Zuzana Sedlacekova

Food Packaging Materials

Comparison of Materials Used for Packaging Purposes

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Packaging industry was transformed significantly over couple of decades and the world's dependency on plastic materials takes its toll. Packaging industry has direct effect on waste created by households since manufacturers choose packaging processes and materials. Littering and unsustainable waste management options are concerning society and create pressure on companies that operate globally. New materials are being developed and tested for regular packaging of commonly used goods.

Three common products packages are studied: chocolate, tea and milk packaging. Each of these products has various forms of package design with use of different materials, essentially based on product's requirements and characteristics. This thesis's objective is to analyse how certain packaging materials fulfil chosen functions. It was discovered that currently the packaging materials are fundamentally different than 50 years ago. Plastics continue to dominate the market while other materials for packaging such as paper and metals remain being commonly used, however, glass is becoming rare as type of package material. In addition, packaging industry introduces new innovations in identification, recycling and monitoring of environment, in forms of intelligent and active packaging combined with technology.

Keywords	Packaging, package, milk, chocolate, food, packaging functions, manufacturing, production, logistics, package, sustainability, plastics, packaging materials

Contents

Table of Figures

1 Introduction

Keywords such as "food" and "packaging" relate to variety of new articles, publications and materials when typed into search bar. Nowadays, the topic of packaging arises interest seeking more detailed information about different aspects and influence it has over supply chain and consumer's attitude. The potential of package itself is still one of concepts in companies that are not developed to its true extent. The awareness about the issue is presently rising, and there is growing number of materials to learn from, as this issue taps into every individual's life. In addition, it affects companies in multiple various ways starting from presentation of products to customer, resources apportionment, protecting products, however the materials can also influence logistics, waste, cost structure and environment as explained further in other chapters. The packaging industry totally covers 2% of the gross national product (GNP) in developed countries (Robertson, 2013: 1), having potential to rise in the future because new products enter market every day. As Coles and Kirwan mentioned in the beginning of the book Food and Beverage Packaging Technology, there are rising pressures from the public and organisations that attempt to convince large brands producing physical goods to be conscious about environment and consider their impact on it by choosing sustainable packaging (Coles and Kirwan, 2011: 2).

The issue does not only cover the material used on the package itself, but also the waste regulations, energy allocation while considering the purpose of the package itself. As J.P. Jacob (2010) mentioned in his book about food packaging: there are three functions of a package: preservation, presentation and protection. Determining his three attributes is rather simple, logical but it leaves aside other necessary functions to consider. He was followed by Gordon L. Robertson (2013), who describes four package functions: Containment, Protection, Convenience and Communication, also taking into account consumer's usability factor so the package is easy to open, and possibly close, carry, handle, dispose of. The opinion about package functions is argued by many other authors based on their expertise. For example, Will Burke who is a branding and packaging expert, identifies three main categories when choosing a successful package design: authenticity, meaning and whether it is compelling with the brand image (Burke, 2011).

This thesis analyses package materials used for three products: tea, chocolate and milk, which are familiar to audience and they represent typical household products purchased rather often. Modern companies do not use package only as a means of cover for the product, they developed it as a tool which enables brands to communicate with customers, it contains information not only about the content of the package itself, but about the brand. there is a whole science behind choosing colours, fonts, images and other means of presentation which are the main focal point of design team, later followed by the engineering side of the manufacturing which has to bring the concept to life. It would be ideal if sustainability, energy and waste management would be on top of designer's mind when creating new product, however as evidence from grocery stores, supermarkets and department stores across the world shows, in most large brands, there are usually different priorities.

1.1 Research Question and Aim of This Thesis

The aim of this paper is to analyse packaging industry with focus on frequently used materials and the role of synthetized polymers with emphasis on sustainability. To provide all readers with sufficient information, this paper includes history of packaging, regulations regarding materials that come to contact with food, product marking and symbols used, plus a short introduction to sustainability and logistics aspects that influence packaging market today. Technology and new materials allow companies to substitute elements which cause emissions together with post-consuming issues (such as littering and increased waste) for renewable, recyclable and re-usable resources.

Which compounds are performing on highest level for chosen products, considering the packaging functions?

The research question is derived from the fact that majority of packages are not universal or suitable for all the products they are used to cover. Every product has specific requirements for packaging, therefore certain package materials are performing on higher level to sustain its desired condition. The reasons why certain package types provide enhanced fortification is explained further in this thesis when considering packages of

three specific products. Example of advanced level of performance could be demonstrated with milk. Using a package that provides light barrier extends the shelf life and protects milk substance when exposed to daylight. Moreover, even packages that maintain thermoregulation are available, even if not companies are using those as their packaging material. Finally, it is obvious that laminated carton box represents advanced form of milk packaging than transparent glass bottle.

1.2 Methodology and Research

The study is based on secondary qualitative research of literature about packaging technology with regard on three products: milk, tea and chocolate. These three products were chosen based on familiarity and popularity among consumers. Tea, chocolate and milk are products purchased globally and they are simply recognized.

Tea represents dry product category and therefore it connects to those types of packaging suitable for majority of dry food products such as: candy, flour or peanuts. Milk represents still drink category, even though, milk is bio-based and more difficult to maintain fresh. Therefore, it represents common drink category such as water, soda, other drinks packaged in bottles, plus the conservation requirements of milk could be applied to other products that have to be sterilised such as pickled products which are packaged in similar fashion. Chocolate embodies food category that is thermos-sensitive in order to remain is specific shape, similar to other products as butter or cheese.

Information provided in this paper is founded on multiple recent publications, online research and knowledge gained throughout studies without affiliation to any companies or organisations. Majority of information is based on factual data; however also fundamental packaging theory is mentioned as well. The thesis includes introduction into fundamentals of packaging, history and development of packaging materials, government regulations, sustainability and logistics followed by direct description of packaging types, their benefits and disadvantages throughout company's supply chain.

2 Terms and Abbreviations

Package- enclosure of products, items or packages
Packaging- noun, general term for materials and technology of packing process
Packing- activity of filling something
Primary package- first layer of packing material
Secondary package- second layer of packing material
Polymer- chemical compound containing of repeating smaller compounds, synthetic polymers are plastics while natural polymers consist of amino acids.
PVC- polyvinyl chloride, strong plastic that is suitable for extreme temperatures
PET- polyethylene terephthalate, lightweight plastic
OM- overall migration
FCM- food contact material
FMCG- fast moving consumer goods
PLC- Product life cycle
Intelligent packaging- monitors and communicates conditions of product's environment through sensors
Active packaging- packaging enhancing quality, shelf life or safety
Aseptic- sterile
RFID- radio frequency identification technology
HDPE- high-density polyethylene, stronger plastic than polyethylene,

3 History of Packaging

As opposed to packaging trends of today, the main focus in packaging used to be on the covering and protection aspects of the product. The goods were placed in reliable, common materials usually from natural resources such as wood pulp (paper, cardboard) or textiles (flour sacks) that enabled consumers to enjoy the contents of package at home. For millenniums, the most common material used to protect goods were paper and glass. People understood the role of package as meant to protect their product on the way home from market. The manufacturing technology changed the whole concept of packaging after the Industrial Revolution in eighteenth century when manufacturers were forced to develop more resilient types of protection so the products could be transported

from factory to shop and later to customer's home. Unfortunately, even 200 year ago, companies did not have enough information and research to discover techniques that would expand the shelf life of products. Plastic and other compounds were not used then, so manufacturers had rather low variety of materials to choose from. It is commonly acknowledged that the development of the plastic materials for manufacturing began in the 1860s (Robertson, 2013: 11) by altering hard rubber. Later, synthetic plastics were gradually invented, starting with Celluloid. Nobel prize winner Hermann Staudinger dedicated his career to study polymer science. He invented multiple compounds amongst which was polyvinyl chloride (PVC) used in vast quantities in modern packaging. In the middle of 1940s, further study of synthetic polymers by DuPont chemists synthesized polyethylene terephthalate (known as PET) used for manufacturing of plastic bottles until this day (Petra, 2015). In twentieth century, American brewers grew fond of tins manufactured from tinplate and steel coated with chromium which were previously used in Europe during war, to sell their beverages inside protected atmosphere (Coles and Kirwan, 2011: 3) but this invention was also attractive for companies producing soup or preserved fruits (Robertson, 2013: 190). As mentioned in book written by Anne and Henry Emblem, describing fundamentals of packaging, the first easy-open beverage can was invented in 1962 by American Ermal Fraze.

4 Package Functions

Every package has several basic functions that are described by authors and textbooks in various forms, although they contain similar structure. Fundamentally these functions are containment, protection, preservation, convenience and information. The list of additional functions mentioned by publications and organisations include: communication, selling, presentation, promotion, environmental responsibility and other. Gordon L. Robertson mentions in his book (2013: 4) also the environment function, previously suggested by Lockhart in 1997. This theory implies that if a package is designed to fulfil its function, it must endure all basic functions in three environments: ambient, human and physical. When designing and manufacturing, these functions are taken into consideration by companies and the output is the specific package found on shelves of retailers. Packaging functions are all considered necessary for each product even though some

are being more endorsed by certain manufacturers. It often occurs that a package lacks in one or more of the functions categories.

When producing goods, the main focus often shifts from the end consumer. The fact that package is supposed to fulfil the requirements of customers may conflict with business objectives set by producers as for example costs, availability, brand image, marketing and therefore the objectives of society are considered secondary. One of the functions that is rarely mentioned in books when reading sections about package functions is sustainability. Especially in current state of the environment, this function should be on the top of manufacturer's priorities in order to create less waste and enable consumers to recycle or reuse the package after they consume or unbox their product.

4.1 Containment

The role of containment is to conceal the product and its parts and prevent them from spillage and loss, starting from the packing line through transportation phases until it arrives to customer's home. Some goods can have dangerous consequences when not contained properly inside a package- especially liquids and chemicals. Also, if a product which consists of multiple parts does not contain all of them or the instruction for use when customer opens it, it degrades the product proving it unusable. Every type of package has its sensitive areas which may get damaged and cause loss of containment and therefore producers enforce protocols and testing of package to ensure that the contents are properly contained.

4.2 Protection

Since ancient times, the products that people used, such as tools, clothes or food, had to be transported to their homes without the goods being altered by the environment, air, dust, vibration, weather conditions or animals. The protection function of package represents preventing all outside forces to intervene with the product inside. Certain products also require special temperature or humidity levels to preserve their shape or purpose, therefore package should protect the contents from changing their nature. In

order to provide sufficient package that will protect the products, it is necessary to understand the product's characteristics and address potential hazards that would tamper those. It often proves efficient to use a secondary package when protecting larger quantities of products together and transporting them.

4.3 Preservation

This function is not universal for all the goods, it should be considered especially when dealing with food products, pharmaceutics and other perishable products. The importance of preservation is to keep products in controlled environment so it remains safe to use for longer time period. The key to correct preservation is to package the product while it is in safe condition and it is imperial to understand how can this state be sustained inside the package by defining the product-spoilage mechanisms (Emblem and Emblem, 2012: 41). The package attributes therefore have to address potential causes of spoilage in order for the product to maintain in desired state. Preservation is necessary for products that need to maintain certain levels of oxygen, moisture, volatiles or they are light sensitive (Emblem and Emblem, 2012: 42).

4.4 Convenience

Based on a fact that package is a tool which helps goods remain in desired condition when reaching consumers, it also should be convenient for them to carry, transport and open the package while maintain safe. As known from retail assortment theory, customers make decisions while shopping and the fundamental choice is which size of product they will buy according to their needs and convenience. Global performance management company Nielsen Holdings PLC based in United Kingdom provided retailing solution based on sophisticated data from local customer researches. They also offer consultancy services for large retailers or supermarkets where they assort the goods based on psychology theory of customer behaviour. One of decisions customers tend to make while shopping is choosing the amount and also size of package either by price or their preference. To portray an example, when a person needs to buy eggs for a 6-member family that appreciates omelette, it is unlikely that they would pick the package of 6 eggs.

Another available option, package of 12 or more eggs is much more relevant and convenient. Another example of convenient package is when customer purchases drink inside tin can for immediate consumption, however he would rather choose a bottled drink which can be re-opened when planning to continue drinking in a period of several hours. Different packages offer variety of uses. These examples represent common situations when convenience is truly important and therefore majority of manufacturers offer their products in various sizes and shapes to satisfy needs of their customers. The convenience function extends also to secondary package, the pallets or boxes used when transporting goods are often determined by equipment and the ability to fit primary packages into secondary one without wasting space based on resource utilization and easy handling. To improve food quality, intelligent packaging provides optimization and enhancement of certain foods. As mentioned by Yam, Takhistov and Miltz, the intelligent packaging can include gas absorption technology or gas emitting to extend shelf life or improve food quality. Another example of intelligent packaging is including metal structures in package which interact with microwave activity to ensure the food would become crispy (Yam, Takhistov and Miltz, 2005).

4.5 Information

There are several categories of information included in every package:

- Tracking information
- Product information
- Marketing and brand information

Tracking information is usually in form of bar or matrix code; however, they might be also triple dimensional or chips with radio frequencies. It includes the metadata of product. This information is not available for end-users of product, on the contrary it is essential in order for a product to reach customer. Special equipment such as scanners or detectors are needed to access the information which consists of manufacturer, basic description, package dimensions and other data regarding product that are not likely to change over longer period of time. Codes tend to vary across the world, for example UPC code is usually used in USA while EAN code is used primarily in European retail (Scandit, 2015). Considering that radio frequency technology is known for more than hundred years, the use in identifying dates to Mr Charles A. Walton who patented a radio

frequency identifier in 1980 (Walton, 1983). It still remains quite pricy, even though the price of tag decreased from $1 (in 2003) to around 10 cents (Forbes, 2017). the RFID tags are mostly used for high value items while the warehouses and transportation companies are required to possess complex technology to access the information coded into chip which contains extensive amount of data compared to bar codes. The universal tags also diminish language barriers across supply chain and they revolutionize it (Robertson, 2013: 4).

Product information consists of data describing ingredients and nutrition volumes of food products or information with technical details for electronic goods. There are several regulations on product information by government in majority of countries. One of essential information on each product is the country of origin, manufacturer and distributor. Each product requires different information based on its nature and purpose. For example, in textile industry the labels that indicate how to handle clothes when washing and drying are strictly regulated and universal for global distribution. During recent years, society became intensively interested about products, the content of each products and materials, moreover, people became more dependent on other person's opinions about products called reviews which are shared online on websites and forums. Therefore, manufacturers chose to meet the new demand for information by attaching and printing smart codes (QR codes) which can be scanned by smart phones and then detailed product's description would appear on screen. This technology enables consumers to access more data about goods they seek without assistance of store workers.

Obviously, every manufacturer wants consumers to continue shopping products from their assortment and that is the reason why every package in retail store has a distinctive brand logo. Logos, product names, brand slogans, these are all tools used by companies to signal to customers which product they buy. In every retail store, people can choose from tens of different brands in every product category, which makes the competition among brands to impress customer even tougher. Sometimes, even the package itself can be brand-specific so customers can recognize it quicker. A good example provides a company manufacturing potato crisps Pringles. Pringles, unlike their competitors, chose to package crisps neatly into carton tubes instead of traditional plastic or foil bags. Another important communication distinction on the package is colour. Brands tend to follow strict colour code for their product lines for easier recognition. In addition, colour is

one of tools to describe a sub category of products as is common in milk section: blue package means low fat milk, while red package suggests the full fat (cca. 3,5%).

5 Sustainability

The increase in production and retail sector after adaptation of mechanics and automatic production lines in factories offered consumers more products with large variety. Rising demand had effect on environment in form of packaging litter, which triggered creation of citizen's initiatives to decrease the waste during second half of twentieth century (Farmer, 2013: 222). Packaging literature includes sections dedicated to sustainability with emphasis on status of industry not meeting future requirements due to scarcity which increases cost for non-renewable resources, waste produced, climate change, government regulations and involvement in voluntary agreements (Emblem and Emblem, 2012: 65). Nowadays, the problem shifts rather to overproduction and wasting non-used food products after expiry date which also increases package waste. Companies invest their resources in food sector for production to satisfy customers, seeking profits and aiming to avoid empty shelves. The fact that there is surplus of food products consequently increases food waste because people do not consume all products they purchase. People in USA are using over 50% more resources than in 1975 (Robertson, 2013: 646). Unsolicited product circulation also causes waste in transportation, inventory and human resources that are involved in maintaining product movement across the supply chain even though in the end, certain portion of products is wasted.

The influence of waste was a key reason why so called product lifecycle thinking and Life Cycle Analysis (LCA) started to be discussed as a tool for assessing and comparing environmental impacts of products already in early 70s (Farmer, 2013: 222). LCA calculations are intended to examine factors during product's creation including air emissions together with water and energy consumption. Even packing materials that are produced from renewable resource, such as paper have impact on environment in form of deforestation and destruction of natural forests. Using non-renewable resources has also strong influence on habitats starting from mining activities (steel products, petroleum) through processing (emissions), even though for example steel can be 100% recycled. Assessing the product's life cycle takes into account all influences that

are triggered by production. In ideal scenario, each material would be recycled in the end of the cycle, but the reality shows that waste is not reused to its potential even when being separated.

During recent years, a new innovative business approach emerged called circular economy. After media and society started to put pressure on companies about their business practises and ruthless profit seeking, the focus was shifted to formulating new innovations that are based on preserving nature and decrease waste in general. The idea is to profit from recycling or re-using waste from other companies or households and create new products from those. Sustainability becomes an attractive business opportunity and there are continuously new companies proving the fact that one company's waste can be input material for the other. When analysing the sustainability of use of different materials, there are disagreements in recycling policies, efficiency, re-usability and extent of lobbing by organisations that are against certain substances.

Sustainability together with ecology become a priority for consumers when deciding which product to purchase. Also, organic merchandise range is increasing since the demand by consumers who prefer natural produce is growing. Due to growth of environmental consciousness among customers, companies implement sustainability goals concerning packaging and recycling into their corporate social responsibility programs. For example, Procter and Gamble also formed Sustainability Vision, in which they promised to reduce packaging materials used by 20% by 2020 and reduction of use for petroleum-derived materials, confidently aiming to produce all packages from renewable or recycled materials (Farmer, 2013: 2).

To encourage people in environment protection activities, in some states, such as California, Colorado and Texas, individual townships have indorsed plastic bag bans in their regulations. Since 2014, California even passed a state law prohibiting the single use plastic bags in supermarkets (Mendelson, 2014). Much harsher approach was taken this year in Kenya, where the selling, producing and use of plastic bags is considered criminal act and the punishment is large fine or jail time (Houreld and Ndiso, 2017). European Commission also took action by setting goals for plastic bag consumption to average of 40 bags per person annually by 2025 based on study conducted in 2011 about the use of carrier bags in individual EU countries (EU Parliament and The Council, 2015). The

average annual consumption of single-use bags ranges from 4 bags in Finland and Denmark to 297 bags in Czech Republic (EU Commission, 2011). The report assessing impacts and options to reduce of plastic bags consumption consists of over 100 pages of interesting information about problems caused by plastic bags across Europe.

6 Logistics

Globalisation extended range of business activities of firms in a way, that they are able to move production to adequate countries with suitable economic conditions, however this relocation often represents larger distances between suppliers and consumers. The main objective of manufacturers when choosing package remain low expenses or ratio between costs and benefits (Emblem and Emblem, 2012). The transportation links differ based on countries and distances. Sea freight is considered the cheapest mode of transportation when moving goods long distance. Sea vessels use containers as transportation units that protect goods from environment. One of disadvantages of sea transportation is the time factor, based on slow speed of vessels. The utmost used mode of transportation globally is road transport. Using trucks is convenient for medium distances without close vicinity to water. Road transport is also the largest source of Co2 emissions because trucks run on fossil fuels. Transportation of full truck loads is more efficient than moving less than truck loads which have to be specially secured or require additional packaging (Coles and Kirwan, 2011: 91). The most expensive mode of transport with limited capacity is air transport. Also running on fossil fuels, airplanes cause less emissions than trucks as they are not as used for transportation of large quantities of products.

The movement of food products across supply chain is secured with so-called package system which consists of layer of package materials, which role is to prevent damage of goods. Package design influences the supply chain of a company from filling part until picking inside retail store. Package systems must be easy to manipulate, to put them into shelves, load or unload after transportation. Using secondary packaging and package systems such as palletisation enables transportation of more units at the same time (Coles and Kirwan, 2011: 127). Identification of stock-keeping units inside pallets is time consuming, however new innovations (e.g. RFID) simplify the identification of products throughout supply chain. While being stored, packages of products sensitive to moisture

of temperature changes are being improved by intelligent packaging technology which monitors the conditions of product and communicates through sensors or RFID technology if something interferes with the contents of package. The storage and distribution section of supply chains is the most common part of PLC where goods come to be damaged (Emblem and Emblem, 2012: 20). Corporations and logistics providers recognize the risks and consequently, products are often packages in extra unnecessary layers of packaging material (up to 100% upsurge) to provide sufficient protection, nevertheless this approach increases waste (Emblem and Emblem, 2012: 15). Appropriate packaging provides several benefits across the supply chain, especially when using packaging innovations as intelligent packaging and radio frequency identification: monitoring expiry dates, low waste levels, preventing theft and reducing costs in transportation (Farmer, 2013: 36).

When transporting a load of goods, the dimensions and weigh play an important role in optimal fulfilment of vehicle without wasting space and saving fuel, while still protecting the product's features. Producing an effective package with low manufacturing costs and weight is the aim of many food manufacturing organisations. According to Flexible Packaging Europe, a metalized flexible stand-up pouch requires half the number of ordinary truck loads than packaging in glass bottles of the same volume, due to the decreased weight and a reduced amount of space between packages (Farmer, 2013: 91). To ensure safety while transportation, vibration and compression tests are performed on packages (Coles and Kirwan, 2011: 85). There is higher efficiency of transporting flexible packaging rather than rigid (Coles and Kirwan, 2011: 206.). Flexible packaging reffers to package consisting of material with shape that can be changed, usually based on plastic compounds.

One of main areas of focus of management teams in food corporation are the profit margins of various products. Therefore, the packaging costs and distribution costs are deliberately kept on lower levels based on price elasticity of different products. Coles and Kirwan mentioned that the logistics related costs of FMCG such as pasteurised milk may be larger than 50% of product's retail price (Coles and Kirwan, 2011: 23). Consequently it is understandable that design and engineering departments of companies have to take into account financial goals together with features of package.

7 Regulations in Packaging

7.1 Migration

The process of packaging matter dispersing to some extent into contained material is referred to as migration. When any materials are in contact with food, it is unavoidable that particles of the material will migrate into the product (Farmer, 2013: 168). Various materials have different migration specification based on their chemical structure. Migration is considered as not desired, although expected occurrence when packaging a product. Consequently, a loss of food quality (flavour or colour changes) may occur or it could cause the food to adapt toxicity without distinctively changing the organoleptic properties of products (Robertson, 2013: 122). There are regulations containing specifications for the residual content and minimum molecular mass, and many of them limit overall migration (OM) from the synthetic polymer, metal or other material particle to come to contact with item. As migration trials are time consuming, expensive and difficult to perform, the "generally recognized diffusion models" based on experimental data were approved (Robertson, 2013: 621).

7.2 EU regulations

The food and packaging regulations are governed by European Parliament in the universal regulations for EU countries and also by numerous agencies and organisations that monitor correct manufacturing techniques such as European Food Standards Agency (EFSA). EFSA is a separate organisation following European Commission as well as other EU member states to examine emerging issues in food production (EFSA, 2017). According to European parliament and the council's framework, the basic Community legislation (EC 1935/2004) is covering all food contact materials (FCMs) in Article 3. It defines FCMs and articles and sets basic requirements for them:

> "1. Materials and articles, including active and intelligent materials and articles, shall be manufactured in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could:
> (a) endanger human health; or
> (b) bring about an unacceptable change in the composition of the food; or

> (c) bring about a deterioration in the organoleptic characteristics thereof.
> 2. The labelling, advertising and presentation of a material or article shall not mislead the consumers." (Parliament and Council Regulation (EC) 1935/2004 of 27 October 2004)

Robertson also mentioned that Dainelli et al. (2008) discussed EU legislation about active and intelligent packaging in EU Regulation 1935/2004/EC, Article 3, that presented the opportunity for active packaging to be used in Europe. Active packaging, allowing the application of materials with agents that could migrate into foods, is therefore harmonised into EU law to some extent. The definitions are as follows:

> "a) 'active materials and articles' means materials and articles
> that are intended to extend the shelf-life or to maintain or improve the condition of packaged food; they are designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food;
> b) 'intelligent materials and articles' means materials and articles which monitor the condition of packaged food or the environment surrounding the food."
> (Commission Regulation (EC) No 450/2009 of 29 May 2009).

EU also abolished all materials and substances that proved to be harmful to humans to be in contact with food. For example, ammonium salts are frequently active to improve the properties of specific synthetic polymers in structural applications, however they are not approved in EU (Robertson, 2013: 148). Regulations oversee the use of toluene in ink, based on the residues of the chemical left in the ink after printing that is harmful for humans when consumed. Another kind of regulations to be considered with packaging are also emission regulations. The CO2 reduction initiative is significant in most countries, as well as NOx regulations for production.

Other EU regulations describe shelf life, its connection to expiry dates and the information that is necessary to be printed on a package. European Union has strong definitions and guidelines for food production and packaging and therefore food produced and packaged in EU is considered rather innocuous from containing harmful materials and ingredients. Individual EU states have their own organisations as for example German

company TÜV RHEINLAND which provides customers with certification DinCertco in collaboration with German Institute for Standardization to ensure safe packaging technology in protecting health and the environment. Another similar company that provides technology certification in EU is Vincotte.

7.3 Other Countries

In global economy, food products from one state are available for purchase abroad. To ensure the safety and correct manufacturing methods, countries form either their own legislation or they join international organisations that prevent harmful materials, ingredients and practise. The fundamental regulation considering packaging should be universal in its core, so the products could be exported. Many countries have legislation similar to European law discussed above which states that package should be safe for human health, it should not interfere with quality of food or cause spoilage (EU Commission, 2014). In United States of America, the regulations are formed by United States Food and Drug Administration authority (US FDA), in Canada, the governing body is Health Canada. The extent of regulations varies in different countries, and consequently, in countries such as the United States, Australia and Japan, there are no specific regulations related to active and intelligent packaging (Robertson, 2013: 424). The regulations in certain countries may be strict on specific categories of production, materials or waste management. According to Farmer, in 2006 South Korea introduced regulation concerning limits on the amount of void space in packaging according to the type of product, as well as limits on the number of layers of packaging that are applied to protect the products (Farmer, 2013: 235).

8 Labels and Marking

The first mark is the universal symbol for all packaging materials that come to contact with food products. The material that are made for food preservation such as containers have to be previously tested to avoid harmful impacts on human health. The symbol was approved by European Council and it has a shape of a glass and fork symbolising food and drinks (Emblem and Emblem, 2012: 52). The food contact symbol is used mostly

for plastic containers, however there are other materials that carry this symbol in EU. The Commission principles are same as in regulations part, with emphasis on migration and human safety regarding food contact materials (FCMs). The imported goods from abroad must be tested and results submitted to authorities, especially kitchenware from China and Hong Kong (EU Commission, 2017).

Figure 1 Food Contact Material Symbol

In 1995, the Pro Europe organisation was founded in Germany. Active until today, Pro Europe is governing recycling and responsible packaging manufacturing practises in Europe. The Green Dot trademark is their symbol that signifies the fact that the manufacturers of each package it is printed on financially contributes to national recovery organisation. There are about 170 000 companies listed as members (Pro Europe, 2017).

Figure 2 The Green Dot Symbol (Pro Europe, 2017)

In United States of America, the department of agriculture introduced program called BioPreferred in 2002. The USA government aimed to encourage companies to use natural, renewable resources as substitute for materials derived from petroleum such as synthetic polymers and also make it easier for consumers to find those materials. Bio based products include diverse categories such as inks, fertilizers, and bioplastics. BioPreffered program trademark on the package contains the percentage of bio products used for the product's creation and also the percentage of natural resources used for package itself.

Figure 3 BioPreferred Trademark (USDA, n.d.)

Tidy man symbol is probably known all around Europe and in other countries, for example, USA. The symbol was developed by Tidy up Britain charity organization in United Kingdom which aim is to motivate people to put all litter to containers and separate them. The idea is mainly focused on general need to keep environment clean without littering since 1960s when the littering was a significant issue across the world (Tidy Up Britain, 2017). The activities of charity range from raising awareness to educating and training people. Tidy up Britain has previously launched several campaigns with celebrities to attract citizen to their legacy. The symbol is required by law to be printed on package in certain countries, for example Slovakia.


Figure 4 Tidyman Symbol (Tidy Up Britain, 2017)

Möbius loop is a symbol placed on every package. Even though the name is not widely recognized, the mark itself is well-known triangle of green arrows symbolizing recycling process. It represents the fact that the package can be recycled if placed into correct bin. Since every material can be recycled to some extent, the Möbius loop can be found on thousands of products and in certain countries, it is also required by law to remind consumers about recycling. In United States, the use of Möbius loop is permitted and regulated by Federal Trade Commission (Farmer, 2013: 228). The symbol can have two meanings: the information that material on package can be recycled or that the material used for package was recycled to some extent in which case there would be a percentage

attributed to recycled material portion in the middle of the symbol. Möbius loop does not have a registered trademark and therefore it is available to use according to regulations.

Figure 5 Möbius Loop Symbol for Recycling.

In 1980s The Society of the Plastics Industry (SPI) in USA developed so called SPI symbol. The design is based on Möbius loop; however, the arrows are thinner and plainer. This symbol is designed for plastic materials and the aim is to differentiate polymer compounds and their recycling bins based on the number in the middle (Miller, 2013). The most common SPI symbol can be found on plastic bottles representing the PET sign. The sign indicated that the bottle is manufactured from PET material and therefore has to be placed in suitable container in order to be recycled. Other synthetic polymer types on the sign are HDPE (plastic bottles), PVC (juice bottles), LDPE (frozen food bags), PS (disposable cups) and PP (yoghurt cups).

Figure 6 SPI Symbol for Plastics (AAC, 2017)

9 Tea packaging

Tea is one of most popular beverages in numerous world's countries with traditions dating back thousands of years. Currently, tea is widely available product in every shop specializing in food products, with large variety of options for customers to choose from. Tea is essentially the flavour that is dispersed in water from tea leaves. The leaves are harvested in states with suitable weather conditions, largest exports being from India. The initial processing is done directly on plantation premises, where leaves are fermented and dried. There are three main categories of teas based on the manufacturing process (Robertson, 2013: 589):

1. Fermented: Black Tea
2. Semi-fermented: Oolong
3. Non-fermented: Green tea, Herbal tea

9.1 Packages

In packaging machinery technology, the method form- fill-seal (FFS) is used for a wide variety of packs such as tea bags and sachets (Farmer, 2013: 215). First, the machines form packages to their expected shape, then they are filled with products, in this case dry tea and the last step of packaging is sealing the product in chosen material. Tea bags are made by FFS technology from light-weight permeable tissues. Tea bags are fragile without additional layers of packaging as the material for bags has to be porous so it allows dispersing of tea flavour, meaning that the package is unresisting towards moisture and air. To protect the tea bags, usually secondary package is made from aluminium foil because of its feature to provide a protecting barrier between product and the environment (Farmer, 2013: 188). Many tea manufacturers choose metallic foils to wrap either each tea bag separately which creates extensive waste as well as this packaging method requires enhanced machinery. Moreover, separately wrapped tea bags in two layers of package still need to be composed together inside another package, typically constructed from dense paper in shape of rectangular box. From waste management point of view, if one foil protects numerous tissue tea bags, the package is more sustainable, especially if the foil package can be sealed and re-opened (for example

Saga tea). The external packets are typically made of metallised polypropylene that provides satisfactory moisture barrier (Emblem and Emblem, 2012: 174)

Tea packaged inside a paper box is sometimes protected by another layer of package: transparent cellophane. Cellophane can be characterised either as regenerated cellulose film RCF (Coles and Kirwan, 2011: 302) or polyvinylidene chloride (PVdC). It is a rigid material, chemically classified in manmade polymer that provides excellent moisture barrier (Farmer, 2013: 78). However, being synthesized as plastic material, there are environmental issues with recycling PVdC, since it is not biodegradable. As a substitute for PVdC, cellulose-based materials were developed, providing satisfactory barrier against microorganisms and flavours, however it is not water resistant (only when additionally coated). Two types of renewable cellulosic materials are used in packaging for FMCGs: cellulosic films and compounded cellulosic bioplastics both extracted from wood pulp (Farmer, 2013: 127).

An alternative type of package adopted by popular tea brand was developed by Innovia Films. They produced package called NatureFlex™ a two- side coated, biodegradable cellulosic-based film which is sealable with heat offers intermediate moisture barrier (Reynolds, 2009). The package has high gloss, resistance to grease and oil, even a barrier to gases and aromas which protects tea from losing its desired properties. Although the package looks similar to aluminium foil, the aluminium metal content is less than 0.02% (Coles and Kirwan, 2011: 11). This package encourages people to reduce their waste by composting this package at home, the degradation period being few weeks. Conveniently, the biodegradable primary package is combined with paper box that also offers wide range of recycling options for consumers.

One of package manufacturers that operate on global level is Finnish company Huhtamäki Oyj. Tea products are also among their offering assortment. Their packaging consists of both renewable and non-renewable resources providing the ultimate goal in tea packaging: protection of aroma. They offer package variants ranging from simple printed mono film solutions up to multilayer, re-closable types of packages (Huhtamaki Group, n.d.).

Metallic box as a safe form of food package has long history. Metal package provides a form of differentiation for manufacturers when placed in retail store. In fact, metal manufacturing technology is expensive and not flexible when changing sizes of containers. Each container also requires surface coating to be protected from corrosion. Metal packages are exceptionally effective in protection function, they are non-permeable, resilient in terms of breakage and offer fine light barrier. Metals are 100% recyclable, with truly low waste levels when processing. Even though the largest packaging market for metal is can production, they are also used in other segments due to their features as luxurious gift boxes for various brands.

In tea shops that specialise in various teas from different countries, the leaves are often kept inside glass jars to protect their flavour and odour. Glass also provides excellent barrier when sealed properly so the product would be preserved for longer time. The use of glass package in commercial market like retail becomes impractical for several reasons: high weight, fragility, difficulties with manufacturing and overall higher costs compared to plastic and paper package layers.

9.2 Tea Summary

Tea is a type of FMCG that consist of small sized units wrapped in tea bags, grouped together in either paper of plastic material with typically cellophane layer on top. More than eight package types were described: permeable tissues, aluminium foil, paper wrap, paper box, cellophane, aluminium box and NatureFlex, with glass as alternative package for tea shops. It is common that tea package consists of three layers without counting logistics layers of packaging such as boxes and pallets. For such a miniature product, there is certainly a lot of waste to be disposed of after consuming the leaves. Moreover, the manufacturers produce high variety of flavours and editions that are packaged in dissimilar materials in order to differentiate them on shelves.

Summary table presents comparison of packaging functions for materials mentioned in this thesis. The criteria for comparison are derived from the barrier quality of different materials, from the sustainability prospects those materials have and logistics aspects of diverse package types, all distinguished in table by different colours. The rating system

is based on three main grades for each category: 1 represents poor results, 2 stands for intermediate performance and 3 relates to excellent result. Poor results symbolized by number 1 mean that the performance is truly low or non-existing. In Yellow category (logistics) number one stands for high price, high weight and wasteful stacking. Intermediate performance term means theoretically that other materials have either better or worse results. Intermediate does not refer to middle of a scale, rather it characterizes the area where is space for improvement. Number 3 (excellent) is assigned to materials that in ideal conditions perform well, without any waste or damage. The grades are based on publication materials and internet research. The ideas behind grading are to some extent explained above.

Following table presents several materials and their features for the purpose of clear illustration and differentiation in a form of general overview. Moreover, there are certainly new alternative materials available as packaging options that should be brought to attention and mention in the research despite they are not commonly used yet. As shown below, NatureFlex scored second best result in this category after aluminium box, with slight insufficiencies in protection, however it is considerably lighter material for packaging.

	UV barrier	odour barrier	moisture bar-	impact pro-	containment	flexibility	sterility	recyclability	re-usability	degradable	renewability	price	weight	superposition	Total score
Alumin-ium box	3	3	3	3	3	1	3	3	3	1	1	1	2	3	33
Paper	1	1	1	1	1	3	2	2	1	3	3	3	3	3	28
Cello-phane	1	3	3	1	2	3	1	1	1	1	2	3	3	3	28
Nature-Flex	2	3	2	1	2	3	2	3	1	3	2	2	3	3	32

Table 1- Summary of Tea Packaging Materials

Aluminium box has great results in food protection field with its dense properties and possibilities to shape metal into different types of containers. The downside of metals is that they are produced from non-renewable resource and therefore should be recycled to protect the environment. Aluminium is light and durable metal, which has advantage

in logistics if the thickness of containers is relatively low. One challenge in using metal as package material is that the price for package manufacturing may not have desirable profit ratio especially in low value items such as perishable food products. Aluminium is often used for products that are preserved in certain method, aluminium can being the enduring solution for prolonging their shelf life.

Paper properties are well-known to everyone. Paper is a renewable resource that is commonly recyclable with slight loss in quality. On the other hand, paper does not provide strong barrier against water, odour or sun. To improve the packaging performance, in manufacturing it is improved by combination of other materials such as plastic or wax to be more resilient against environment. The most inconvenient feature of paper for packaging is that it is simple to tear material. In order to provide stronger protection for products, paperboard is commonly used in packaging and especially it is used as secondary package for variety of products. Paperboard boxes are stronger and more convenient to transport. Paper surface is remarkable for printing due to colour resolution and less ink required (Robertson, 2012: 248). Farmer also predicts increase in demand for paper packaging in the future (Farmer, 2013: 304).

Cellophane is truly common package material, not necessarily used for primary packages, but for secondary ones and packaging systems to secure products for transportation. Cellophane offers moisture barrier and ability to hold packages together. It is used for packaging snacks as form of flexible packaging. For logistics packaging the transparent material biaxially- oriented polypropylene (BOPP) is used because it has ability to stretch and shrink (Farmer, 2013: 63). The mentioned table refers to PVdC material that is commonly used for food packaging (Paisley, 2007). Unlike cellulose based film, it is not biodegradable, and the recycling is similar to recycling of PVC and PET materials (Paisley, 2007). PVdC offers high odour and moisture barriers and it has low price similar to other plastics.

The NatureFlex has characteristics similar to wax paper. The main difference is that NatureFlex is designed to be biodegradable material, suitable for composting. Lamination and coating technologies allowed reduced permeation of water vapour and common gas into products (Coles and Kirwan, 2011: 303). NatureFlex being ecological is also more

expensive than cellophane or wax paper, although other characteristics are similar. The disadvantage of this material is that its structure is not structured to contain fluids.

10 Chocolate bars

Chocolate is a type of FMCG that consists of relatively fragile substances and therefore the package is necessary to protect it from outside factors. It is imperative to prevent the shape from deformation that can be caused by humidity or changes in temperature. Chocolate is manufactured from cocoa butter, sugar, milk and other ingredients that are mixed together, however they still remain in relatively raw form because it is not heat-treated. Chocolate matter is fragile and sensitive to various environments. Customers expect chocolate to be in specific shape and its surface to be smooth and lustrous (Jacob, 2010: 94). The main ingredient: cocoa butter is based on fat; thus, it attracts smells. Consequently, chocolate package has to be made of non-permeable material to protect its fragile form. The primary package therefore should be resilient to environment and sustain non-permeable and UV barrier in order to prevent chocolate from changing its characteristics without causing migration.

There are various chocolate packages available for consumers. Packages consist of:

1. Soft paper and aluminium foil
2. Hard paper and aluminium foil
3. Plastic wrap
4. Waxed paper

Chocolate is a popular consumer's goods that is sold every day in immense quantities globally. MTV Finland published an article based on research paper about food market that claims the chocolate consumption in Finland was 6,5kg per person per year in 2014 and it is growing steadily (MTV, 2014). Majority of consumers are only interested in the product itself and they do not acknowledge the significance of waste its package has on our environment.

American chocolate brand Heritage Chocolate has preserved traditional chocolate manufacturing and packaging style from 18th century (Pierce, 2016). The packaging materials they use consist of untreated paper and textile. Although these materials are not efficient in preservation, they were available at relatively low costs since plastic was not available at that time. Implementing historic design to modern product is common marketing strategy for attracting new customer segments plus sustainable materials have good publicity.

The chocolate selection in stores is clearly divided in few packaging types: plastic and the combination of aluminium with paper. Several brands also produce the same type of chocolate in both versions as for example Fazer. A few plausible reasons are behind the decision why companies choose to manufacture same product in different kind of package. Those could include meeting customers' demands, offering choice, filling shelves to increase market share. As companies tend to protect their know-how and process this may be a challenge to discover reason as there may not be a specific motive. Another reason may be the machinery options that they use, it may be designed for specific packaging type. Clearly different package materials have various prices, characteristics and limited availability for manufacturing.

10.1 Packages

Plastic package for chocolate appeared on market few decades ago and many brands based their advertisements on the fact that is can be sealed again after opening (Milka). Majority of plastic packaging is based on petrochemicals. The petroleum is transformed to 240 million tonnes of plastics annually, of which packaging represents about 40% (Farmer, 2013: 59). Advantages of plastic packaging materials are: light weight, possibility to be designed and tailored for a particular product and cheap price. Farmer stated that plastic food packaging covers less than 10% of the final product price. As mentioned before, various synthetic polymers require separation when recycling which causes problems with throwing away and littering (including ocean pollution). The reuse rate of polymers in households is also lower than other materials because of large availability (plastic bags as example). In nature, plastics have sluggish rate of environmental degradation and there is still deficiency of collection and recycling points in many countries.

Taking into consideration Europe only, roughly about 10% of the plastics used annually is recycled or burnt to produce energy (Farmer, 2013: 59). Concerning chocolate packaging, the evaluated plastic material is PET plastic film. PET material description is described further in Milk section.

Lamination is common process in food manufacturing factories, as aluminium enhances permeable materials and therefore the products are soundly preserved in aseptic package (Coles and Kirwan, 2011: 164). As concluded in many publications, the concerns about non-renewable resources such as aluminium causes that companies invest to development of materials with higher sustainability rate such as Stora Enso (Farmer, 2013: 197). Steel materials are known to be 100% recyclable, in detail, melted metals can be forged or processed again without any decline in previous features unlike paper. Steel and aluminium are considered low cost materials with low levels of migration (Coles and Kirwan, 2011: 225). Another great advantage of aluminium is its strength, however in case of chocolate wrap the layer is too thin allowing chocolate to damage when impacted.

Aluminium foil is commonly combined with paper and cardboard materials to extend shelf life of products by providing sufficient barrier. Paper is one of materials that were in great extent used for packaging purposes in the past, first acknowledgements dating back to ancient Egypt. The development of paper products and use of them is significant. Paper is created from natural fibres extracted from wood pulp. The main component of wood cell is cellulose. The wood needs to be pulped either chemically or non-chemically, digested and bleached (Robertson, 2013). The paper is produced in bulk quantities, rolled for the packaging factory use. Paper is a perfect material for printing, because the ink is easily absorbed by fibre. Paper is ultra-light material, truly inexpensive for manufacturing. The disadvantages of paper consist of lack of protection as it changes its structure when facing moisture. The protection function is also challenging for paper based on its thickness. In case of chocolate package, the paper layer is usually thin and the shape can be compromised when transported.

Waxed paper is a separate category of materials due to its origin. It can be produced either from vegetable oils or mineral based. Both types are suitable for packaging food products. On the other hand, the commercially used wax paper is coated with paraffin

which is extracted from petroleum (CGP, 2013). Often, wax paper is combined with other materials to improve the performance of the package. One of advantages wax paper provides is the grease barrier which is why it is often used for chocolate package as inner layer. Even though it needs to be properly sealed to be sufficient moisture barrier, the wax offers water-repellent effects.

10.2 Chocolate Summary

After describing five materials: paper, wax paper, aluminium foil, plastic wrap and laminated plastic, clearly, those materials are often combined to provide sufficient protection of chocolate. One of the most common manufacturer's package option is using paper and aluminium foil which is rarely being separated to paper container and special metal waste container, and it is difficult to recycle unseparated. Waste & Resources Action Programme in UK is motivating municipalities and households to start separating metals because they are sustainable, easy to recycle and re-using them saves CO2 emissions from manufacturing (WRAP, 2009). If aluminium is such a positive material for recycling, it would be more reasonable for chocolate manufacturers to stop using paper as another component of the package to simplify the recycling for household. Paper on its own is also one of easily recyclable materials, however it cannot be lined with foil or plastic. However, these two materials are usually not separated after consumption of chocolate bar. Consumer that throws the package to mixed waste container prevents materials from being re-used, instead they are either processed to landfill or combustion (STAT, 2015). Third most common material for chocolate packages is plastic. There are dozens of plastic compounds that are used for packaging and they have different attributes. In Finland, the plastic waste separation was introduced only in 2016 (YLE, 2016) which suggests that people were collecting plastic waste in mixed waste containers before, restricting the waste to be properly recycled. Besides environmental impacts of chocolate packages, there are also economic and logistic impacts that can influence the producers in their supply chain infrastructure. Different materials have various price and source and they also influence transportation of chocolate as the package must protect it from damage and it affects the weight and size of a product.

In chocolate products category, aluminium foil was determined the most suitable material for package, however if thin, the foil is fragile and therefore manufacturers choose to supplement it with other materials such as plastic film or paper. On the other hand, wax paper proved to be also sufficient package material and its advantage it that is does not have to be accompanied with other layers of packaging.

Table 2- Summary of Chocolate Packaging Materials

	UV barrier	odour bar-	moisture	impact pro-	containment	flexibility	sterility	recyclability	re-usability	degradable	renewability	price	weight	superposi-	Total score
Aluminium foil	3	3	3	1	1	3	3	3	1	1	1	3	3	3	32
Paper	1	1	1	1	1	3	2	2	1	3	3	3	3	3	28
Wax paper	2	2	2	1	2	3	3	1	1	2	2	2	3	3	29
Plastic film (PET)	1	3	3	2	3	2	2	2	2	1	2	3	3	2	31

Paper was already described and explained above. Both materials have similar final score, even though, when analysed in separate categories, their properties differ. Wax paper is more resilient, while normal paper or carton is easily recycled or composted. There are two types of wax paper- wet waxed and dry waxed (Robertson, 2012: 182). As mentioned before, wax provides additional protection especially for paper packaging. Wax is applied to paper to protect it from decomposition by contact with certain enzymes (Robertson, 2012: 182). Unfortunately, as remarked by Coles and Kirwan, wax applied to other materials makes them more difficult to recycle, because the wax layer should be separated (Coles and Kirwan, 2011: 101). From logistics point of view, the wax layer on paper or paperboard improves the strength of a package making it unproblematic to stack.

Aluminium foil is more frequently used in food manufacturing than aluminium itself. It can be used in its raw form as for example in chocolate package or included in another type of container as TetraPak where one layer of package consists of aluminium. The use of aluminium foil or film for endorsing other materials such as paper or polymer proved to be truly efficient, providing the benefits of aluminium together with low-priced,

light materials. Another advantage of foil is that it protects food products from temperature changes as it has thermo-insulation features.

11 Milk

Packaging technology changed significantly throughout last century. Certain products tend to also be packaged differently in various countries, based on the need and habits of society. As an example, milk, a fundamental product, included in most shopping baskets across the world is packaged in multiple materials, sizes and shapes in some countries.

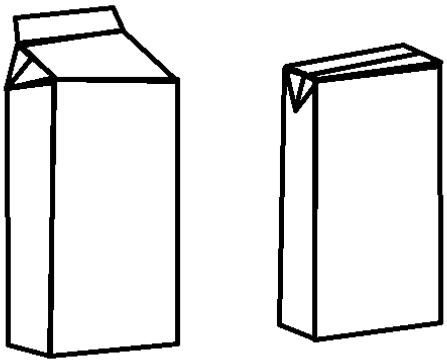
Although majority of food products are seald inside package to protect them from outside bacteria, in case of dairy products, the package's role is to contain desired environment without transforming lactic acid levels in order to maintain milk in its raw form, without turning into unsolicited substances. Raw milk has to be kept in cold, dark environment, not higher than 4°C and even in this condition, the milk will last approximately one week until it starts to show signs of spoilage. The process that enables milk remain in fresh form longer is called pasteurisation, after its inventor Louis Pasteur. Pasteurisation is a process of heating substances to certain temperature level so the bacteria inside would be eliminated, more specifically, when considering milk, the undesired bacteria is lactic acid. The modern process of pasteurisation lasts circa fifteen second, however 80 years ago when it lasted thirty minutes (Coles and Kirwan, 2011: 46). After milk becomes bacteria free, it is necessary to maintain the correct atmosphere inside package to prevent outside environment from intervening with its quality, meaning the package needs to be aseptic. Aseptic cartons are efficient package as the refrigeriatiom is not necessary and products shelf life is extended without wasting fosil fluels or electricity for refrigerator's operation. To achieve even longer shelf life for milk, the walls of containers are sprayed with thin layer of anti-bacterial formula (Farmer, 2013: 87).There are still countries unlike Finland (lactose free), where the fresh unprocessed cow milk is desired without any preservatives. To satisfy customerst in villages and rural areas of Slovakia, the Milk Express vehicle was designed to deliver fresh milk from local cooperatives to announced public places where people can bring containers of their choice and use tap

to fill them with as much milk as they desire (Korzar, 2010). This idea for milk distribution is quite ecological in terms of low packaging waste.

11.1 Packages

The most common type of package for milk in Europe is paper carton laminated with foil film on the inner part. These laminated paper boxes may have different types of closures, that influence the expiry date of milk after opening the package. The two main categories are resealable and unreasealable. It is considered more convenient when a milk box has plastic cap that can be closed, however several other closures do not provide the posibility of closing, for example packages that are meant to be opened by cutting or tearing the corner of the package.

Figure 7: Two types of box folding



Both packages shown above require different folding machines and the volume can differ in various brands. The closeable milk packages have similar shape as boxes on the picture, only there is a plastic closure on the upper part of the package. Cartons offer large potential for printing therefore it is convenient for manufacturers to attract customers by designing appealing package. Paper boxes laminated with foil also offer advantage in logistics due to the fact that it is lightweight and energy efficient, typically, 96 per cent product and 4 per cent packaging by weight (Farmer, 2013: 211). The inner layer of aseptic cartons is usually aluminium which protects the liquid from light, odour and air perfectly. Nowadays, some manufacturers try to replace aluminium foil in aseptic

paper boxes by ethylene vinyl alcohol (EVOH), an exceptional oxygen barrier which is without difficulty managed in the waste stream (Farmer, 2013: 213).

The global leader in cardboard box manufacturing, is Tetra Pak. The world's largest producer of aseptic fluid containers was founded in Sweden in 1940s. First boxes were in tetrahydran shape which enabled the continuous production with one package sealing the other as in sausage production (Tetra Pak India, 2015). The reason for Tetra Pak's success is the innovative technology that enables fluids to last fresh up to twelve months in closed package. The standard carton consists of 6 layers: polyethylene (moisture barrier), paperboard (strenght), polyethylane again, aluminium (light, air and odour barrier), polyethylane third layer, and one more polyethylane layer. The print is applied to paper layer and then all layers are laminated and flame threated together one after another, to create the cardboard mixture. This process output does not have shape yet, the material is curled on large rolls. In this form, rolls are transported to customers where they fill them with their products. The roll is secured in machine, which cuts it and creates cylindricall continuous roll which is filled with fluid. Filling machines are immensely fast, filling 7 packages every second. Gripper machine changes shape of the tube, then machine seals both ends and separates individual packages. Last step is sealing folded flaps of the packages so they become to have brick shape. TetraPak's package for milk TetraBrick is cost effective and it provides satisfactory barrier for protecting milk with advantage in logistics as it is light and non fragile. In addition, brick package is easy to stack and transport without wasting space. They produce both closable and non-closable packages. As recent innovation, TetraPak introduced bio based caps made from HDPE. Another carton company that is active in Finland is for example Elopak.

Glass bottles as containers for milk products are the oldest package type still used today. However, the trend of using other materials rose since 70s and glass is rather rare package possible to be found only in a few grocery stores in Europe. In the past, glass was the best container for liquids because it is made from natural resources with great ability to contain it and protect it with non-permeable barrier. Still, several problems with glass bottles connected with contamination occurred when the food and beverage regulations were imposed. As stated in the beginning of the section, milk is rather unstable and fragile substance that requires certain conditions in order to last longer. Glass bottles

have to be sterilised thoroughly with pressure steam or dry heat when filled with milk and the caps cannot leak oxygen, but they must remain equally easy to open. Moreover, glass does not provide UV barrier so the bottles cannot protect milk when exposed to daylight. The list of disadvantages continues with parameters such as weight which is higher than other materials and shape that is not efficient in allocating space when a bottle has its standard curves. Another impractical feature of glass is fragility preventing bottles from being thinner and therefore lighter. Based on all its characteristics, glass turned from the most common package of milk into the least used. In other drinks categories as alcohol, beer and soft drinks, glass remains popular because of its tradition and features. Glass material does have benefits in terms of fairly unchanging pricing and outstanding sustainability together with environmental features allowing 100% recyclability without limits. Robertson mentioned in his book about trends in packaging that a survey made in December 2010 for the European Glass Container Federation, FEVE (2010), resolved that glass was the preferred material for food and drink for more than 75% of the 8600 participants in 17 countries. FEVE announced that consumers preferred glass because of three main reasons: the taste preservation, its health benefits (low migration levels) and its recyclability (Farmer, 2013: 292). Glass bottles have different standard shapes and volumes. The universal bottle parts are (top to bottom): sealing surface, ring, neck, shoulder, body and insweep (Coles and Kirwan, 2013: 143). The manufacturing process of glass bottles starts from melting the glass material, creating gobs with the weight of a bottle, hovewer the shape is cylinder and later the mass is blown into desired shape and cooled. Coles and Kirwan mentioned that the aluminium foil cap on a milk bottle is one of the simplest forms of closure. Because of special requirement for manufacturing, bottling companies tend to use suppliers for finished glass bottles and have them delivered rather than producing them. One of glass bottle's advantages is that they can be reused, resolving in creation of return stations for glass bottles in many countries. In Finland, one bottling company that is reusing glass bottles is Hartwall.

Plastic containers for milk and other drinks are produced from various types of synthetic polymers. Among the most commonly used due to their recyclability rate are PET, HDPE or PVC. Polymers are produced by distillation process from heavy natural oil. Different plastics offer various features. PVC is hard plastic material, manufactured to withstand high temperatures. The use of PVC for food packaging is decreasing at the moment

based on its toxicity and environmental issues (Farmer, 2013: 72). Moreover, the price of PVC is higher compared to PET. Numerous companies are working on enhancement of barrier properties for PET bottles, to create even more resilient package. High density polyethylene (HDPE) is currently increasingly used material for packaging. HDPE, similar to PET has high recycling rates: over 40% (Farmer, 2013: 59). Issues with plastic containers are their low tolerance for higher temperatures and problems with gathering, sorting and recycling mixed plastics (Farmer, 2013: 3). HDPE can be also incorporated into other package materials as one of their layers, for example Nampak presented an ultra- lightweight HDPE milk bottle which contains of 15% recycled materials (Farmer, 2013: 60). Nampak engineers developed new design for bottles with repositioned handle with focus on avoiding pressing excessivve amount of material into the bottle corners, making it ligher.

In 2010, European Commission approved funding for a pilot project from United Kingdom to manufacture GreenBottle, bottle based on compostable paper with detachable inner layer of palstic (European Commission, 2010). Bottles are easily recyclable and are meant to be used for packaging milk available for sale in UK retail stores. In their application, company developing GreenBottle claims that their product has lower carbon footprint than laminated cardboard box or HDPE bottles (GreenBottle, 2009). Unfortunatelly, the results of project are unknown and GreenBottle's website is cancelled. Just as curiosity, there is similar company, One Green Bottle which manufactures metal bottles for personal use that are ecological (One Green Bottle, 2016).

11.2 Milk Summary

The variety of aseptic packages for milk consists of plastic bottles, flexible packaging, glass bottles or foil laminated paperboard cartons. Milk, being product derived from animals, requires quite many procautions to sustain its freshness. There was significant appeal for innovation of milk packages during last decade, creating GreenBottle and improving laminated cartons. The expiry date of milk is continuously extended to ensure longer shelf life by choosing appropriate package. The symbols mentioned before are frequently present on milk packages, mostly Möbius Loop for recycling, Tidyman and SPI

symbol on plastics. The best package for milk preservation is currently laminated carton, however plastic bottles are popular as well. The sustainability of milk package is rather neglected at the moment to satisfy customers who demand a products that will not be spoiled in a few days. Even though, all packaging materials for milk mentioned above are recyclable, the recycling rates should improve globally. Following table presents scores for each material discribed with highest score for HDPE due to its characteristics providing strong barrier for external environmnet combined with low price. However, the sustainability of plastic materials is rather low.

Table 3- Summary of Milk Packaging Materials.

	UV barrier	odour barrier	moisture bar-	impact protec-	containment	flexibility	sterility	recyclability	re-usability	degradable	renewability	price	weight	superposition	Total score
Glass bottle	1	3	3	1	3	1	3	3	3	1	3	1	1	1	28
HDPE	2	3	3	3	3	1	3	2	1	1	2	3	3	2	32
PET	1	3	3	2	3	2	2	2	2	1	2	3	3	2	31
Tetra-Pak	3	3	3	2	3	2	3	1	1	1	2	1	2	3	30

First material, glass bottle, is a typical transparent bottle for soft drink. The scores in table take into accounts the fragility, rigidness of glass, and its non-permeable surface. Glass is made of renewable resources: sand or cullet, however, even though the recycling is common and popular among consumers, the glass has to be thoroughly cleaned from residues of other substances and materials and in addition, it cannot be mixed with other types of glass. The Glass packaging institute based in Virginia, US, promotes the use of glass containers used in manufacturing because it is 100% recyclable and is possible to be recycled infinitely without loss in quality or purity (GPI, 2017). The disadvantages of glass as mentioned before are its weight, as compared to plastics, its price and low flexibility which prevents products to be stacked efficiently without secondary package or pallets in order to protect the glass. Moreover, transportation of bottles usually leaves free space between the neck parts. One of positive attributes concerning glass bottles is their high level of sustainability. People tend to re-use glass bottles and companies collect them back after consumption. The European Container Glass Federation

(FEVE) announced in their report that in 2014, an average glass recycling level was 70% in European countries (FEVE, 2015).

Packaging is a key industry utilizing use of plastic materials, which is continually increasing (Farmer, 2013: 14). HDPE proved high recycling rates and according to portal Plastics Today, polyethylene terephthalate (PET) and high-density polyethylene (HDPE) at present indicate about 86% per cent of the plastic package industry (Plastics Today, 2017). The downside of HDPE is its low resistance to higher temperature which can cause cracking or expansion of the material (United Plastic Components, 2010). HDPE is as majority of plastic materials also flammable; therefore, it may prove dangerous. HDPE with its higher density is considered more resilient than PET.

PET is the most common plastic for thermoforming packaging designs because of its high-strength barrier that can resist outside tampering or other elements (Elmke, 2014). However, majority of publications mention the high environmental price of PET bottles production because of high levels of emissions. PET bottles and packages are suitable for many types of food products because it provides odour and moisture barrier. Also, its oxygen barrier is strong, however the UV light can cause damage to contained product if UV sensitive. PET bottles are cheap to produce and transport because of low weight and before filling, they are not blown into their full shape, therefore they do not require excessive space for storage. The problem that environmental organisations as Greenpeace have against plastics is the pollution caused by littering and low recycling rates (Elmore, 2017). Recently, The Guardian published article describing Greenpeace criticizing CocaCola because of their high levels of plastic bottles distribution unlike their strategy in past when they operated on re-usable glass bottles (Elmore, 2017). The logistics benefits of PET bottles are possibly outweighing the negative environmental impacts for certain companies. Robertson claims that PET has better properties for packaging than HDPE (Robertson, 2013: 24). The UV barrier of plastics is influenced by additives and coating of material. Robertson mentioned an experiment organised by Van Aardt that compared UV filters of plastics on milk and the results showed that materials without additional filters have proven to cause oxidation (Robertson, 2009).

The fact that TetraPak is a combination of multiple different materials ensures high level of protection for fluid food products. However, the TetraPak is not efficient to use for

hard or dry products that does not require as many barriers for protection. Based on complex composition of it, it also causes difficulties when recycling. LCA of TetraPak proves that the package is produced with low emissions and energy wasted than other materials, however the recycling is causing a debate (Filou, 2010). Moreover, the reason why TetraPak scored lower points in price category is the monopoly situation in some countries (e.g. China) which boosted the price of machines and services, plus prevents other companies to gain market share (Barboza, 2013).

12 Conclusion

This thesis aimed to clearly define most used materials for packaging of three common products: milk, tea and chocolate. In addition, it portrayed fundamentals of terminology, functions, regulations and use of packaging technology in logistics. With growing environmental issues, the importance of sustainable packaging materials concerns consumers, society and companies. Using renewable resources and practises for packaging, without over-packaging and waste is beneficial for environment in same extent as it can be economically beneficial for companies because less space and weight represents lower costs for transportation. The summary part of three products discussed in this thesis shows majority of mentioned materials with emphasis on their performance in fulfilling package functions, logistics and sustainability. It was proven that several companies put effort in development of new materials that would be efficient and at the same time ecological. The summaries for individual products show tables with symbolic scores for different materials with highest points for metal and HDPE. Metal represent traditional material category, however the use is still popular, because the benefits of metal as packaging materials are attractive for production of many products, mainly cans. HDPE belongs to synthetic polymer category and therefore it represents the plastics with environmental disadvantages, even though the recycling rates for HDPE bottles are increasing. The manufacturing world is not ready to detach from use of plastic materials although they are not a sustainable source of packaging material. The benefits of plastics were palpably described, the most vivid ones are directly connected to logistics: low weight and price, together with availability. These reasons are convincing enough for manufacturers when they choose their packaging materials and the performance of HDPE, PET, BOPP and other plastics are too lucrative at affordable price. Hopefully,

companies would improve their effort in developing packaging even further and support use of sustainable, renewable materials. In conclusion, the determination of firms in improving environment and future of our planet has to be also supported by consumers who are required to recycle package materials and also by governments and other stake-holders who have power over packaging regulations.

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