color measurement are: (1) to place an object in front of the lense of the CHROMA METER as close as possible with the most suitable lense cover (none in the case of product contained in the packaging material and the protector MAV with plastic cover in the case of powders), (2) to press the trigger to start the measurement ,and (3) to read the display.

The samples were put into an angle of 30 degrees and measured each time in an established area, whether inside the Ljus lab or in Kemicentrum Lab. In order to avoid results with poor reproducibility of the readings, in practice attention was paid to the following parameters:

- Ambient light, for the L* value(Itai et al 2006).
- The powders move inside the containers, so the fixed position improved and stabilized the contents in the package to perform the measurement.
- The packaging material might reflect the light if not positioned correctly.
- The CHROMA METER was calibrated with the white plate before starting the measurements after the calibration,3 measurements in 3 different sections of the containers were performed to characterize the color, and finally proceed to color conversion.

Color Detector X-Rite CAPSURE

Color Detector for detailed analysis of colors on various materials and surfaces / Data logging of up to 100 measurements / more than 20,000 pantone standard colors / optimized color selection / Color formulation / simple operation / quick and accurate

The color detector X-Rite CAPSURE is a portable color meter for very accurate measurements on a number of surfaces and materials. The color detector CAPSURE guarantees an accurate calibration with thousands of colors within electronic color lines. The color detector is a easy to handle and user-friendly. It recognizes a maximum of 4 color within the sample area and indicates them as the relevant color and name. Due to the integrated camera even smallest areas can be selected for the measurement in order to identify the color. The integrated diaphragm can be adjusted to 2.4 or 8 mm, thus even smallest spaces can be focused for measurement.

The color detector CAPSURE is a portable, electronic color chart, which has 20,000 pantone standard colors installed. By means of the color detector CAPSURE a maximum of 100 measurements can be saved with text- and voice- memos. Afterwards the recorded data can be retrieved via the USB port and be processed in design-applications. By means of the software included in delivery the measured colors can be administered and compared.

The color detector CAPSURE is a perfect device for any operator, who desires an identification of the closest pantone color shade within short time. With a short briefing the personnel in businesses specialized on color trading can easily advise customers by determining the color on walls, rugs, furniture, floorings, clothing or any objects of the customer's choice. The color detector CAPSURE recognizes samples with a single color as well as color-combinations.

If there are any questions about this Color Detector X-Rite CAPSURE please have a look at the technical specification with the technicians and engineers will gladly advise you regarding all color detectors and all products in the field of measuring instruments, regulation and control and scales.

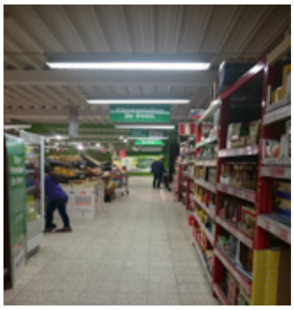
9.4. Appendix 4. Retailer's facilities

WILLYS SUPERMARKET

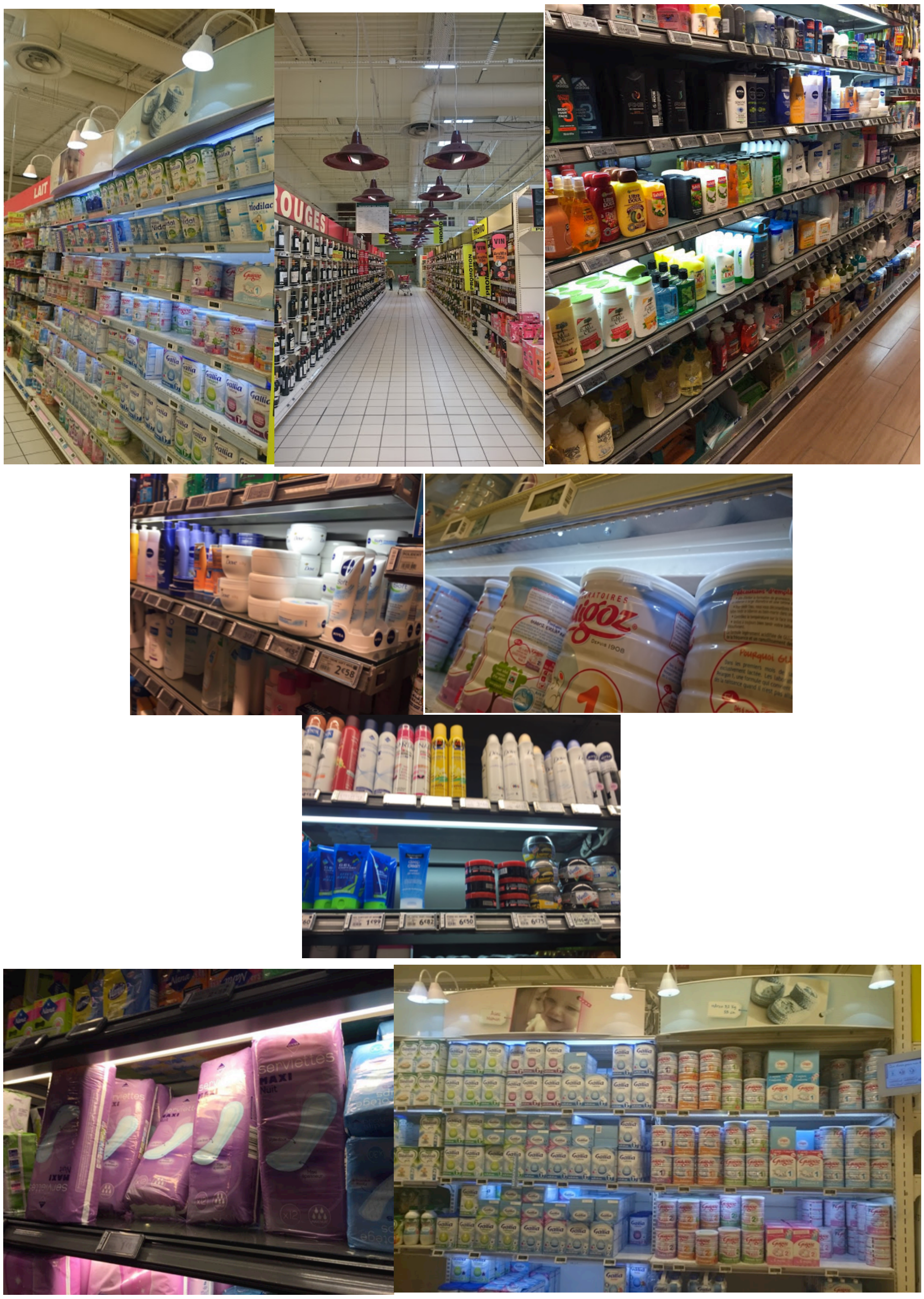
ICA SUPERMARKET (Sparta and Central Station)

COOP SUPERMARKET

9.5. Appendix 5: Light arrangements in the retailer’s facilities

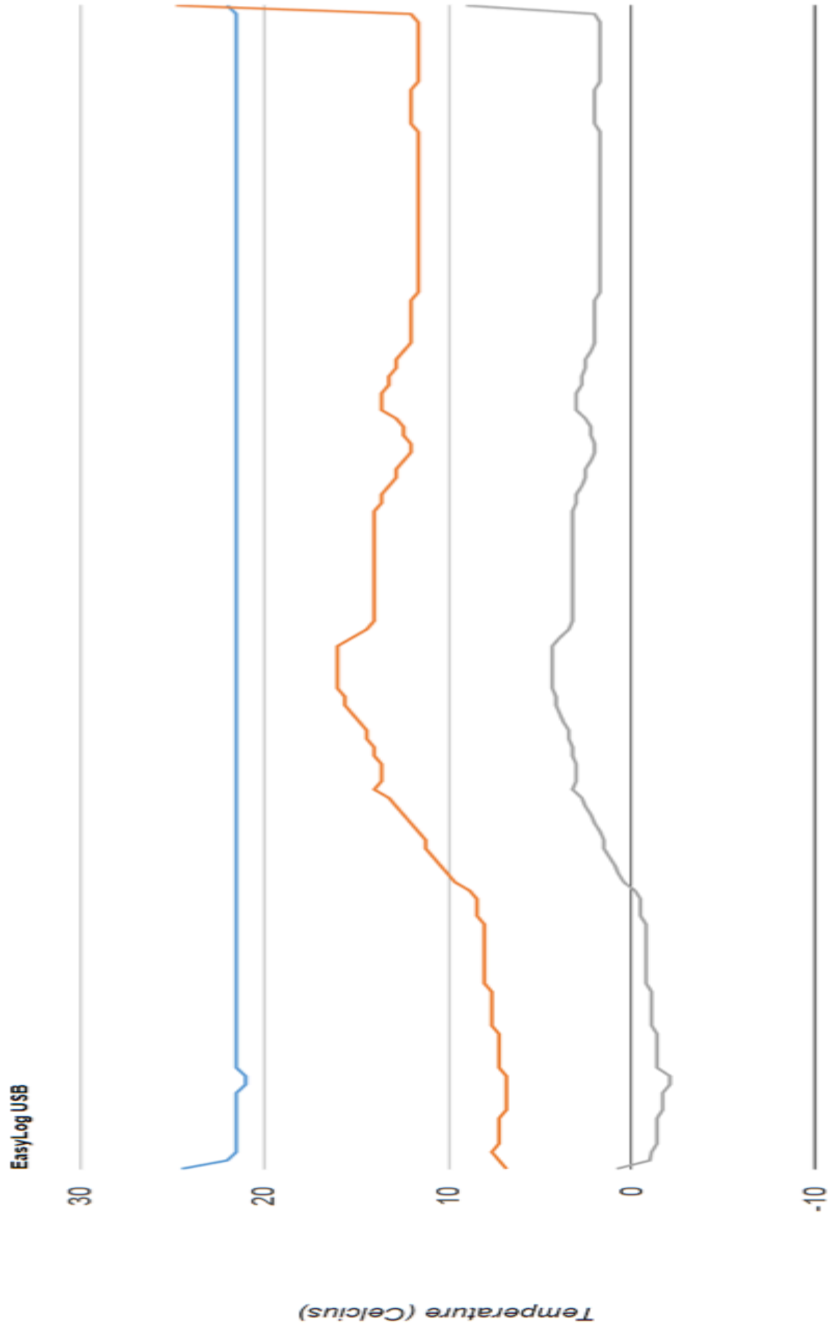


9.6. Appendix 5: Lights creating ambiance (France):



9.7. Appendix 6: Storage conditions in households (Sweden).

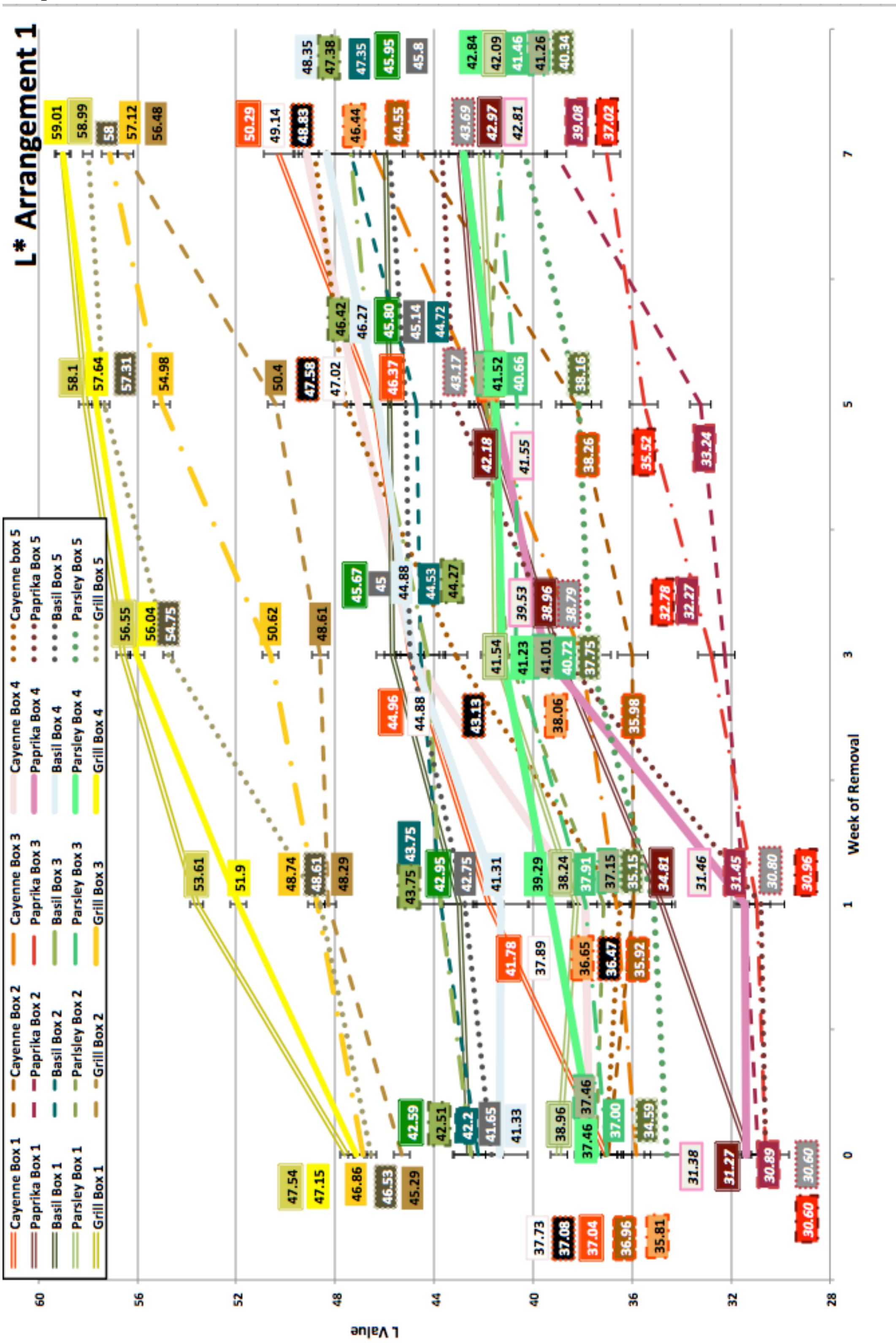
9.8. Appendix 7: Temperature and relative humidity from the data logger.



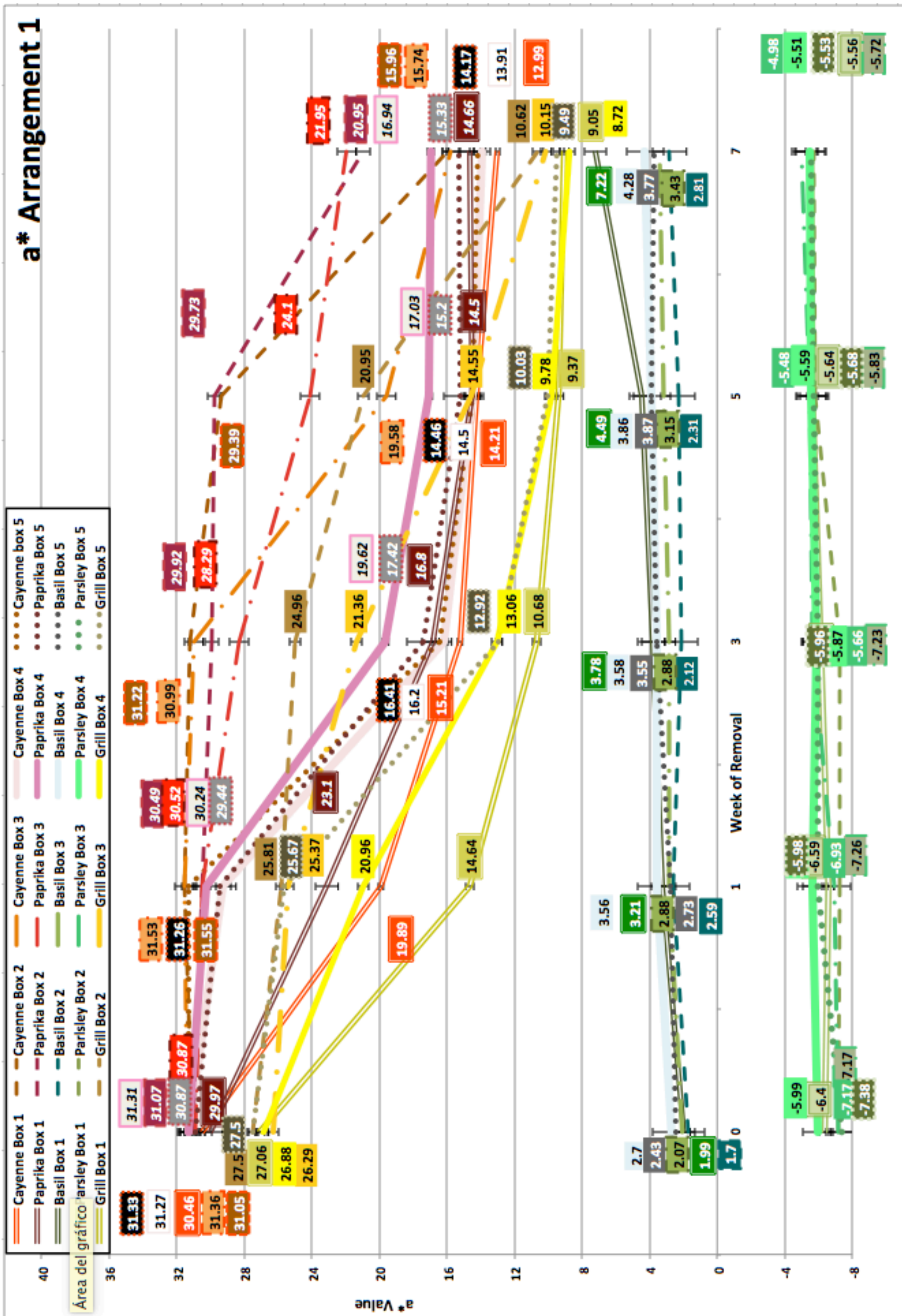
9.9. Appendix 9: Color meter charts

9.9.1. L* a* b* values Arrangement 1

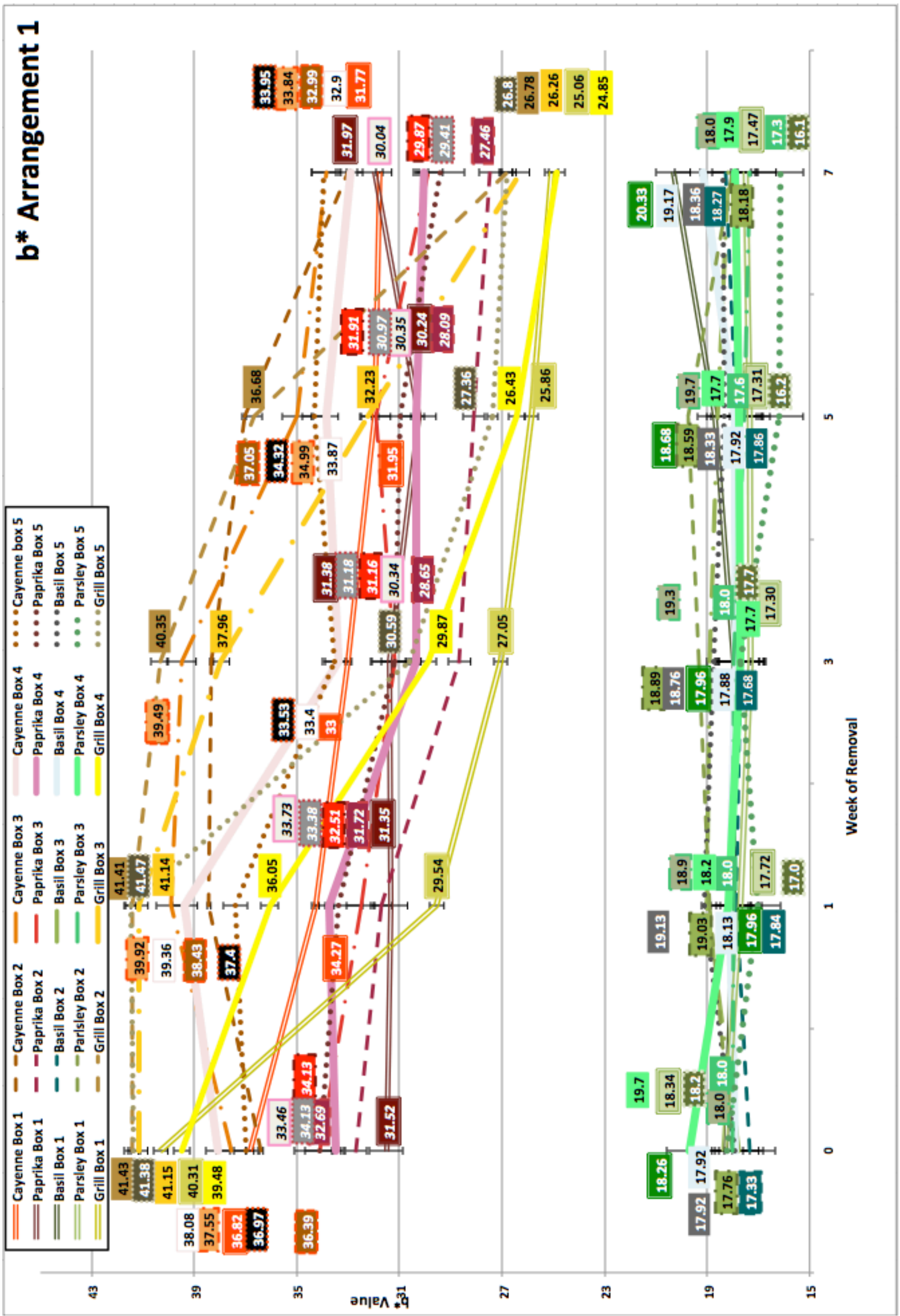
Graphic 1:L* value



Graphic 2: a* value



Graphic 3: b* value



9.9.2. L*a* b* values Arrangement 1

	WEEK	0	1	3	5	7	SD AV
L* Paprika	P1	31.27	34.81	38.96	42.18	42.97	
	SD	0.09	0.55	0.59	0.60	0.27	0.42
	P2	30.89	31.45	32.27	33.24	39.08	
	SD	0.9	0.1	0.3	0.6	0.3	0.43
	P3	30.60	30.96	32.78	35.52	37.02	
	SD	0.6	0.5	0.9	0.3	0.5	0.56
	P4	31.38	31.46	39.53	41.55	42.81	
	SD	0.1	1	0.2	0.6	0.8	0.51
	P5	30.60	30.80	38.79	43.17	43.69	
	SD	0.5	0.5	0.7	0.1	0.1	0.39
L* Basil	B1	42.59	42.95	45.67	45.80	45.95	
	SD	0.52	1.35	0.96	0.49	0.04	0.67
	B2	42.20	43.75	44.53	44.72	47.35	
	SD	0.8	2	1.1	0.6	0.4	0.99
	B3	42.51	43.75	44.27	46.42	47.38	
	SD	2.1	0.8	0.7	1.6	0.7	1.17
	B4	41.33	41.31	44.88	46.27	48.35	
	SD	2.1	0.9	0.9	1.2	0.5	1.11
	B5	41.65	42.75	45.00	45.14	45.80	
	SD	1.8	1.9	0.5	0.2	0.4	0.96
L* Cayenne Pepper	C1	37.04	41.78	44.96	46.37	50.29	
	SD	0.27	1.07	0.38	0.95	0.34	0.60
	C2	36.96	35.92	35.98	38.26	44.55	
	SD	0.7	0.8	0.7	0.3	0.6	0.62
	C3	35.81	36.65	38.06	41.98	46.44	
	SD	0.6	0.1	0.4	1.4	0.3	0.56
	C4	37.73	37.89	44.88	47.02	49.14	
	SD	0.2	0.7	0.5	0.5	0.4	0.48
	C5	37.08	36.47	43.13	47.58	48.83	
	SD	0.4	0.4	0.5	0.6	0.5	0.47
L* Parsley	Pa1	38.96	38.24	41.54	41.63	42.09	
	SD	0.64	0.24	0.43	0.17	0.26	0.35
	Pa2	37.46	37.15	41.01	41.90	41.26	
	SD	1.5	0.7	1.4	1.7	0.2	1.10
	Pa3	37.00	37.91	40.72	40.66	41.46	
	SD	0.4	0.4	0.6	1.1	0.4	0.55
	Pa4	37.46	39.29	41.23	41.52	42.84	
	SD	1.5	1.6	0.6	0.4	0.3	0.88
	Pa5	34.59	35.15	37.75	38.16	40.34	
	SD	0.6	0.6	1.2	0.9	1.3	0.92
L*Gryllkrydda	G1	47.54	53.61	56.55	58.10	58.99	
	SD	0.16	0.18	0.52	0.32	0.21	0.28
	G2	45.29	48.29	48.61	50.40	56.48	
	SD	0.7	0.4	0.3	0.2	0.1	0.33
	G3	46.86	48.74	50.62	54.98	57.12	
	SD	0.3	0.4	0.3	0.4	0.3	0.33
	G4	47.15	51.90	56.04	57.64	59.01	
	SD	0.3	0.1	0.3	0.2	0	0.18
	G5	46.53	48.61	54.75	57.31	58.00	
	SD	0.2	0.2	0.3	0.2	0.2	0.20

	WEEK	0	1	3	5	7	SD AV
a* Paprika	P1	30	23	17	15	15	
	SD	1.3	0.3	0.5	0.7	0.6	0.67
	P2	31	30	30	30	21	
	SD	0.4	0	0.4	0.1	0.6	0.31
	P3	31	31	28	24	22	
	SD	0.2	0.2	0.2	0.1	0.2	0.20
	P4	31	30	20	17	17	
	SD	0.1	0.3	0.1	1.5	1	0.59
	P5	31	29	17	15	15	
	SD	0.3	0.3	0.1	0.2	0.1	0.18
a* Basil	B1	2	3.2	3.8	4.5	7.2	
	SD	0.4	0.2	0.3	0.1	0.1	0.24
	B2	1.7	2.6	2.1	2.3	2.8	
	SD	0.2	0.5	0.1	0.1	0.1	0.23
	B3	2.1	2.9	2.9	3.2	3.4	
	SD	0	0.4	0.3	0.2	0.1	0.22
	B4	2.7	3.6	3.6	3.9	4.3	
	SD	0	0.2	0.2	0.8	0.4	0.32
	B5	2.4	2.7	3.6	3.9	3.8	
	SD	0.4	0.4	0.1	0.3	0.1	0.24
a* Cayenne Pepper	C1	30	20	15	14	13	
	SD	0	0.3	0	0.3	0.1	0.14
	C2	31	32	31	29	16	
	SD	0	0.1	0.1	0.1	0.1	0.07
	C3	31	32	31	20	16	
	SD	0.5	0.4	0.4	0.4	0.1	0.36
	C4	31	29	16	15	14	
	SD	0.2	0.3	0.1	0.1	0	0.17
	C5	31	31	16	14	14	
	SD	0.2	0.2	0.2	0.1	0.2	0.15
a* Parsley	Pa1	-6.4	-6.6	-6.2	-5.6	-5.6	
	SD	0.2	0.2	0.2	0.3	0.1	0.20
	Pa2	-7.2	-7.3	-7.2	-5.8	-5.7	
	SD	0.3	0.3	0.1	0.8	1.3	0.55
	Pa3	-7.2	-6.9	-5.7	-5.5	-5	
	SD	0.1	0.2	0.1	0.6	0.1	0.24
	Pa4	-6	-5.6	-5.9	-5.6	-5.5	
	SD	0.2	0.2	0.1	0.4	0.1	0.22
	Pa5	-7.4	-6	-6	-5.7	-5.5	
	SD	0.1	0.1	0.5	0.3	0.1	0.21
a*Gryllkrydda	G1	27	15	11	9.4	9.1	
	SD	0.2	0.1	0.1	0.1	0.1	0.11
	G2	28	26	25	21	11	
	SD	0.2	0.2	0.2	0.1	0.2	0.17
	G3	26	25	21	15	10	
	SD	0.1	0.2	0.4	0.1	0	0.15
	G4	27	21	13	9.8	8.7	
	SD	0.1	0.1	0.3	0	0.1	0.10
	G5	28	26	13	10	9.5	
	SD	0.1	0.1	0.1	0	0.1	0.09

	WEEK	0	1	3	5	7	SD AV
b* Paprika	P1	32	31	31	30	32	
	SD	1.2	0.1	0.3	0.1	2.8	0.88
	P2	33	32	29	28	27	
	SD	0.1	0.3	1	1.4	0.2	0.59
	P3	34	33	31	32	30	
	SD	0.2	0.5	0.2	0.4	0.1	0.28
	P4	33	34	30	30	30	
	SD	0.7	0.8	0.1	0	0.1	0.34
	P5	34	33	31	31	29	
	SD	0.2	0.2	0.4	0.1	0	0.19
b* Basil	B1	18	18	18	19	20	
	SD	0.4	1.1	0.4	0.3	0.2	0.48
	B2	17	18	18	18	18	
	SD	0.1	0.4	0.4	0.1	0.7	0.34
	B3	18	19	19	19	18	
	SD	0.9	0.5	0.3	1.2	0.2	0.62
	B4	18	18	18	18	19	
	SD	0.9	0.3	0.3	0.2	0.2	0.38
	B5	18	19	19	18	18	
	SD	0.4	0.4	0.3	0.4	0.6	0.41
b* Cayenne Pepper	C1	37	34	33	32	32	
	SD	0.3	0.3	0.1	0.3	0.1	0.19
	C2	36	38	38	37	33	
	SD	0.9	1	1.1	0.4	0.1	0.69
	C3	38	40	39	35	34	
	SD	0.6	0.9	0.2	0.1	0.1	0.41
	C4	38	39	33	34	33	
	SD	0.4	0.6	0.3	0.2	0.1	0.33
	C5	37	37	34	34	34	
	SD	0.8	0.8	0.2	0.4	0.1	0.45
b* Parsley	Pa1	18	18	17	17	17	
	SD	0.1	0.9	0.5	0.2	0.2	0.38
	Pa2	18	19	19	20	18	
	SD	0.4	0.4	0.1	0.6	0.5	0.39
	Pa3	18	18	18	18	17	
	SD	0.4	0.3	0.2	0.5	0.2	0.29
	Pa4	20	18	18	18	18	
	SD	1	1.6	0.3	0.1	0.4	0.68
	Pa5	18	17	18	16	16	
	SD	0.8	0.8	0.5	0.2	0.4	0.54
b*Gryllkrydda	G1	40	30	27	26	25	
	SD	0.6	0.1	0.2	0.5	0.1	0.31
	G2	41	41	40	37	27	
	SD	0.4	0.1	0.4	0.2	0.3	0.27
	G3	41	41	38	32	26	
	SD	0.6	0.2	0.4	0.3	0.3	0.36
	G4	39	36	30	26	25	
	SD	0.6	0	0.3	0.1	0.4	0.29
	G5	41	41	31	27	27	
	SD	0.2	0.2	0.5	0.3	0.4	0.34

9.9.3. L* a* b* values Arrangement 2.

L* Values Tables (SD: standard deviation, AV: average of standard deviations)

L*

L * Packaging 1	400 LM										1000 LM									
Week	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD
0.00	31.73	0.45	43.65	0.18	34.71	0.43	37.38	0.66	43.94	0.85	31.73	0.45	43.65	0.18	34.71	0.43	37.38	0.66	43.94	0.85
2.00	31.06	0.91	43.36	0.24	38.62	0.84	39.16	0.90	45.94	0.43	32.54	1.05	43.37	0.50	38.79	0.72	40.73	0.72	45.70	0.27
4.00	33.55	1.36	43.80	0.31	41.07	0.57	43.27	0.74	53.36	0.74	37.95	0.47	44.95	0.83	41.63	0.66	42.20	0.87	53.52	0.07
6.00	37.57	0.13	45.14	0.40	41.70	0.27	43.39	0.40	53.68	0.40	38.90	0.12	46.65	1.17	43.75	1.02	43.53	0.81	55.67	0.77
8.00	38.47	0.45	46.38	0.63	42.18	0.25	43.54	0.27	54.15	0.63	40.23	0.56	48.22	1.23	48.15	0.84	44.98	0.13	56.01	0.64
AV		0.66		0.35		0.47		0.59		0.61		0.53		0.78		0.73		0.64		0.52

L * Packaging 2	400 LM										1000 LM									
Week	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
0.00	31.73	0.45	43.65	0.18	36.12	1.58	37.38	0.66	43.94	0.85	31.73	0.45	43.65	0.18	34.71	0.43	37.38	0.66	43.94	0.85
1.00	33.07	0.31	43.86	0.86	40.62	1.42	39.75	1.26	46.91	0.42	32.16	0.95	44.37	0.90	40.20	0.94	39.63	0.96	46.51	0.35
2.00	35.16	0.60	44.43	0.97	39.09	0.77	42.10	0.28	52.96	0.12	33.25	0.79	45.18	1.05	41.63	0.66	40.73	1.27	52.57	0.32
3.00	36.53	0.26	45.97	0.23	39.19	0.43	43.11	0.43	53.45	0.40	36.93	0.93	44.96	1.53	43.75	1.02	41.42	1.21	52.28	0.48
4.00	37.12	0.36	46.21	0.06	41.38	1.09	43.30	0.35	53.06	0.09	38.28	1.14	45.24	0.69	44.96	0.68	41.67	0.22	53.27	0.46
AV		0.40		0.46		1.06		0.60		0.38		0.85		0.87		0.75		0.86		0.49

L * Packaging 3	400 LM										1000 LM									
Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
0.00	NA	NA	44.39	0.54	37.99	0.51	NA	NA	48.72	1.92	NA	NA	39.33	0.12	37.70	1.42	NA	NA	48.72	1.92
1.00	NA	NA	41.21	0.26	41.08	0.78	NA	NA	50.64	0.63	NA	NA	43.00	0.84	39.03	1.10	NA	NA	49.74	0.90
2.00	NA	NA	42.93	1.25	44.58	0.37	NA	NA	51.48	0.44	NA	NA	41.33	0.31	43.20	0.60	NA	NA	52.70	0.37
3.00	NA	NA	42.78	0.69	45.08	0.29	NA	NA	52.55	0.20	NA	NA	42.83	0.60	44.98	0.35	NA	NA	52.93	0.85
4.00	NA	NA	43.18	0.48	46.19	1.07	NA	NA	53.91	0.93	NA	NA	43.00	0.14	45.72	0.73	NA	NA	53.89	1.00
AV				0.64		0.60				0.82				0.40		0.84				1.01

L * Pack 5	400 LM										1000 LM									
Week	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD
1.00	34.91	0.47	45.23	0.47	41.14	0.21	41.01	0.26	50.20	0.39	34.91	0.47	45.03	0.99	41.14	0.21	39.04	1.36	49.71	0.18
8.00	36.01	0.49	47.03	0.49	41.42	0.14	41.48	0.80	50.74	0.06	36.26	0.29	45.97	0.72	42.95	0.48	39.50	0.65	50.62	0.21
AV		**0.48**		**0.48**		**0.18**		**0.53**		**0.23**		**0.38**		**0.86**		**0.35**		**1.01**		**0.20**

L * Pack 6	400 LM										1000 LM									
Week	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD
1.00	34.91	0.47	45.23	0.47	40.81	0.27	41.01	0.26	50.20	0.39	34.77	0.33	45.14	0.95	40.81	0.27	38.80	1.23	49.71	0.18
5.00	35.59	0.19	45.93	0.19	40.79	0.09	41.30	0.19	50.49	0.22	35.94	0.27	45.85	0.56	41.30	0.27	38.96	1.84	49.85	0.19
AV		**0.38**		**0.38**		**0.18**		**0.33**		**0.28**		**0.33**		**0.79**		**0.30**		**1.36**		**0.19**

L * Packaging 7	400 LM										1000 LM									
Week	P P7	SD	B P7	SD	C P7	SD	Pa P7	SD	G P7	SD	P P7	SD	B 72	SD	C P7	SD	Pa P7	SD	G P7	SD
0.00	34.91	0.47	43.56	0.18	34.71	0.43	41.01	0.26	49.38	0.30	34.91	0.47	43.56	0.18	37.70	1.42	38.80	1.23	49.38	0.30
1.00	35.05	0.54	44.84	0.21	38.97	0.33	40.83	0.12	50.53	0.39	34.80	0.86	44.50	0.36	39.11	0.69	39.69	0.23	47.96	0.25
2.00	35.24	0.24	45.45	1.04	42.20	1.72	41.42	0.31	51.28	0.86	37.71	1.63	44.70	1.34	45.43	0.96	41.42	0.31	51.28	0.86
4.00	39.46	2.03	46.24	1.35	45.75	1.79	41.62	1.05	51.06	0.75	39.86	0.51	45.38	0.20	46.42	0.81	42.15	0.37	51.31	1.28
6.00	41.63	0.84	46.88	0.71	46.45	0.75	42.72	1.04	52.42	0.95	41.50	1.26	46.30	0.76	46.79	0.46	46.79	0.81	53.39	0.54
8.00	42.11	0.38	46.65	0.62	46.61	0.65	43.57	0.85	53.31	0.65	42.24	41.68	46.76	0.19	46.88	0.14	43.94	0.57	53.78	0.72
AV		0.75		0.69		0.95		0.61		0.65		7.74		0.51		0.75		0.59		0.66

a* Values Tables

a*

L * Packaging 1

Week	400 LM										1000 LM									
	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD
0.00	16.88	0.65	-1.51	0.02	23.62	0.47	-3.14	0.43	21.18	0.60	16.88	0.65	-1.51	0.02	23.62	0.47	-3.14	0.43	21.18	0.60
2.00	16.88	0.15	-1.13	0.15	22.52	0.74	-3.35	0.95	17.59	0.97	21.06	0.63	-1.02	0.15	18.15	1.25	-3.94	1.12	18.90	0.32
4.00	15.76	0.13	-1.11	0.13	17.50	2.26	-4.62	0.17	17.27	0.52	14.06	1.93	-1.02	0.12	19.83	0.83	-3.47	0.39	15.33	0.39
6.00	14.90	0.04	-0.92	0.04	17.34	1.08	-4.50	0.52	16.05	0.92	13.39	0.04	-0.98	0.04	18.99	1.86	-3.87	0.17	19.60	0.87
8.00	13.82	0.14	-0.83	0.14	17.18	0.54	-5.02	0.28	13.91	0.99	10.82	1.69	-0.94	0.28	19.60	0.04	-4.16	0.49		
AV		0.22		0.10		1.02		0.47		0.80		0.99		0.12		0.89		0.52		0.55

L * Packaging 2

Week	400 LM										1000 LM									
	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
0.00	16.88	0.65	-1.51	0.02	24.08	2.03	-3.14	0.35	21.18	0.60	16.88	0.65	-1.51	0.02	23.62	0.47	-3.14	0.43	21.18	0.60
2.00	16.88	0.15	-1.05	0.10	23.86	1.63	-3.82	0.58	16.59	1.72	16.87	0.64	-1.11	0.11	15.80	2.65	-5.17	1.04	17.04	0.78
4.00	15.76	0.13	-1.20	0.24	19.91	0.29	-4.19	0.50	17.61	0.57	16.57	2.44	-1.10	0.24	20.48	1.74	-3.33	0.15	16.93	0.62
6.00	14.90	0.04	-1.21	0.17	18.05	0.51	-5.08	0.26	13.81	0.81	14.25	0.36	-1.10	0.07	17.57	0.73	-4.47	0.33	13.96	0.89
8.00	13.82	0.14	-0.65	0.06	17.15	0.28	-4.24	0.37	15.00	0.65	11.57	0.63	-1.16	0.07	16.84	0.07	-4.54	0.34		
AV		**0.22**		**0.12**		**0.95**		**0.41**		**0.87**		**0.94**		**0.10**		**1.13**		**0.46**		**0.72**

L * Packaging 3

Week	400 LM										1000 LM									
	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
0.00	NA	NA	2.20	0.50	22.16	2.85	NA	NA	17.94	2.72	NA	NA	2.18	0.19	23.40	0.79	NA	NA	17.94	2.72
2.00	NA	NA	2.50	0.70	19.94	0.67	NA	NA	14.12	0.63	NA	NA	1.51	0.27	21.89	0.25	NA	NA	18.73	1.28
4.00	NA	NA	1.80	1.80	14.89	0.73	NA	NA	15.85	3.60	NA	NA	2.12	0.30	17.75	0.22	NA	NA	9.93	0.39
6.00	NA	NA	1.90	0.50	14.99	1.30	NA	NA	17.24	1.91	NA	NA	2.70	0.32	13.72	0.24	NA	NA	17.32	0.26
8.00	NA	NA	2.60	1.10	19.34	0.42	NA	NA	18.14	1.06	NA	NA	2.00	0.28	14.70	0.52	NA	NA	14.44	0.72
AV						**1.19**				**1.98**				**0.27**		**0.40**				**1.07**

L * Pack 5

Week	400 LM										1000 LM									
	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD
0.00	26.82	0.07	1.77	0.31	27.48	0.09	-7.26	0.09	23.79	0.39	26.82	0.07	1.87	0.07	27.35	0.07	-7.05	0.17	23.87	0.16
8.00	25.82	0.26	2.06	0.22	27.39	0.36	-6.39	0.57	23.93	0.54	25.80	0.69	2.47	0.10	27.50	0.55	-6.59	0.65	23.98	0.54
AV		**0.17**		**0.27**		**0.55**		**0.33**		**0.97**		**0.38**		**0.15**		**0.34**		**0.41**		**0.59**

L * Pack 6

Week	400 LM										1000 LM									
	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD
0.00	26.82	0.07	1.77	0.31	27.16	0.21	-7.26	0.09	23.79	0.39	26.82	0.07	1.85	2.60	27.16	0.21	-7.02	0.16	23.87	0.16
8.00	25.82	0.26	2.18	0.47	26.97	0.18	-5.56	0.92	24.19	0.20	25.76	0.67	2.22	0.30	27.27	0.36	-6.59	0.65	24.50	0.33
AV		0.17		0.39		0.20		0.51		0.30		0.37		1.45		0.29		0.41		0.25

L * Packaging 7

Week	400 LM										1000 LM									
	P P7	SD	B P7	SD	C P7	SD	Pa P7	SD	G P7	SD	P P7	SD	B 72	SD	C P7	SD	Pa P7	SD	G P7	SD
0.00	26.82	0.07	2.10	0.02	23.62	0.47	-7.26	0.09	22.38	0.42	26.82	0.07	2.10	0.02	23.40	0.79	-7.02	0.16	22.38	0.42
1.00	23.92	0.22	2.43	0.30	24.77	0.85	-4.74	0.38	20.62	0.96	23.84	0.97	2.30	0.43	24.50	0.61	-4.34	0.30	22.79	0.11
2.00	22.37	0.70	2.61	0.45	23.08	1.37	-3.96	0.30	18.97	0.95	19.10	1.60	3.00	0.24	19.21	1.60	-3.96	0.30	18.97	0.95
4.00	20.47	1.60	2.40	0.47	20.07	0.80	-3.41	0.17	19.93	0.65	19.44	1.38	2.48	0.25	18.93	0.78	-3.45	0.81	19.49	0.90
6.00	19.13	0.63	1.78	0.06	18.82	0.60	-3.59	0.70	19.24	0.61	18.32	1.96	2.60	0.78	17.43	0.35	-3.59	0.27	17.49	0.87
8.00	16.72	1.65	2.61	0.68	17.96	0.72	-3.56	1.65	18.34	0.46	15.86	1.24	2.12	0.58	17.84	0.45	-3.40	0.37	16.64	0.42
AV		0.81		0.33		0.80		0.55		0.68		1.20		0.38		0.76		0.37		0.61

b* Values Tables

b*

L * Packaging 1	400 LM										1000 LM									
Week	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD
0.00	17.08	1.31	7.63	0.63	26.22	0.99	6.12	0.75	30.78	1.84	17.08	1.31	7.63	0.63	26.22	0.99	6.12	0.75	30.78	1.84
2.00	14.75	1.13	6.64	1.02	24.41	1.61	4.62	2.61	28.36	2.61	21.46	1.40	8.54	0.44	27.64	0.32	7.35	2.14	27.79	0.44
4.00	17.87	2.18	8.35	0.96	18.25	3.19	8.62	0.68	20.59	0.68	17.37	2.36	7.53	0.63	24.12	7.07	3.96	0.71	20.53	1.13
6.00	19.02	0.71	8.74	0.93	23.75	0.94	9.06	0.79	22.07	0.79	19.40	0.15	8.09	1.05	24.55	0.60	7.06	1.25	22.30	0.93
8.00	19.69	0.25	8.91	1.34	29.26	0.29	9.79	0.80	23.21	0.80	18.29	1.80	8.58	0.59	20.57	1.05	7.77	0.89	19.38	1.10
AV		1.12		0.98		1.40		1.13		1.34		1.40		0.67		2.01		1.15		1.09

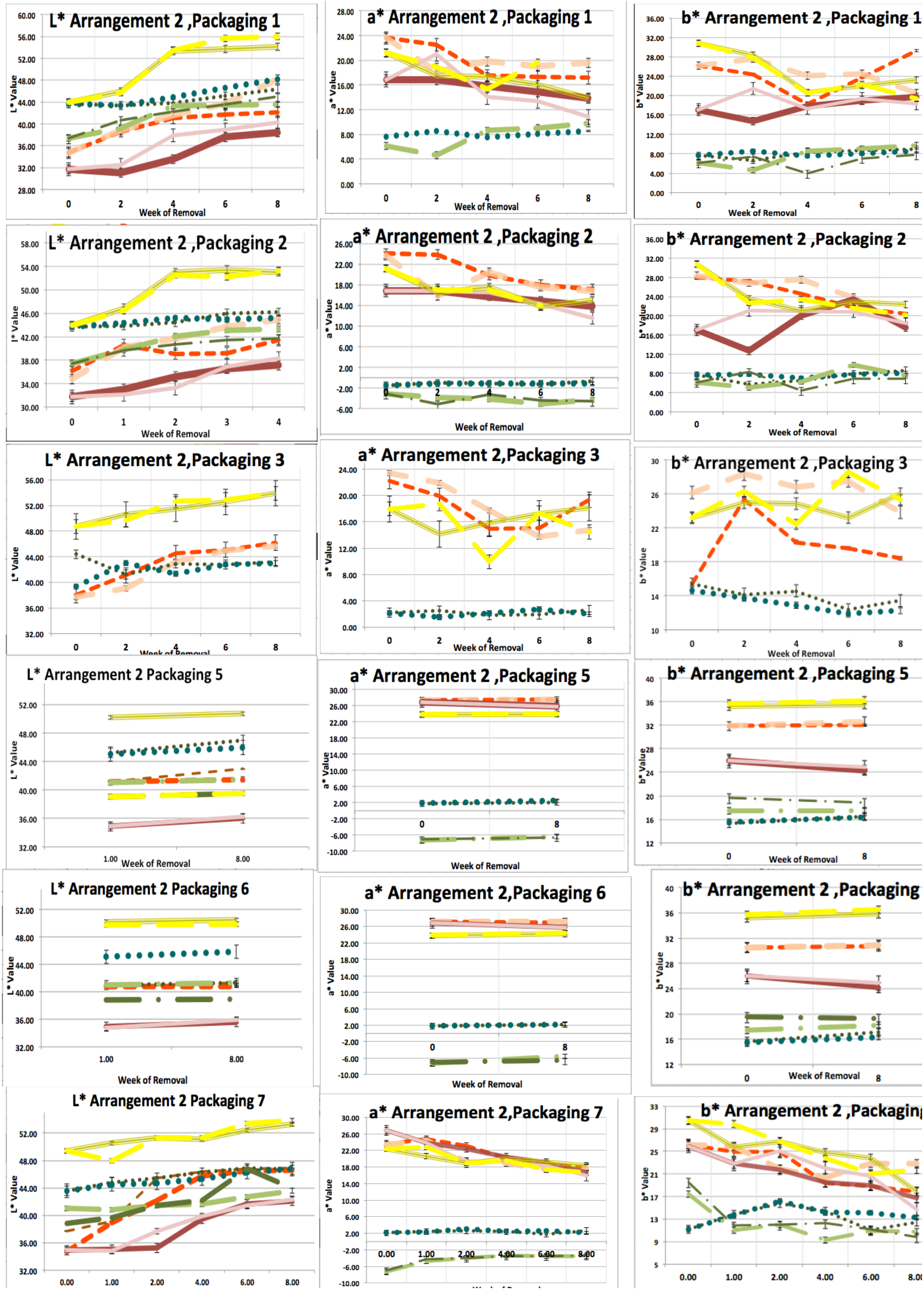
L * Packaging 2	400 LM										1000 LM									
Week	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
0.00	17.08	1.31	7.63	0.63	27.96	2.52	6.12	0.75	30.78	1.84	17.08	1.31	7.63	0.63	28.35	1.46	6.12	0.75	30.78	1.84
2.00	12.71	0.11	5.73	0.32	27.24	3.55	5.03	2.02	23.57	2.87	21.05	0.46	7.75	1.18	26.86	0.71	8.38	0.56	22.68	1.18
4.00	20.04	0.75	6.49	1.63	24.58	0.89	6.30	1.32	21.04	1.17	20.96	2.47	6.97	1.25	27.54	1.32	4.43	0.60	23.43	0.16
6.00	23.42	2.44	7.91	0.47	21.78	2.10	9.79	0.89	22.92	0.91	20.86	0.39	7.78	0.29	23.83	1.75	6.84	0.43	21.59	1.58
8.00	17.57	1.36	8.63	0.74	20.38	1.09	7.56	1.98	22.34	1.75	18.44	1.47	8.05	0.29	18.01	1.16	6.86	1.73	20.13	1.35
AV		1.19		0.76		2.03		1.39		1.71		1.22		0.73		1.28		0.81		1.22

L * Packaging 3	400 LM										1000 LM									
Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
0.00	NA	NA	15.41	1.70	15.41	1.70	NA	NA	23.21	4.91	NA	NA	14.61	2.44	26.18	2.00	NA	NA	23.21	4.91
2.00	NA	NA	14.18	1.30	25.38	1.11	NA	NA	24.98	1.91	NA	NA	13.76	1.39	28.35	1.46	NA	NA	26.30	2.11
4.00	NA	NA	14.58	0.54	20.33	3.23	NA	NA	24.85	1.71	NA	NA	12.91	2.00	26.86	0.71	NA	NA	22.41	0.17
6.00	NA	NA	12.35	0.50	19.64	3.28	NA	NA	23.23	4.38	NA	NA	11.86	0.57	27.54	1.32	NA	NA	28.54	0.45
8.00	NA	NA	13.42	2.20	18.42	1.31	NA	NA	26.08	2.35	NA	NA	12.25	2.60	23.83	1.75	NA	NA	25.31	0.50
AV				1.25		2.13				3.05				1.80		1.45				1.63

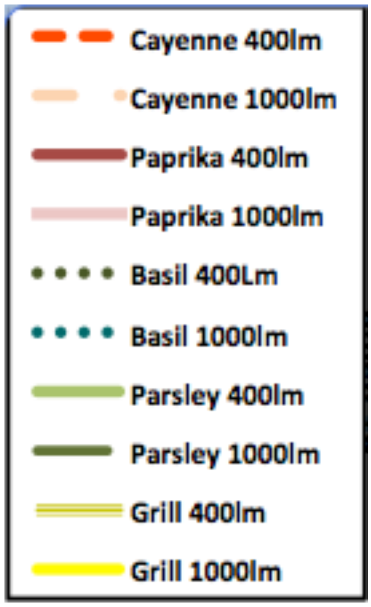
L * Pack 5	400 LM										1000 LM									
Week	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD
0.00	25.94	0.28	15.32	0.45	31.86	0.32	17.43	0.11	35.20	0.53	25.94	0.28	15.43	0.47	31.86	0.32	19.70	0.96	35.65	0.34
8.00	24.30	0.22	16.46	0.23	32.02	0.70	17.51	1.14	35.42	0.57	24.84	1.58	17.76	0.50	32.65	1.36	18.85	0.78	36.21	0.71
AV		0.25		0.34		0.51		0.63		0.55		0.93		0.49		0.84		0.87		0.53

L * Pack 6	400 LM										1000 LM									
Week	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD
0.00	25.94	0.28	15.57	0.59	30.49	0.57	17.43	2.39	35.20	0.53	25.94	0.28	15.49	0.45	30.49	0.57	19.58	0.92	35.65	0.34
8.00	24.17	0.44	17.14	0.76	30.73	0.27	18.21	2.39	35.79	0.38	24.87	1.60	16.30	0.50	30.91	1.15	19.27	1.25	36.50	0.56
AV		0.36		0.68		0.42		2.39		0.46		0.94		0.48		0.86		1.09		0.45

L * Packaging 7	400 LM										1000 LM									
Week	P P7	SD	B P7	SD	C P7	SD	Pa P7	SD	G P7	SD	P P7	SD	B 72	SD	C P7	SD	Pa P7	SD	G P7	SD
0.00	25.94	0.28	11.18	0.63	26.22	0.99	17.43	2.39	30.45	0.43	25.94	0.28	11.18	0.63	26.18	2.00	19.58	0.92	30.45	0.43
1.00	22.80	0.13	13.85	0.20	24.90	0.65	11.01	0.97	25.82	1.93	22.78	2.21	13.70	1.34	25.85	1.17	11.84	0.67	29.84	1.25
2.00	21.69	1.01	15.72	1.96	24.91	2.81	12.03	0.40	26.80	2.25	25.07	2.12	16.20	1.30	21.86	1.35	12.03	0.40	26.80	2.25
4.00	19.48	3.29	14.35	1.22	19.44	0.93	9.31	1.71	24.82	0.49	22.05	0.40	14.20	0.43	20.33	2.13	12.31	0.93	23.76	1.29
6.00	18.99	0.90	11.07	1.02	18.85	1.88	10.92	0.86	23.79	1.18	20.58	0.76	14.11	0.89	22.87	0.39	11.13	1.27	21.00	0.86
8.00	16.73	3.39	12.48	2.56	17.84	1.40	10.76	1.87	17.84	0.51	14.72	20.65	13.26	0.80	22.81	1.08	9.83	1.45	21.69	0.49
AV		1.50		1.27		1.44		1.37		1.13		4.40		0.90		1.35		0.94		1.10



L* Arrangement 2 ,Packaging 1
a* Arrangement 2 ,Packaging 1
b* Arrangement 2 ,Packaging 1
L* Arrangement 2 ,Packaging 2
a* Arrangement 2 ,Packaging 2
b* Arrangement 2 ,Packaging 2
L* Arrangement 2,Packaging 3
a* Arrangement 2,Packaging 3
b* Arrangement 2 ,Packaging 3
L* Arrangement 2 Packaging 5
a* Arrangement 2 ,Packaging 5
b* Arrangement 2 ,Packaging 5
L* Arrangement 2 Packaging 6
a* Arrangement 2,Packaging 6
b* Arrangement 2 ,Packaging
L* Arrangement 2 Packaging 7
a* Arrangement 2,Packaging 7
L* Value
a* Value
b* Value
Week of Removal


Cayenne 400lm
Cayenne 1000lm
Paprika 400lm
Paprika 1000lm
Basil 400Lm
Basil 1000lm
Parsley 400lm
Parsley 1000lm
Grill 400lm
Grill 1000lm

9.9.4. L* a* b* values Arrangement 3.

L* Values Tables (SD: standard deviation, AV: average of standard deviations)

		L*																			
		SM										SM +LED									
L * Packaging 1	Week	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD
	0.00	41.94	0.56	43.7	0.18	40.7	3.82	41.43	1.30	51.1	0.58	41.9	0.56	41.8	0.31	46.1	0.09	41.43	1.30	51.1	0.58
	2.00	42.12	0.21	44.8	0.28	45.6	0.3	43.30	0.61	51.6	0.12	42.5	0.05	44.8	1.43	47.2	0.23	44.75	1.32	53.2	0.68
	4.00	43.50	0.79	44.9	0.45	45.7	0.55	43.70	1.41	52.7	1.04	43.9	0.78	45.2	0.43	47.9	0.06	45.00	0.49	53	0.48
	6.00	44.39	0.77	45.1	0.45	46.4	0.84	44.82	0.75	53.4	0.16	44.3	0.16	45.3	0.3	49.4	0.88	45.13	1.06	55.9	1.51
	AV		0.58		0.34		1.38		1.02		0.48		0.39		0.62		0.32		1.04		0.81

		SM										SM +LED									
L * Packaging 2	Week	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
	0.00	41.94	0.56	43.7	0.18	40.7	3.82	41.43	1.30	51.1	0.58	41.9	0.56	41.8	0.31	46.5	0.34	46.51	0.34	51.1	0.58
	2.00	40.52	0.68	44.6	0.12	43.3	1.05	43.44	0.15	51.4	0.16	42.6	1.16	43.8	0.99	46.2	0.25	46.21	0.25	51.6	0.12
	4.00	41.24	0.37	45	1.33	44.7	0.26	43.57	0.48	52.3	0.32	43.7	1.21	44.6	1.43	46.4	0.3	46.43	0.30	53.4	0.32
	6.00	43.91	0.22	45.8	1.37	44.8	0.19	44.38	0.45	53.3	0.74	44.2	0.42	45.2	0.19	48.1	0.12	47.39	1.02	53.9	0.45
	AV		0.46		0.75		1.33		0.60		0.45		0.84		0.73		0.25		0.48		0.37

		SM										SM +LED									
L * Packaging 3	Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
	0.00	NA	NA	43.1	1.29	37.7	1.42	NA	NA	48.7	1.92	41.9	0.56	43.1	1.29	34.7	0.43	NA	NA	48.7	1.92
	2.00	NA	NA	45.2	0.98	38.2	0.52	NA	NA	52.1	0.9	40.9	1.77	44.7	1.34	35.8	0.88	NA	NA	51.6	0.27
	4.00	NA	NA	46.2	0.35	37.1	0.81	NA	NA	52.3	1.6	41.7	0.8	45.8	1.02	36.9	0.39	NA	NA	49.4	0.86
	6.00	NA	NA	46	0.49	42.2	0.33	NA	NA	53.7	1.64	44.4	1.65	45.7	0.61	40.8	0.5	NA	NA	56.1	0.68
	AV				0.61		0.55				1.38				1.07		0.55				0.93

		SM										SM +LED									
L * Packaging 4	Week	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
	0.00	41.94	0.56	NA	NA	NA	NA	NA	NA	51.1	0.58	41.9	0.56	NA	NA	NA	NA	NA	NA	51.1	0.58
	2.00	38.22	1.14	NA	NA	NA	NA	NA	NA	50.8	1.14	42.5	0.05	NA	NA	NA	NA	NA	NA	52.4	0.34
	4.00	40.46	0.93	NA	NA	NA	NA	NA	NA	51.6	0.93	43.9	0.78	NA	NA	NA	NA	NA	NA	56.2	0.27
	6.00	43.57	1.24	NA	NA	NA	NA	NA	NA	52.6	1.24	44.3	0.16	NA	NA	NA	NA	NA	NA	56.8	0.16
	AV		1.10								1.10		0.33								0.34

L * Pack 5	SM										SM +LED									
Week	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD
1.00	33.03	0.32	41.8	0.2	37.3	0.43	37.68	0.97	46.6	1.09	32.8	0.17	41.9	0.81	37.6	0.92	38.84	0.21	45.9	0.24
2.00	33.36	0.16	41.8	0.1	38	0.22	37.64	0.93	47.3	2.02	33.2	0.4	41.9	0.6	38.1	0.42	38.92	0.34	46.5	0.24
6.00	34.10	0.57	42.5	0.06	39.3	0.74	39.97	0.63	48.8	0.54	35.4	0.8	43.6	0.31	40.1	0.33	39.34	0.32	47.8	1.19
AV		**0.35**		**0.12**		**0.46**		**0.84**		**1.22**		**0.46**		**0.57**		**0.56**		**0.29**		**0.56**

L * Pack 6	SM										SM +LED									
Week	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD
1.00	32.22	0.91	41.7	0.16	37.8	0.33	37.17	1.01	46.6	0.82	32.4	0.25	42.5	0.14	37.4	0.22	38.71	0.72	45.8	0.25
2.00	32.54	0.17	41.7	0.66	37.8	0.46	37.88	0.50	46.3	0.38	32.7	0.04	42.8	0.5	37.8	0.21	39.02	0.61	45.4	0.67
6.00	34.43	1.05	42.4	0.27	40.2	0.49	39.16	0.65	48.8	1.11	34.8	0.41	42.6	0.31	39.5	0.86	39.63	0.08	48	0.54
AV		**0.62**		**0.30**		**0.44**		**0.75**		**0.88**		**0.29**		**0.38**		**0.46**		**0.43**		**0.50**

L * Packaging 7	SM										SM +LED									
Week	P P7	SD	B P7	SD	C P7	SD	Pa P7	SD	G P7	SD	P P7	SD	B 72	SD	C P7	SD	Pa P7	SD	G P7	SD
0.00	41.94	0.56	46.9	0.18	40.7	3.82	39.16	0.65	51.1	0.58	41.9	0.56	46.9	0.31	46.5	0.34	46.51	0.34	49.4	0.3
2.00	42.45	0.75	51.3	0.22	40.7	0.46	40.49	0.88	40.7	0.46	41.6	1.93	50	1.6	42.2	0.46	43.48	0.41	51	0.46
4.00	41.86	0.07	51.2	1.03	40.2	0.24	42.03	0.56	40.2	0.24	43.9	0.62	50.6	1.75	46.7	1.47	46.07	0.74	51	0.99
6.00	43.46	0.36	52.2	0.4	43.2	1.05	43.31	0.30	43.2	1.05	45.4	1.05	51	0.39	48	0.25	48.15	0.76	55.5	0.98
AV		0.44		0.46		1.39		0.60		0.58		1.01		0.63		0.63		0.56		0.68

a*

a * Packaging 1	SM										SM +LED									
Week	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD
0.00	17.92	0.21	-1.5	0.02	22.5	1.81	-4.38	0.35	19.5	0.19	17.9	0.21	-1.5	0.02	19.7	1.44	-4.38	0.35	19.5	0.19
2.00	16.32	0.85	-1.1	0.3	20.2	0.68	-4.19	0.18	18.6	0.17	14.4	0.65	-1.1	0.29	20	0.46	-4.73	0.21	16.5	0.19
4.00	14.74	0.93	-0.9	0.29	20.7	0.71	-4.89	0.31	16.1	2.42	14.6	19.2	-1.3	0.06	19.7	0.62	-3.63	0.57	15.1	1.3
6.00	14.54	0.44	-0.8	0.3	21.1	0.36	-5.25	0.28	14.8	0.77	14.8	0.74	-0.7	0.35	16	3.29	-3.66	0.48	12.7	3.43
AV		0.61		0.23		0.89		0.28		0.89		5.19		0.18		1.45		0.40		1.28

a * Packaging 2	SM										SM +LED									
Week	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
0.00	17.92	0.21	-1.5	0.02	22.5	1.81	-4.38	0.35	19.5	0.19	17.9	0.21	-1.5	0.02	20.4	0.77	-4.83	0.77	19.5	0.19
2.00	17.17	0.06	-1.1	0.4	19.9	0.2	-4.16	0.26	18.3	0.89	16.9	0.74	-1	0.26	20.1	0.22	-7.27	0.22	18.6	0.17
4.00	17.11	0.80	-1.3	0.36	19.1	1.01	-4.66	0.49	16.9	1.35	16	0.49	-1	0.32	15.5	1.6	-3.82	1.60	16.6	1.31
6.00	15.87	0.86	-1.1	0.29	19.4	0.63	-4.69	0.27	15.4	1.53	16	0.41	-1.3	0.1	17.5	1.43	-3.70	1.43	15.4	0.54
AV		0.48		0.27		0.91		0.34		0.99		0.46		0.18		1.01		1.01		0.55

a * Packaging 3	SM										SM +LED									
Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
0.00	NA	NA	2.32	0.33	26	0.79	NA	NA	17.9	2.72	NA	NA	2.32	0.33	23.6	0.47	NA	NA	17.9	2.72
2.00	NA	NA	2.89	0.24	26.2	0.87	NA	NA	19.1	1.18	NA	NA	3.02	0.24	27.3	0.59	NA	NA	18.9	3.15
4.00	NA	NA	2.83	0.25	23.1	5.26	NA	NA	16.1	0.87	NA	NA	3.25	0.15	26.3	0.58	NA	NA	20.1	0.98
6.00	NA	NA	1.37	0.04	20.3	1.31	NA	NA	17.1	2.21	NA	NA	2.57	0.17	20.8	2.04	NA	NA	15.9	15.9
AV						2.06				1.75				0.22		0.92				5.68

a * Packaging 4	SM										SM +LED									
Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
0.00	17.92	0.21	NA	NA	NA	NA	NA	NA	19.5	0.19	17.9	0.21	NA	NA	NA	NA	NA	NA	19.5	0.19
2.00	20.65	0.39	NA	NA	NA	NA	NA	NA	20.7	0.39	19.2	1.3	NA	NA	NA	NA	NA	NA	16.5	1.29
4.00	19.57	1.68	NA	NA	NA	NA	NA	NA	19.6	1.68	19.5	0.49	NA	NA	NA	NA	NA	NA	13.5	1.31
6.00	15.65	0.36	NA	NA	NA	NA	NA	NA	15.7	0.36	16.3	16.3	NA	NA	NA	NA	NA	NA	12.4	1.3
AV		0.66								0.66		4.58								1.02

a * Pack 5		SM										SM +LED									
	Week	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD
	1.00	25.94	0.21	3.2	0.7	25.7	0.33	-7.32	0.37	24.7	0.46	25.4	0.35	2.35	0.31	25.6	0.27	-7.25	0.22	25.2	0.17
	2.00	25.86	0.17	2.5	0.38	25.7	0.25	-6.59	0.84	23.8	0.11	24.8	0.45	2.15	0.31	25.2	0.2	-6.68	0.60	24.4	0.57
	6.00	27.01	0.35	2.25	0.01	27.3	0.28	-6.93	0.23	23.6	0.92	25.5	0.33	2.08	0.03	25.8	0.56	-5.15	0.19	23.7	0.29
	AV		**0.50**		**0.36**		**0.73**		**0.48**		**0.72**		**3.00**		**0.22**		**0.49**		**0.34**		**1.31**

a * Pack 6		SM										SM +LED									
	Week	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD
	1.00	25.31	0.47	2.39	0.19	25.7	0.25	-6.77	1.03	24.6	0.49	25.3	0.41	2.63	0.5	26.3	0.15	-6.58	0.47	25.1	0.36
	2.00	25.38	0.24	2.11	0.57	26	0.19	-6.83	0.53	25.2	0.35	24.8	0.05	2.23	0.52	25.8	0.24	-5.75	0.54	24.4	0.91
	6.00	25.58	0.82	2.54	0.12	27	0.31	-6.51	0.27	24.5	0.11	25.8	0.36	2.46	0.25	25.7	0.22	-4.81	0.04	24.4	0.32
	AV		**0.51**		**0.29**		**0.25**		**0.61**		**0.32**		**0.27**		**0.42**		**0.20**		**0.35**		**0.53**

a * Packaging 7		SM										SM +LED									
	Week	P P7	SD	B P7	SD	C P7	SD	Pa P7	SD	G P7	SD	P P7	SD	B 72	SD	C P7	SD	Pa P7	SD	G P7	SD
	0.00	17.92	0.21	1.29	0.02	22.5	1.81	-5.51	0.27	19.5	0.19	17.9	0.21	2.18	0.19	20.4	0.77	-4.83	0.77	22.4	0.42
	1.00	18.32	0.16	1.38	0.09	23.3	0.1	-4.93	0.88	23.3	0.1	19.2	1.41	1.84	0.43	22.4	0.3	-3.85	0.57	19.2	0.34
	2.00	19.38	0.07	1.47	0.13	24.5	0.7	-4.78	0.56	24.5	0.7	17	0.52	1.58	0.1	17.4	1.89	-3.88	0.32	18.5	2.94
	4.00	19.05	0.62	1.79	0.33	21.3	0.46	-3.73	0.30	21.3	0.46	15	0.55	1.52	0.09	16.4	2.4	-3.11	0.12	14.3	0.83
	AV		0.27		0.14		0.77		0.50		0.36		0.67		0.20		1.34		0.45		1.13

b*

b * Packaging 1		SM										SM +LED									
	Week	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD	P P1	SD	B P1	SD	C P1	SD	Pa P1	SD	G P1	SD
	0.00	14.68	0.02	7.63	0.63	26.1	2.6	12.34	0.19	23.6	0.37	14.7	0.02	7.63	0.63	17.4	2.51	12.34	0.19	23.6	0.37
	2.00	11.58	0.94	8.18	0.75	19.5	0.29	7.41	0.21	22.3	0.76	10.9	0.81	7.34	1.7	18.7	0.22	9.11	0.82	21.8	0.59
	4.00	9.98	0.89	8.42	0.52	19.5	0.93	9.50	1.18	20.1	3.92	13.3	13.3	9.46	0.13	18.6	1.39	7.76	2.06	22.8	2.12
	6.00	12.05	1.33	9.24	0.79	19.4	0.54	8.69	1.09	19.2	2.04	12.7	0.94	6.11	1.83	17.6	1.61	9.77	0.23	21.8	1.32
	AV		0.80		0.67		1.09		0.67		1.77		3.78		1.07		1.43		0.83		1.10

b * Packaging 2		SM										SM +LED									
	Week	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD	P P2	SD	B P2	SD	C P2	SD	Pa P2	SD	G P2	SD
	0.00	14.68	0.02	7.63	0.63	26.1	2.6	12.34	0.19	23.6	0.37	14.7	0.02	7.63	0.63	19.1	0.71	9.23	0.45	23.6	0.37
	2.00	14.03	1.06	8.51	1.17	19.6	0.32	7.76	0.92	22.6	0.92	13.3	1.26	8.6	0.39	18	0.52	20.84	0.49	22.3	0.76
	4.00	13.70	2.59	8.16	0.88	19.6	0.29	8.16	0.56	22.3	0.44	14	1.89	7.87	0.35	12.6	2.48	7.98	0.56	20.8	0.87
	6.00	10.94	1.06	7.56	0.15	19.3	0.6	8.37	1.04	21.1	1.61	14.4	0.75	7.31	0.28	15.6	1.24	11.66	5.25	22.3	1.98
	AV		1.18		0.71		0.95		0.68		0.84		0.98		0.41		1.24		1.69		1.00

b * Packaging 3		SM										SM +LED									
	Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
	1.00	NA	NA	14.1	0.04	26.2	2	NA	NA	23.2	1.46	NA	NA	14.1	0.04	26.2	0.99	NA	NA	23.2	1.46
	2.00	NA	NA	13.9	0.58	28.3	2.47	NA	NA	25.9	3.85	NA	NA	16.2	1.3	29.1	1.3	NA	NA	28	5.82
	4.00	NA	NA	13.7	2.11	28.5	2.62	NA	NA	24.7	1.91	NA	NA	12.6	1.66	27.8	0.79	NA	NA	31.6	1.41
	6.00	NA	NA	10.3	1.53	27.3	0.4	NA	NA	25.2	1.41	NA	NA	13.3	0.74	25.9	1.55	NA	NA	20.9	1.04
	AV				1.07		1.87				2.16				0.94		1.16				2.43

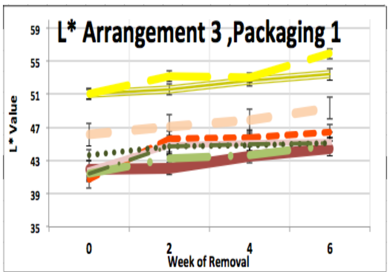
b * Packaging 4		SM										SM +LED									
	Week	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD	P P3	SD	B P3	SD	C P3	SD	Pa P3	SD	G P3	SD
	1.00	14.68	0.02	NA	NA	NA	NA	NA	NA	23.6	0.37	14.7	0.02	NA	NA	NA	NA	NA	NA	23.6	0.37
	2.00	14.03	1.06	NA	NA	NA	NA	NA	NA	26.1	0.52	12.3	1.2	NA	NA	NA	NA	NA	NA	25.1	1.08
	4.00	13.70	2.59	NA	NA	NA	NA	NA	NA	26.2	1.12	14.2	3.02	NA	NA	NA	NA	NA	NA	20.9	0.61
	6.00	10.94	1.06	NA	NA	NA	NA	NA	NA	24	1.85	10.3	1.47	NA	NA	NA	NA	NA	NA	17.2	0.87
	AV		1.18								0.97	12.89									0.73

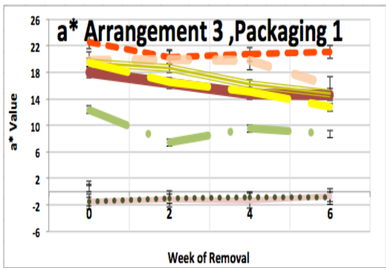
b * Pack 5		SM										SM +LED									
	Week	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD	P P5	SD	B P5	SD	C P5	SD	Pa P5	SD	G P5	SD
	1.00	24.60	0.60	19.8	0.67	29.8	0.48	19.86	0.45	41.1	0.08	24.7	0.27	18.5	0.68	30.3	1.29	20.04	0.40	41.6	0.64
	2.00	25.13	0.30	19.1	0.55	31.4	0.27	19.82	1.05	39.2	0.63	25.4	0.74	19.6	0.89	31.7	0.46	21.07	0.47	40.7	0.46
	6.00	27.11	0.49	17.9	0.57	31	0.84	17.93	0.19	39	0.93	25.9	0.4	16.6	0.36	31.9	1.07	18.20	1.02	39.8	0.58
	AV		0.46		0.60		0.53		0.56		0.55		0.47		0.64		0.94		0.63		0.56

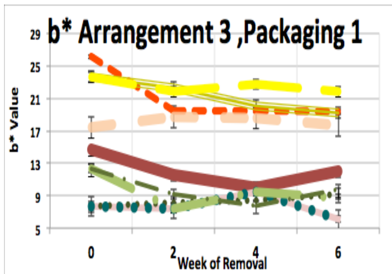
b * Pack 6		SM										SM +LED									
	Week	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD	P P6	SD	B P6	SD	C P6	SD	Pa P6	SD	G P6	SD
	1.00	24.25	0.61	19.5	0.95	31.4	0.27	19.66	1.22	41	0.26	24.3	0.64	19.6	0.66	30.7	0.31	20.56	0.66	41.3	0.9
	2.00	24.64	0.05	19.7	0.57	31	0.03	19.30	0.50	40.7	0.41	24	0.43	19.7	0.48	31.3	0.19	20.34	0.35	40.8	1.44
	6.00	25.90	1.32	17.7	0.7	31.7	1.33	17.80	0.61	39	1.33	25.5	0.77	17	0.15	32.8	1.11	18.69	0.57	39.3	0.4
	AV		0.66		0.74		0.54		0.78		0.67		0.61		0.43		0.54		0.53		0.91

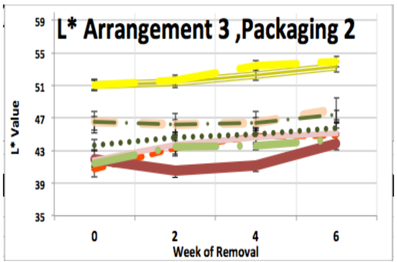
b * Packaging 7		SM										SM +LED									
	Week	P P7	SD	B P7	SD	C P7	SD	Pa P7	SD	G P7	SD	P P7	SD	B 72	SD	C P7	SD	Pa P7	SD	G P7	SD
	2.00	14.68	0.02	7.63	0.63	26.1	2.6	12.80	0.61	23.6	0.37	14.7	0.02	7.63	0.63	19.1	0.71	9.23	0.45	30.5	0.43
	4.00	15.46	0.29	10.2	0.86	25.8	0.25	12.59	0.73	25.8	0.25	17.8	2.05	9.58	0.9	24	0.8	8.98	1.64	24.9	0.31
	6.00	18.19	0.33	9.47	0.7	29.2	2.17	11.62	1.77	29.2	2.17	15.3	1.08	9.57	1.16	21.2	2.34	8.89	1.40	27	1.8
	8.00	16.67	1.42	8.54	0.64	22.4	0.86	9.42	0.32	22.4	0.86	13.3	1.7	8.3	0.2	17.8	2.75	11.10	0.85	23.5	1.18
	AV		0.52		0.71		1.47		0.86		0.91		1.21		0.72		1.65		1.09		0.93

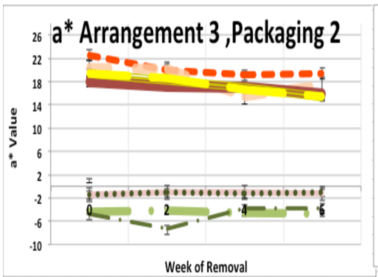
GRAPHICS

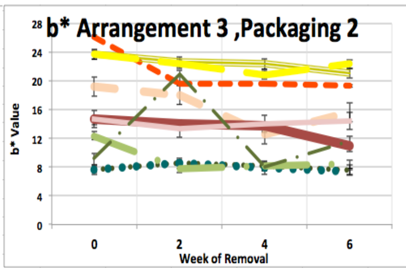


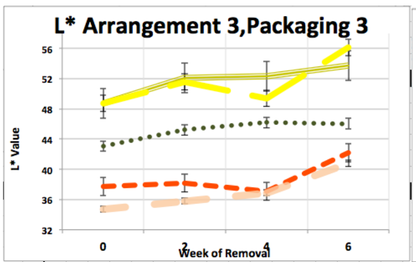


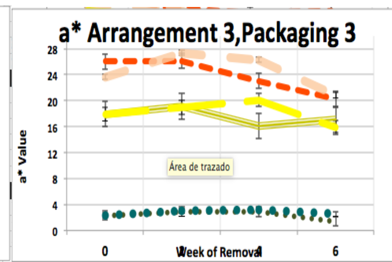


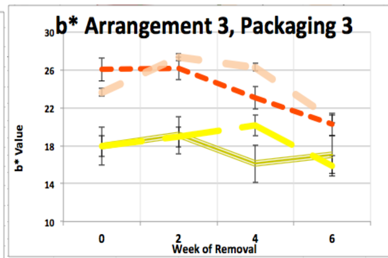


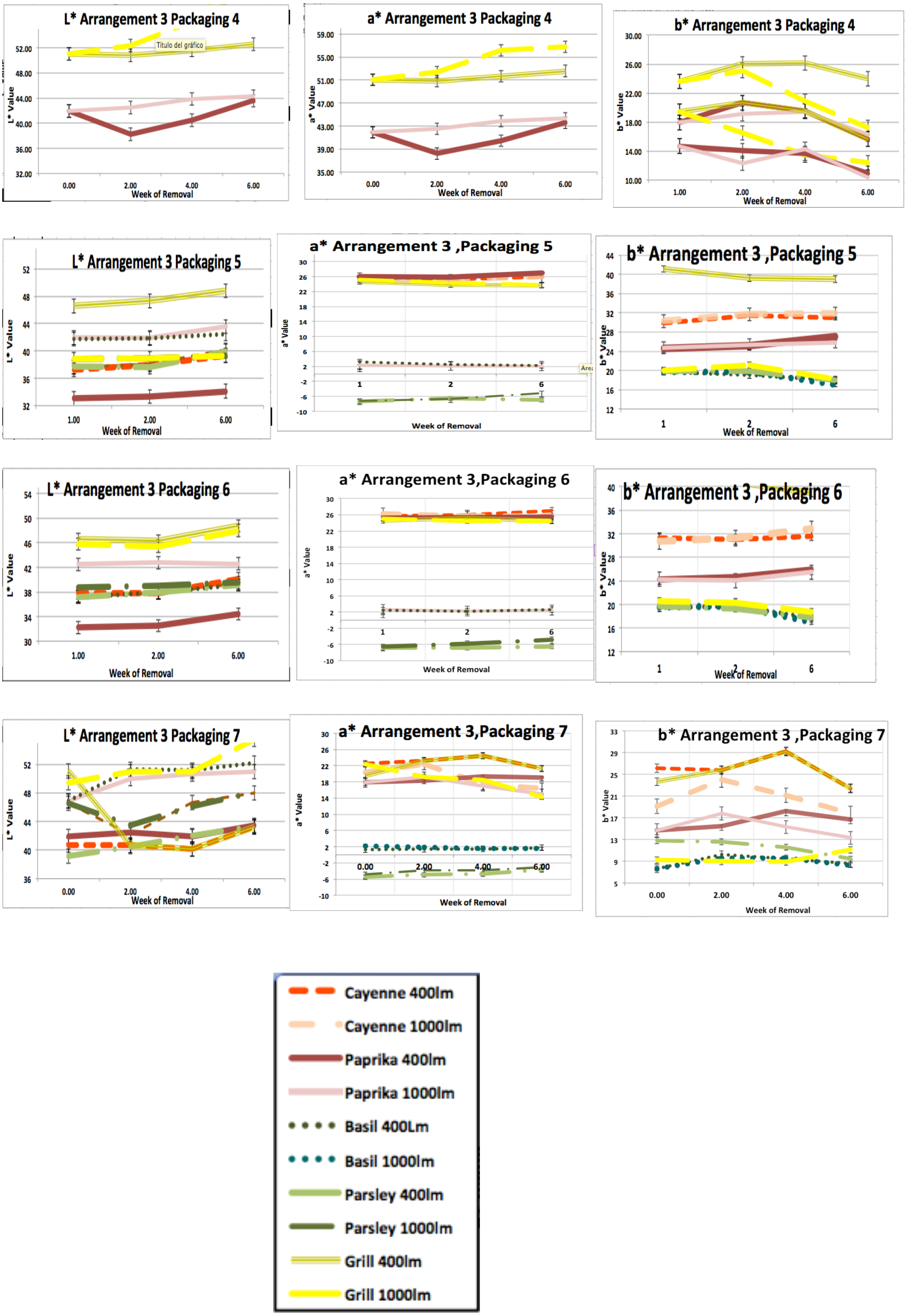











L* Arrangement 3 Packaging 4
L* Value
Week of Removal
Título del gráfico
a* Arrangement 3 Packaging 4
a* Value
Week of Removal
b* Arrangement 3 Packaging 4
b* Value
Week of Removal
L* Arrangement 3 Packaging 5
L* Value
Week of Removal
a* Arrangement 3 ,Packaging 5
a* Value
Week of Removal
b* Arrangement 3 ,Packaging 5
b* Value
Week of Removal
L* Arrangement 3 Packaging 6
L* Value
Week of Removal
a* Arrangement 3,Packaging 6
a* Value
Week of Removal
b* Arrangement 3 ,Packaging 6
b* Value
Week of Removal
L* Arrangement 3 Packaging 7
L* Value
Week of Removal
a* Arrangement 3,Packaging 7
a* Value
Week of Removal
b* Arrangement 3 ,Packaging 7
b* Value
Week of Removal
Cayenne 400lm
Cayenne 1000lm
Paprika 400lm
Paprika 1000lm
Basil 400Lm
Basil 1000lm
Parsley 400lm
Parsley 1000lm
Grill 400lm
Grill 1000lm

9.10. Appendix 9: Color changes in spices from Arrangement 1.

Week 0

This image represents the original colors of all the spices, from the moment they were poured from closed containers stored in closed boxes with no contact to light. The order from left to right is P, B, C,Pa,G.	

Week 1 /Removal 1

After the first week of exposure the Grillkryddor started to present evident changes, more specifically the samples under the exposure of the luminary Cool White HE 24 W/ 940 and in the LED, which were the higher in emitting energy	

Week 3/ Removal 2

Changes in red spices were more evident that such of the green spices, the most notorious changes were in the boxes 1,4 &5, with the lamps Cool White HE 24 W/ 94, LED and OSRAM Lumilux Interna HE 14 W/827, lamps which possessed the highest Illuminance values.

Week 5/Removal 3

In general the samples that maintained more the initial colors were the ones stored in Box 2: OSRAM Lumilux Cool White HE 14 W/ 840. Also this light was not turned on completely and the light modulator was in use.

Week 7/ Removal 4

This final week the samples were organized in the order, P,B,C,Pa & G. All the G samples were totally clear no visual difference was appreciated against the different lamps. In the case of the P and C the samples that retained more the color were in Box 2.	

9.11. Appendix 10: Two-way ANOVA Analysis

9.11.1. Two way ANOVA Arrangement 2:

400 Lm

ANOVA							
Source of Variation	*SS*	*d.f.*	*MS*	*F*	*p-level*	*F crit*	*Omega Sqr.*
Factor #1 (PACKAGING)	56.06661	5	11.21332	1.93499	0.10820	2.43224	0.06037
Factor #2 (SPICE)	65.80437	4	16.45109	2.83883	0.03561	2.58884	0.09499
Factor #1 + #2 (PACKAGING x SPICE)	71.88548	20	3.59427	0.62023	0.87519	1.81969	0
Within Groups	249.18600	43	5.79502				
Total	442.94247	72	6.15198				
Omega squared for combined effect	0.05727						

1000 Lm

ANOVA							
Source of Variation	*SS*	*d.f.*	*MS*	*F*	*p-level*	*F crit*	*Omega Sqr.*
Factor #1 (PACKAGING)	87.83665	5	17.56733	3.00402	0.01755	2.37098	0.08907
Factor #2 (SPICE)	147.53576	4	36.88394	6.30718	0.00027	2.52791	0.18870
Factor #1 + #2 (PACKAGING x SPICE)	71.64076	20	3.58204	0.61253	0.88758	1.75104	0
Within Groups	345.02800	59	5.84793				
Total	652.04118	88	7.40956				
Omega squared for combined effect	0.20888						

9.11.2. Two way ANOVA Arrangement 3:

SM

ANOVA							
Source of Variation	*SS*	*d.f.*	*MS*	*F*	*p-level*	*F crit*	*Omega Sqr.*
Factor #1 (PACKAGING)	41.31417	6	6.88569	2.32221	0.04838	2.30351	0.10753
Factor #2 (SPICE)	13.79036	4	3.44759	1.16271	0.33960	2.57404	0.00882
Factor #1 + #2 (PACKAGING x SPICE)	24.28868	24	1.01203	0.34131	0.99702	1.75645	0
Within Groups	136.39667	46	2.96514				
Total	215.78988	80	2.69737				
Omega squared for combined effect	0						

SM+LED

ANOVA							
Source of Variation	*SS*	*d.f.*	*MS*	*F*	*p-level*	*F crit*	*Omega Sqr.*
Factor #1 (PACKAGING)	145.01949	6	24.16991	4.00996	0.00260	2.30351	0.17660
Factor #2 (SPICE)	25.51371	4	6.37843	1.05823	0.38794	2.57404	0.00228
Factor #1 + #2 (PACKAGING x SPICE)	162.56668	24	6.77361	1.12379	0.35768	1.75645	0.02905
Within Groups	277.26333	46	6.02746				
Total	610.36321	80	7.62954				
Omega squared for combined effect	0.20793						

9.12. Appendix 11: Images of changes in color in Arrangement 3

9.13. Appendix 12: Packaging evaluation results and evaluation criteria.

9.13.1. Results for Packages evaluation applying 9.12.2

	P1	P2	P3	P4	P5	P6	P7
Cost	5	4	5	5	2	2	2
1st moment of truth	5	4	5	5	3	3	4
2nd moment of truth	2	4	2	2	5	5	2
Light Protection	1	3	1	1	5	5	1
Premium finishing	5	5	5	5	4	4	5
Supply chain fit	5	4	5	5	3	3	3
Sustainability	4	4	4	4	3	3	4
Transparency	5	4.5	5	5	1	1	5
TOTAL	**32**	**33**	**32**	**32**	**26**	**26**	**26**

9.13.2. Evaluation criteria

Cost	Premium finishing
5: No investment required	5: The information contained in the package is easily readable and the printing quality is excellent, every user can intuitively open the container.
4: Change of image costs, Performance tests, minor machine costs investments	4:The printing quality excellent and instructions are present in the package, because opening is not intuitive. Even surface.
3: Change of image costs, Performance tests, medium machine investments, moulds costs,training costs.	3: Material quality could be better, good printing quality, not an even surface, ergonomic features are included.
2: Change of image costs, Performance tests, mayor machine investmenst, moulds costs, training costs.	2: Material quality is average, average printing quality, not an even surface, ergonomic features are not included.
1: Change of image costs, Performance tests, mayor machine investment,moulds costs, training costs, manufacturing line modification	1: Materials are not premium enogh, the quality of the printing is bad, text are not easy to understand, images deformated.
First moment of truth	**Supply chain fit**
5: Easily recognized package on the shelf, maintaining weight perception and brand image	5: No modifications are requested on the production line.
4: Slighty change in brand image, package still recognizable, consumer can see the product.	4: Very little modifications are requested to adapt new equipment to the production line, actual suppliers can cover demand.
3: Slighty change in brand image, package still recognizable, consumer cannot see the product.	3: Minor modifications are requested to adapt new equipment to the production line, new suppliers are reauested.
2: Moderate change in brand image, package recognizable at short distances, consumer cannot see the product.	2: Larger modifications are requested to adapt new equipment to the production line, as line distribution arrangement and new suppliers are needed.
1: Mayor change in brand image, package not recognizable even in short distances, consumer cannot see the product.	1: Mayor modifications are requested to apply the packaging solution, line distribution changed, new suppliers add complexity to supply chain.
Second moment of truth	**Sustainability**
5: Package can be stored everywhere without any deterioration, shelf-life maintained.	5: Packaging is totally recyclable, no efforts requested.
4:Package portrays the suggested storage conditions, shelf-life maintained because suggestions are followed.	4:Very little effort is requested to separate and recycle the materials.
3: Package is stored in optimal storage conditions ocassionaly , shelf-life is sometimes maintained.	3: Moderate effort is requested to separate the materials and recycle them+ cleaning.
2: Package commonly does not present a sufficient barrier againsts environmental factors.	2: Big effort is requested to separate the materials and recycle them + cleaning.
1: The consumer is dissapointed because product does not last the suggested shelf life.	1: Not recyclable
Light Protection	**Transparency**
5: The barrier against light of the packaging material is robust enough.	5: Package allows to see its content easily.
4: The barrier against light of the packaging material is good.	4:Package allows to see part of its content easily.
3: The barrier against light of the packaging material is moderate	3: Package allows to see part of its content requesting a minor effort.
2: The barrier against light of the packaging material is little	2: Package allows to see part of its content when grabbed or requesting a considerable effort.
1: The barrier against light is negligible	1: Package does not allow to see its content easily.

9.14. Appendix 13: Benchmarking on existing products

The products considered were only those in which the shape of the container was not based on straight shape and if they used a shrinked plastic sleeve. This comparison was conducted in order to evaluate the quality of the shrinking, how the textures shrink in curved sections and the sharpness of graphics and arts after the shrinking, how easy is to read the information contained in the pack.

Tear- to-open plastic sleeves (They maintain the image on the bottom of the container)

Or the lid covers the edges of the plastic sleeve, and it remains in its position.

9.15. Appendix 16: Equipment used

Image	Quantity	Description
	1	AEG Heat Gun 1500W, 300°/560°C Power input 1500 WattAir flow 400/450 l/min Temperature control 300/560 °C Weight 0.6 kg
	2	Aluminium lamp with Large clip clamp Maximum 60 W.
	1	Flexible lamp Maximum 60 W.
	1	Golvlampa upp IKEA (unarmed to simulate position of prior lamp)
	2	LED BULBS IKEA E27LED1332G7 1000 Lm□100Wats 13 Watts 2700 Kelvin 25 000 hours
	2	LED BULBS IKEA E27LED1332G7 400 Lm□40Wats 6.3 Watts 2700 Kelvin 25 000 hours

	AquaLab Series3 Accuracy:± 0.003 aw Range:0.030 to 1.000 aw Operating Enviroment: 5 to 43°C (41 to 110° F) 20 to 85% humidity Calibration: 10/03/2015
	Chroma meter CR-400/410 Calibration: 10/03/2015
	Color Detector X-Rite CAPSURE Measuring geometry:45°/0° coverage Light source:Irrespective of tri-directional LED-lights, 25 LEDs (8 x visible wave lengths, 1 x UV) Receptor:Image recognition Measurement time: 1.8 seconds Measurement range:2.4 and 8 mm with automatic recognition of four different colors Operator interface:5 -point navigation key, 2 - ary measurement / preview key, integrated microphone with speekers > 45,000 reference colors
	Hagner Universal photometer Model S2 Silicone diodes as detectors. The instrument measures the luminance of a circular surface with a diameter of 1□ (i.e. within a solid angle of 2.4 steradians). The scales of the different sensitivity ranges give the luminance directly in candela per square metre (cd m^{-2}). Calibration: 10/03/2015
	AvaSpec-2048-USB2 Grating UA (200-1100nm), 50µm slit, DCL-UV Fiber Optics 2 x FCB-UV/IR600-2, 1 UV/VIS, 1 VIS/NIR, 2m, SMA
	EL-USB-2-LCD Temperature and humidity USB data logger with LCD display
	NIKON PS500 36x f3.4-5.7 21.5-800mm lens (35mm equivalent)

9.16. Appendix 16: Batches and products considered for the study

9.16.1. Batches

This section was removed due to confidential issues and as requested by Santa Maria