Improvement areas for packaging and logistics: a study of long shelf-life products in Danone Nutricia

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MASTER THESIS

This Master's thesis has been don within the Joint European Master Course FIPDes, Food Innovation and Product Design.

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Abstract

This thesis aims at defining the improvement areas for packaging and logistics of a long shelf-life Danone Nutricia aseptic product. By literature research and interview, the author is able to build a product mapping protocol to define the sensitive components requiring particular concerns on packaging and logistics. This protocol could be implemented in both academic researches and industry projects. Then based on a representative product, the packaging system and supply chain physical flow are mapped. Also, the critical points of storage and transport conditions throughout 7 representative logistics routes are defined. The results show that the improvement areas include tertiary packaging (corrugated box) handleability, temperature control in warehouses and transporters, humidity control throughout the supply chains and lead time reduction.

Keywords: long shelf-life, aseptic, supply chain, packaging system, logistics, advanced medical nutrition products

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Lund, June 2018

Zhuxuezi Zhao

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List of acronyms and abbreviations

AGV	automatic guided vehicle
AMN	advanced medical nutrition
B2B	business to business
CBU	country business unit
DC	distribution center
EPT	electric pallet truck
PD	product developers
PDS	product development specification
R&D	research and development
SKU	stock keeping unit

Glossary

Headspace	The empty space left above the contents in a sealed primary packaging. In this study it specifically refers to the space between the filling line of product and the aluminum sealing foil.
Aseptic filling	The filling of a commercially pre-sterilized product into a pre-sterilized container, followed by hermetic sealing with a pre-sterilized closure under an atmosphere free of microorganisms (Mannheim & Havkin, 1981).
Pasteurization	Heating 71-74°C for 15-40s, eliminates all vegetative micro-organisms. Pasteurized products require 4°C chilling system for storage and transport with less than 1-week shelf life (Claeys et al., 2013).
UHT	Ultra-high-temperature heat treatment, heating 130 -140°C for 6-10 seconds. Destroys vegetative as well as most sporulating pathogens, therefore offering in most cases a so-called commercially sterile product. UHT treated products can be stored and transported in ambient environment (Rudloff & Lönnerdal, 1992).

1 Introduction

1.1 Project background

Danone Nutricia, an important part of Danone which is a global food product corporation, focuses on medical specialized nutrition and early life nutrition. Advanced Medical Nutrition (AMN) is one of the significant divisions of Danone Nutricia, which develops various medical products to support patients across a range of diseases and health issues as well as to enhance patients' recovery or to improve their quality of life.

This project only focuses on the plastic bottled liquid oral nutrition adult products in AMN. There are over one hundred types of products within this range, however, there are only four types of plastic bottle packaging (see Figure 1). These products contain different chemical, physical and sensorial characteristics as well as shelf life specifications. Also, they are sold in 42 countries worldwide, which determine their various requirements towards packaging and logistics. The current four types of plastic bottle packaging, and similar storage and transportation conditions for all delivery routes, are not able to fulfill the diverse requirements of over one hundred products.

Figure 1 Current plastics bottles of AMN liquid products (125ml, 200ml, 300ml, 500ml)

A previous project (Kim, 2016) explored the possibilities of improving the packaging of AMN plastic bottled products by focusing on the goal of reducing the oxygen permeation and extending product shelf-life from the packaging material point of view. In that project, the author discussed the solutions including enhancing the thickness of the oxygen barrier, applying a higher grade of oxygen barrier material, and decreasing headspace to reduce the residual oxygen within the product. However, the products' specific requirements regarding sensitive components, and the conditions of storage and transport, are not studied in that project (Kim, 2016).

As mentioned above, the current four types of plastic bottle may not be enough for over one hundred products. Based on this discrepancy between product requirements and packaging & logistics, as well as the under-investigated areas of the previous project, the following research questions are raised in this study:

- What are the requirements of the product's packaging system and logistics, regarding storage and transport in supply chain?

- What are the critical points of storage and transport conditions throughout the product's supply chain and are there any potential opportunities for improvement?

1.2 Research Objectives

Due to the fact that the packaging material optimization needed to enhance the barrier performance has already been analyzed and discussed in detail in the previous project mentioned above (Kim, 2016), the main research purpose of this project is to explore opportunities for improvement of a product's packaging and logistics, by taking into account the product requirements for storage and distribution. Due to the extensive range of AMN products in plastic bottles, a comprehensive study of all of these products and their packaging and supply chain conditions is not attempted in the study. Instead, one product is strategically chosen as a representative product for this particular study. Several sub-objectives are proposed to support the main research questions.

1) Define the sensitive components of the products that have specific requirements in terms of packaging and logistics, and explore how these are influenced by storage and transport conditions.

2) Select one representative product on which to conduct the supply chain study. Use the current selection protocol of Nutricia if available, if there is no available protocol, propose one with valid references and then conduct the selection.

3) Describe the current packaging system of the selected representative product.

4) Map the representative product 's current supply chain, focusing on representative routes, in order to understand the optimal conditions for storage and transport.

1.3 Delimitations

Because of limited time and resources, and given the 20-week limit of a master thesis project, the following study delimitations have been made:

1) Only liquid, aseptic, room temperature stored, adult customer targeted products which are produced in Netherlands are within the project scope. Then only one representative product is selected in agreement with Danone for further investigation regarding packaging and supply chain.

2) For the supply chain study, the logistics system of 7 representative countries including Netherlands, Belgium, Germany, France, Italy, UK and Brazil for the

chosen representative product are studied. Even in the same country, there are different delivery systems and routes; thus, due to the available limited information, only representative routes are discussed in a simplified approach.

3) The information regarding lead time, warehousing and transportation conditions in foreign countries outside the Netherlands are acquired through second hand resources (within the company) without verification via on-site trip or datalogger confirmation. The actual situation may be different and should be verified in future work.

4) Due to the equipment limitation, after defining the critical points of supply chain that deserve attention, it is not possible to conduct relevant experiments, such as residual oxygen in headspace, to verify the influences of storage and transport on packaging.

5) Concerning the defined improvement opportunities, practical solutions are suggested. Only general solutions are proposed at the end of this thesis; detailed solutions will be discussed under suggestions for future work.

6) The sustainability and recycling system is not within the study scope of this project.

7) According to the confidential agreement with Danone Nutricia, photos taken inside the Nutricia factory and distribution center are only for recording purposes and thus are only allowed to be used in internal company reports rather than the published thesis. Therefore, some contents of the thesis are only explained in text, with the aid of summarized flow charts but without the actual images of the facilities; the sensitive information in available photos are covered with mosaics.

2 Methodology

In this chapter, the research design will be illustrated to explain how the decisions are made step by step. Then the specific data collection and analysis approaches will be introduced.

2.1 Research approach and design

It is always the top priority to conduct projects in a structured way with clear objectives and practical research plan (Wells, 2012). Also, regarding the changing situation and specific context, the research strategy also need to adapt to the real situation. The research approach applied in this project is illustrated in 7 steps in the, adjusted from the model build by Reger (2001)

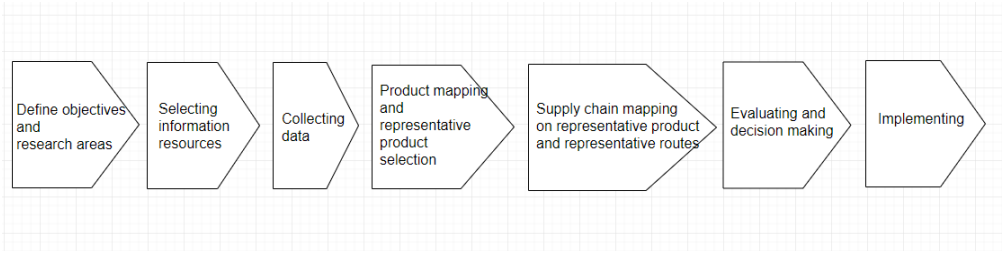

Figure 2 Summary of research approach

The research objectives and areas are required to be defined clearly to guide the whole project in the right direction. Then based on the availability, information resources are selected based on criteria (see 2.2). Collected data are filtered and analyzed according to research objectives to ensure the right information is interpreted in the right way. At the end, decisions are made based on evaluation of results, implementations are desired both within the company and in general academic environment, which means that this thesis is aiming to have both theoretical and practical relevance.

2.2 Selection of information resources

Considering the research objectives mentioned in 1.2, the targeted data need to fulfill the following criteria:

1) Focus on Danone Nutricia AMN oral nutrition products that are liquid, plastic bottled, aseptic filling, for elderly use, room temperature stored, and produced in Netherlands.

2) Focus on the requirements from the product point of view regarding sensitive components, and from the supply chain aspects regarding the storage and transport conditions, and then try to link the requirements to packaging perspectives.

3) The data in this thesis need to be up-to-date. It means that the information should not still remain trial stage nor already ceased from the market by the time this thesis is approved.

2.3 Data collection and analysis

Necessary data are collected through both secondary research and primary research. Secondary research includes bibliographic research in published literature and internal reports, allowing the author to obtain a general overview of research areas. Then follows the primary research including internal interviews and site visits which enables the author to have a better understanding of the study areas and to collect first-hand data.

All the data which are summarized by the author after collection are confirmed by relevant Nutricia employees to guarantee the information accuracy, and also to comply with the confidential agreement with Danone Nutricia. The analysis is based on the company context and relevant scientific references.

The overview of data collection methodology with correspondingly objectives are summarized in Table 1.

Table 1 Summary of methodology

Methodology		Objectives
Secondary research	Published scientific papers	Gain an overview of: – Interview techniques – Sensitive components of long shelf-life and influencing factors and critical effects – Shelf-life indicators – Storage and transport condition control during the supply chain
	Internal reports of Danone Nutricia	Acquire insights of Nutrica context from – Previous packaging improvement projects – Previous shelf life extension projects – Previous logistics management improvement projects
Primary research	Face-to-face interview	– Understand the current representative product selection procedure – If there is no selection protocol, define the requirements of building a practical protocol to select a product with severe issues during shelf life
	Semi-structured interview via email	– Map out the supply chain structure of 7 representative routes – Calculate the lead times of 7 representative routes – Map out the current storage and transport condition control of 7 representative routes
	Site visit	– Map out the packaging-related logistics activities in manufacturer and central DC (Distribution Center)

2.3.1 **Secondary research**

Secondary research involves the re-use of pre-existing data derived from previous research studies (Heaton, 2008). The secondary information builds up a solid foundation at the very beginning of this project in a relatively quick and inexpensive way, and is almost the point of departure for primary research (Stewart & Kamins, 1993). Based on previous studies, the author is able to investigate new or additional research questions and to take advantage of practical approaches to design the research plan.

The secondary data used in this project include the published scientific papers and the relevant internal reports from Danone Nutricia. The study scope of the scientific papers includes interview techniques, the influencing factors of sensitive vitamins and unsaturated fatty acid, shelf life indicators, storage and transport condition control during the supply chain, and the integration of supply chain evaluation and packaging design. The internal reports study mainly focuses on the previous packaging improvement projects, shelf life extension projects and logistics management improvement projects. The published bibliographies give a general illustration of the required information. In addition to that, the internal reports provide more specific and detailed information that is based on the specific context of Nutricia. With the combination of both published papers and internal reports, the author is able to build up the academic framework in an integrated way. The key informations that are relevant to this project are summarized and synthesized into text, then are used in the thesis to build the theoretical framework (or related literature) and to subsequently help analyze the primary data.

2.3.2 **Primary research**

Primary research is an important piece of many research projects. Using proper techniques ensures that both qualitative and quantitative data are collected in a scientific and consistent manner. Also, choosing practical data collection methods helps enhance the accuracy, validity and reliability of research findings (Harrell & Bradley, 2009).

2.3.2.1 Internal Interview

Interviews are discussions meant to gather information on a specific set of topics between an interviewer and an interviewee. Interviews can be conducted in person or over other tools like cellphone or email.

The internal interviews conducted in this project include face-to-face meetings and semi-structured interviews via email. The former aims at understanding the interviewee's perceptions of how to define the product's sensitive components' requirements on packaging and logistics, while the latter aims at collecting data about current storage and transport condition control during the supply chain, as well as the product lead time in different countries.

1) Face to face interview

Face to face interview is a practical way to seek prompt and complete response with straightforward determined emphasis. Information gathered in this way are highly specified and clear since the unclear questions can be directly repeated and re-explained. However, face-to-face interviews are quite time-consuming and require the proper arrangement of guidelines, location and time to fit both interviewer and interviewees' availability (Brinkmann, 2014).

The arranged internal interviews follow the 2-stage strategy, exploration stage and clarification stage, for different purposes. The interview contents are not transcribed but instead manually documented through note-taking, and then are organized and summarized in a structured way. The details of face-to-face interviews are attached in Appendix.1.

Table 2 Face-to-face interview arrangement

Interview Stage		Number of interviews	Time devoted (hour)	Involved teams
Exploration stage		19	15	Packaging, R&D, technology*, shelf life
Clarification stage	First round	4	2	Packaging, shelf life, R&D, technology
	Second round	3	2	Packaging, R&D, technology
Total		26	19	Packaging, R&D, technology, shelf life

*R&D team focuses on product recipe development and the technology team contributes to formulation and processing.

2) Semi-structured interview via email

Due to the limited time and budget, it is not possible to visit each country to conduct face-to-face interviews and site visits to collect first-hand data. Interview via email is an effective method to receive precise responses regarding time and budget saving (McCoyd & Kerson, 2006). However, it has to be admitted that the actual situation may be different since all these informations are acquired from second-hand sources without verification, e.g., through site visit by author or datalogger confirmation.

The aim of this set of semi-structured interviews is to understand the supply chain including delivery route, transporter, warehouse and transport condition control and lead time. In total, 7 representative countries including Netherlands, Belgium, Germany, France, Italy, UK and Brazil are studied with a focus on representative

routes, taking into account their geographic locations and the availability of key contacts in local teams.

All the reply emails are synthesized into text and flowcharts, then all the contents are sent back to the local contacts for confirmation and verification to guarantee the information accuracy. The final results are discussed in chapter 4.

2.3.2.2 Site visit

Conducting site visits is an effective way to collect first-hand information through clear on-site observation and prompt replies from the instructors (Rudmann, 1994).

In this project, checklists are prepared in advance by the author and sent to the staff who will arrange the visit, in order to illustrate the main purposes of the visit as well as the desired information the author would like to collect during the trip. The special instructions for visiting, such as clothing requirements, are explained as well by the visit organizer. The visits are strictly based on the agreement on the above information between both author and the trip organizer. Photos are taken to record the on-site situation but the sensitive information are not allowed to be contained in this thesis according to the confidential agreement with Danone. The results of site visits are summarized by text and demonstrated via flowcharts or photos with mosaics on sensitive information in the afterward chapters.

1) Site visit in manufacturer

The main purpose of the site visit is to understand the logistics activities in filling process and warehousing process at the manufacturer, especially the packaging material utilization and warehouse conditions. In order to define the critical points that related to packaging improvement.

This visit is arranged in AMN production factory in Zoetmeer, Netherlands. A guided tour at the filling line, the packing line and the manufacturer warehouse is provided by a packaging engineer.

2) Site visit in DC

The main purpose of the site visit is to map and evaluate the logistics activities in receiving, storing, repacking, picking and shipping processes in DC, as well as the storage condition control. This is done in order to define the critical points that deserve attention for improvement.

This visit is arranged in AMN distribution center in Venlo, Netherlands. A guided tour in the inbound dock, the repackaging line, the storage areas and the outbound dock is provided by a logistics quality control manager and an operation manager.

3 Theoretical framework

This chapter demonstrates the theoretical framework to support and motivate the research questions proposed in 1.1 and the research objectives in 1.2.

3.1 Sensitive components of AMN products during shelf life

During the face-to-face interviews, it is mentioned that there is no available mapping protocol in Nutricia to help select the representative product, thus it is necessary to propose one practical product mapping protocol and apply it for representative product selection. This part introduces the definition of shelf life in Nutricia context and the sensitive components of AMN products regarding their influencing factors and potential critical effects.

3.1.1 **Definition of shelf life**

In general, shelf life is the time during which all of the primary characteristics of the food remain acceptable for consumption (Robertson, 2009). To specify, in Nutricia, the definition of shelf life includes three areas, nutrient label claim, sensorial attributes and physical stability. The nutrient label claim means that by the end of the shelf life, the nutrients stay in the acceptable ranges regarding label claims on the packaging. This is mainly related to the nutrient loss during processing and degradation during storage and transport. Sensitive vitamins and unsaturated fatty acids are the main concern in this area (Nijssen, 2004). The sensorial attributes refer to the noticeable changes of color, flavor, odor, texture etc. These changes normally result from the microbiologic deteriorations (Taoukis, Labuza, & Saguy, 1997) which should not be an issue in aseptic processing unless contamination. Another sensorial change is related to continuous Maillard reaction when facing severe temperature fluctuations during shelf life (Davies et al., 1998). A previous research also showed that the bigger headspace is related to the worse

sensorial performance (e.g., rancid taste, dark color) due to the component oxidation (Hassell, 2016). The physical stability illustrates the phenomena such as creaming, sedimentation and crystal formation. These unwanted instabilities are mainly related to the properties of raw materials, especially the protein ingredients, and are triggered by temperature variation during the shelf life (Simon & Hansen, 2001).

3.1.2 **Sensitive vitamins**

The liquid products of Nutricia AMN division are enriched with vitamins to increase the nutritive value and to adjust for losses during processing and shelf life. The products may either be the only source of vitamins essential for health or may provide a proportion for patients and customers. Thus it is very important to guarantee vitamin levels in these products to ensure adequate intakes. Any changes of these micronutrients in the products could be crucial for patients. Therefore, further efforts are required to understand their requirements regarding the packaging as well as the storage and transport conditions.

According to the internal case study of Nijssen (2004) and Hassell (2016), the most unstable vitamins during shelf life of Nutricia AMN products are vitamin A, B1, B9, B12, C, D3 and E. The respective characteristics of these sensitive vitamins are introduced in the following part. However, due to the limited time, the interactions between vitamins and the influences from minerals are not studied in this research.

3.1.2.1 Fat soluble vitamins

1) Vitamin A

Vitamin A is sensitive to oxidation by air in the presence of light. Exposure to light and presence of oxygen are the major factors destroying vitamin A in milk-based beverage (Vassila et al., 2002). Storage temperature and storage time also affects vitamin A stability a lot. The mean vitamin A loss in AMN liquid product under higher temperature and longer storage time is much more severe (Table 3), which implies the importance to control storage time and storage temperature within the acceptable ranges (Van et al., 2014).

Table 3 Mean vitamin A losses in an AMN liquid product during storage (Van et al., 2014)

Storage time (months)	Storage temperature		
	25 °C	37 °C	45 °C
3	5%	18%	39%
6	9%	32%	63%
12	18%	55%	86%

In addition, at pH 4.5 or lower, partial isomerization of vitamin A from the all-*trans* form to *cis* forms will occur during storage. This will result in the decrease of vitamin potency due to the lower potencies of the *cis* isomers, thus may be not compatible with label claim (Ritter, 1976).

2) Vitamin D3

Vitamin D3 is one of the important forms of vitamin D and naturally occurs in milk. As the protein powder sourced from cow milk is the basic ingredient of most of Nutricia products, it is significant to focus on vitamin D3. There are no losses of vitamin D3 when facing heat treatment. Moreover, exposure to air does not affect the stability of vitamin D3 in milk, but loss occurs when milk is exposed to light (Lešková et al., 2006). This vitamin is also adversely affected by acids (Ottaway, 1993).

3) Vitamin E

Similar to vitamin A, vitamin E is also sensitive to oxidation by air in the presence of light, but this effect should be readily avoidable during storage. The effect of temperature is little, there is no significant difference of the mean vitamin E losses when exposing the liquid sample to 20 °C and 30 °C for 12 months (Albalá-Hurtado et al., 2000).

3.1.2.2 Water soluble vitamins

1) Vitamin B1

Storage temperature is the major factor that affects the stability of vitamin B1. UHT sterilization and 6-week storage at room temperature causes 10% loss of vitamin B1 in milk (Lešková et al., 2006). Also, vitamin B1 becomes increasingly unstable as the pH increases. Even at the room temperature vitamin B1 can be destroyed relatively fast in solutions above pH 7.0 (Allwood & Kearney, 1998; Frias & Vidal-Valverde, 2001). This fact is of importance to an AMN product, Renilon, whose PH is 7.2.

2) Vitamin B9

Sunlight and particularly ultraviolet radiation has a serious effect on the stability of vitamin B9. The oxidation under anaerobic conditions (i.e. no air present) can be accelerated under heat and light (Papastoyiannidis et al., 2006). The oxygen seems to be not the key influencing factor of vitamin B9 according to the relevant study in milk samples (Ryley & Kajda, 1994). In addition, high initial

concentration of oxygen (8.4 ppm) within packaging only results in less than 6% loss compared to original value during storage for 28 days at 23 °C in the dark (Ryley & Kajda, 1994).

3) Vitamin B12

Vitamin B12 is stable against pasteurization and storage of the pasteurized milks (<10% loss). But UHT heat treatment and in particular storage of UHT milk cause great losses (McSweeney, 1998). This fact is significant because the majority of AMN products (92.5%) are treated in a combination of pasteurization and UHT. Storage temperature has a great influence on the stability of vitamin B12 in UHT products. Losses during storage at 7°C are minimal for up to 6 months, but at room temperature (25°C, the common storage condition for AMN products), losses can be significant after only a few weeks. This vitamin is also affected by oxidizing when exposed to a high level of oxygen (McSweeney, 1998).

4) Vitamin C

To retain vitamin C, proper attention must be given to oxidation and storage temperature of the products. The oxidation results from 2 factors, oxygen in ambient and the residual oxygen within headspace. According to the previous study, the application of good oxygen barrier in packaging reduces the oxidation significantly by decreasing the permeation of oxygen from outside to inside (Gliguem and Birlouez-Aragon, 2005). The residual oxygen is used primarily to oxidize vitamin C. Maximal 70% reaction of oxygen takes place with vitamin C (Borger, 2005). No further oxidation takes place once the residual oxygen has been used up. The rate of the oxidation is dependent on both oxygen and vitamin C concentrations. If the vitamin C is overdosed and the headspace is larger than 25 ml, the reaction rate is higher. And it is good to know that the headspace of the smallest bottle (125ml) of AMN aseptic products is 29ml. The concern about storage temperature is based on the fact that the minimum reaction temperature for vitamin C degradation is +23°C (Schmidl & Labuza, 2000) which is below the common storage temperature (+25°C) of most of AMN aseptic products.

3.1.3 **Unsaturated fatty acids**

Unsaturated fatty acids, especially Eicosapentaenoic acid (EPA) and Docosahexaenoic Acid (DHA), are important ingredients and the selling point of many Nutricia AMN products and are claimed to enhance patients' memory. The negative effects of oxidation of unsaturated fatty acids of AMN products include the reduction of shelf life and sensorial changes like unpleasant flavours and

odours which can be readily noticed by customers. Regarding the chemical structure of fatty acids, more double bonds contribute to higher risks of oxidation. Moreover, temperature is the key factor that accelerate the oxidation. Within +21 °C to + 63 °C, with increase of every 16°C, the oxidation speed will double (Wang, Zhang, & Jiang, 2008). Oxygen also affects the oxidation to a great extent. According to the study of Bielski, Arudi and Sutherland (1983), oxidation speed is directly proportional to oxygen concentration with the limited presence of oxygen (Zhao et al., 2011). Light and radiation also accelerate the oxidation to a certain extent (Bielski, Arudi, &Sutherland, 1983).

3.1.4 **Other components**

Based on internal testing reports, protein, fat and sugar are relatively sensitive components that requires considerations regarding the sensorial attributes and the physical stability. Protein and fat are related to creaming (Figure 3), sedimentation (Figure 4) crystal formation and viscosity increase when exposed to high temperature. Sugar normally results in colour and flavour changes during shelf life because of the continuous Maillard reaction, which is accelerated by the increase of temperature and storage time (Nunda & Dix, 2017).

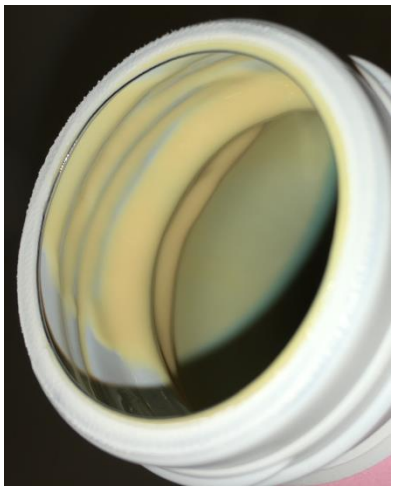

Figure 3 Visible creaming (Nunda & Dix, 2017)

Figure 4 Visible creaming and sedimentation in a translucent bottle (Nunda & Dix, 2017)

3.1.5 **Summary**

To summarize and to provide a clear demonstration, a synthesis of the influencing factors of the sensitive components mentioned, and potential critical effects during shelf life after oxidation or degradation, is presented in Table 4. The parameters in this table are based on the literature review and internal reports to adjust to Nutrica context. The degree of sensitivity regarding different influencing factors is illustrated with three level, very sensitive, slightly sensitive and stable. The relevance to potential phenomena is presented with cross mark.

As can be seen from the table, temperature and oxygen are the main influencing factors for majority of sensitive components. Also, longer storage or transport time is directly proportional to the nutrient degradation, sensorial and physical deterioration.

Table 4 Influencing factors and corresponding results of sensitive components deterioration

Factors which influence component stability*						Factors which are affected by sensitive component variation**							
			pH		Sensitive Components	Sensory Attributes			Physical Stability				Nutrient
Temperature	O_2	Light	Acid	Alkaline	Vitamins	Color	Flavour	Ordour	Viscosity	Creaming	Sedimentation	Crystal Formation	Degradation
xx	xx	xx	x	o	Vitamin A								x
x	xx	xx	o	xx	Vitamin B1								x
xx	o	xx	xx	o	Vitamin B9								x
x	xx	o	o	o	Vitamin B12								x
o	xx	o	o	x	Vitamin C								x
x	xx	xx	x	o	Vitamin D3								x
o	xx	xx	o	x	Vitamin E	x							x
					Unsaturated fatty acid								
xx	xx	x	o	o	ω-6, EPA, DHA		x	x					
					Other components								
xx	o	o	o	o	Protein +Fat				x	x	x	x	
xx	o	o	o	o	Sugar***	x	x						
xx	o	o	o	o	Calcium****						x	x	
*very sensitive	xx					**Related to the phenomenon			x				
slightly sensitiv	x												
stable	o												

3.2 Packaging system and supply chain

3.2.1 **Packaging system**

Packaging plays six primary functions: (1) Containment; (2) Protection; (3) Apportionment; (4) Unitization; (5) Convenience; and (6) Communication (Paine, 1981). These functions impact the product design, manufacturing, transportation, distribution, warehousing and marketing functions of a firm (Paine, 1981); conversely, these functions are determined by the requirements from product development and logistics aspects.

Packaging is a system with hierarchical levels. Packaging system performance is affected by the performance of each level and by the interactions between these levels (Hellström & Saghir, 2007). Normally the packaging system can be classified into three levels, primary, secondary and tertiary. Primary packaging refers to the packaging that in direct product contact; the secondary packaging is designed to contain a group of primary packaging; an assembly of a number of primary or secondary packages on a pallet or a roll container is defined as tertiary packaging (Jönson, 2000).

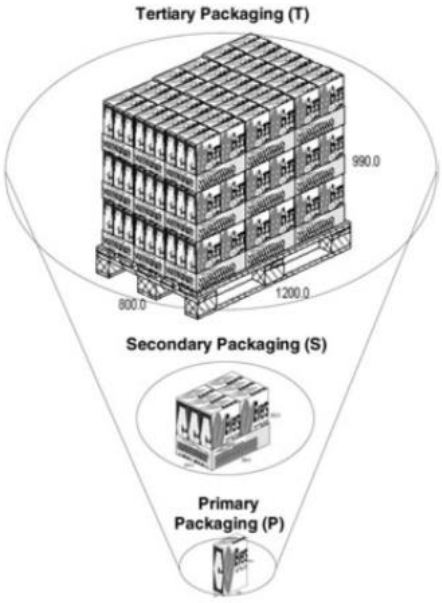

Figure 5 Packaging system levels (Jönson, 2000)

Therefore, in this research, defining the packaging levels and mapping out their characteristics is a fundamental step in packaging and logistics evaluation.

The mapping of packaging system is conducted through on-site visits in manufacturer and central DC in Netherlands.

3.2.2 **Supply chain**

Christopher (1992) defined that a supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer. In other words, a supply chain consists of raw material and component producers, product assemblers, wholesaler, retailer merchants, distribution companies as well as the ultimate consumer.

Regarding the research objectives of this study, the supply chain is defined as a set of three entities in including product manufacturer, distributer and retailer which are involved in the production, storage and transport of the products. More specifically, the studying scope starts from after-filling point in the manufacturer and ends up at the retail outlets, mainly considering the **B2B approaches**.

The information of supply chain physical flows of different delivery routes is collected through semi-structured interviews via email.

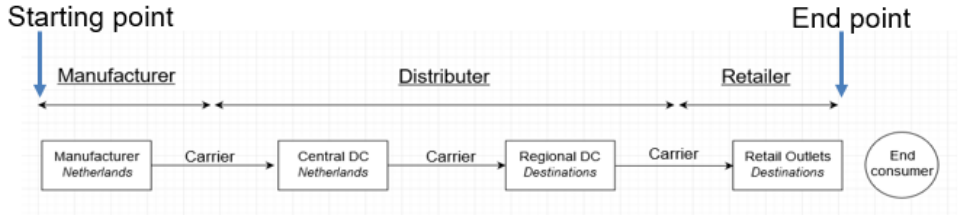

Figure 6 Studying scope of supply chain in this case

3.2.3 **Interactions between packaging and supply chain**

Packaging specifications directly influence the time required for completion of packaging operations (Lee & Lye, 2003), which ultimately affects product lead time and due date performance (delivery) to the customer (Lockamy, 1995). Considering logistics activities, packaging affects activities such as warehousing, transport and material handling. By adapting logistics and packaging activities to

each other, the packaging becomes more efficient in fulfilling its logistics role (Bowersox & Closs, 1996).

Therefore, it is necessary to recognize packaging and logistics as an integrated system and to explore the interactions between different packaging levels and logistics activities in this study, in order to define the improvement spaces to ensure that packaging and logistics fit each other.

The interactions are defined through packaging-related logistics activity mapping. The mapping is conducted through on-site visits in manufacturer and central DC in Netherlands.

3.2.4 **Supply chain mapping and evaluation**

From a strategic perspective, a supply chain study can perform as a building block for further decision making. By measuring the performances of the current supply chain in a qualitative way, all the relevant details are presented, which enables the author to see through the appearance to perceive the essence of improvement possibilities (Liang et al., 2006).

In this research, supply chain mapping and evaluation cover the description of the packaging system, flow of representative routes and packaging-related logistics activities in manufacturer and Distribution Centre (DC), which provide a better understanding of current packaging and logistics system.

3.2.5 **Lead time**

3.2.5.1 Definition of lead time

The conventional definition of total lead time in supply chain management is the combination of the internal lead time (the time required for planning the order and preparing the manufacture materials) and the external lead time (the time required for manufacturing, distribution and delivery). Lead time is an important indicator of supply chain performance measurement and determines the order planning and inventory (De Treville, Shapiro, & Hameri, 2004).

In this case, lead time starts from when an order is placed and ends until the order is delivered to the end customers. To specify, it is the sum of planning time, manufacturing time, storage time in manufacturer, delivery time from manufacturer to DC, storage time in DC, delivery time from DC to next distribution stops and rotation time in retail outlets (the time between the retailer receiving the order and the products are sold to customers).

3.2.5.2 Lead time and shelf life

Many case studies show that by reducing lead time, firms are able to stand out in "Time-Based Competition" with higher productivity (Blackburn, 1991; Holmström, 1995; Schmenner, 1988). In this case, with lead time reduction, it leaves longer period of time until the use-by date. Thus, it allows end customers to consume products with all the characteristics remaining as same as possible to the original status. It means that with shorter lead time, the consumer experience will be enhanced because there is a greater chance that the nutrient label claims, sensorial attributes and physical stability practically remain the same as when the products were just produced. Regarding this, the lead time from after-filling in the manufacturer until the retail outlets is the main focus of this study.

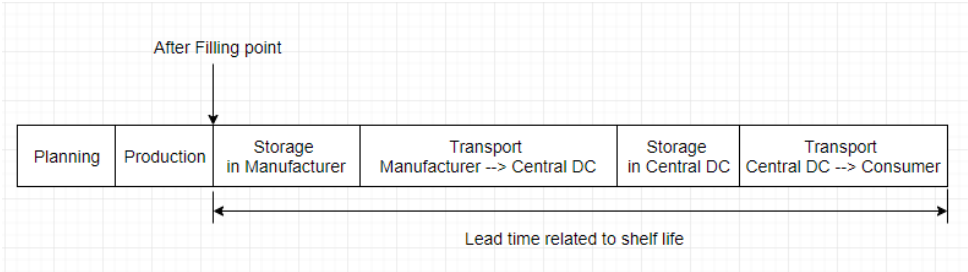

Figure 7 Lead time in this case

The data of lead time in this case are collected through semi-structured interviews via email.

3.2.6 **Summary**

Packaging system mapping provides an important platform to have straightforward perception of the different levels of packaging. After analyzing the requirements of packaging in the supply chain, it is possible to show which packaging aspects are the most important in logistics activities along the supply chain.

Logistics activity mapping provides a way to analyze tangible issues, and is also a practical approach to understand how and why these activities are conducted. By analyzing the mapping results, it is possible to identify the inefficiency spaces and unnecessary or excessive activities, which makes this work an elementary step to understand the role of packaging in logistics levels (Hellström & Saghir, 2007).

By linking packaging mapping and logistics study results, it is applicable to enhance integrated decision making.

By calculating the lead time of representative routes and comparing it to the product shelf life, the improvement spaces can be determined. The results and analysis will be presented in the following chapters.

The specified data collection approaches and corresponding mapping areas are summarized in Table 5.

Table 5 The data collection approaches of packaging system and supply chain mapping

Data collection approaches	Mapping areas
Semi-structured interview via email	Physical flows of the representative delivery routes Lead times of the representative delivery routes
On-site visit	Packaging system description Packaging-related logistics activities

4 Results and discussion

This chapter aims at answering the research questions proposed in 1.1.

- What are the requirement of the product's packaging system, regarding storage and transport in supply chain?

- What are the critical points of storage and transport conditions throughout the product's supply chain and are there any potential opportunities for improvement?

In this chapter, research results are presented with corresponding analysis. Firstly, the process of creating the product mapping protocol is explained. The initial intension was to select a representative product by applying 94 AMN products to this protocol, and then coming up with one representative product. However, due to the lack of critical data like shelf life testing reports, the product selection decision is instead made according to the latest production schedule as it is possible to follow the product. Afterwards, by focusing on the selected product, the supply chain evaluation is performed, including the packaging system and supply chain mapping, interactions between packaging and logistics activities, lead time calculation, and representative routes storage & transport conditions mapping. Finally, the critical points within the supply chain are defined for further improvement based on the representative product's requirements towards packaging and logistics, with regards to optimal operation, storage and transport conditions.

4.1 Product mapping protocol

It is practical to choose one representative product, regarding the sensitive components, as the representative subject for further supply chain study. This part explains how the product mapping protocol is built to facilitate product selection and how a representative product can be selected by applying this protocol.

4.1.1 **Motivations of the mapping protocol**

Based on the study on sensitive components of Nutricia AMN products in 3.1, a mapping protocol is built to map the variations of sensitive vitamins, unsaturated fatty acid and other components that have negative effects on sensorial attributes and physical stability.

As illustrated in Table 6, the protocol includes 3 main parts: basic product information, sensitive components and data references.

Table 6 The outline of mapping protocol

Basic information	Family
	PDS Number
	Product Name
	Flavour
	Volume
	Shelf life (Month)
	PH
Sensitive components	Sensitive vitamins
	Unsaturated fatty acids
	Functional components
	Other components
Data references	

4.1.1.1 Basic product information

This part starts with product family name, which illustrates the classification of products according to their different clinical functions. This setting makes it easier to compare the stability of products within one family. Then follows the PDS number (Product Development Specification), which is the unique identity code for each product and also is an effective “common language” to communicate with other teams internally. Product name and flavour may be slightly different in different marketing areas, hereby the product name and flavour are based on the marketing portfolio in European countries. Then it comes to volume, which is directly linked to the corresponding packaging characteristics like packaging format, material, inner surface and headspace etc. For each packaging volume format, the headspace is different, which decides the amount of residual oxygen within headspace which affects the variation of sensitive components regarding oxidation. The current shelf life (month) gives a reference for how long the shelf life testing should last and is the end point to compare the component variation with original values. Moreover, shelf life is of significance for further supply chain performance measurement regarding the comparison between shelf life and lead

time. pH is practical for packaging material selection regarding the acidity tolerance limit. Furthermore, in Nutricia the application of heat treatment approach depends on product pH. Products with pH over 5 go through pasteurization and UHT treatment whereas products with pH below 5 go through only pasteurization. The heat treatment approach has a great influence on nutrient degradation, especially vitamin B12 (see 3.1.2.2) during the storage.

4.1.1.2 Sensitive components

This part aims to quantitatively interpret the variations and target values of sensitive vitamins, total amount of unsaturated fatty acids and other components. For some products containing special functional components like EPA, DHA or UMP, these components also need to be included in this protocol because they are the selling points for these products and it is necessary to have them remain on acceptable levels. The variations of other components, meanwhile, are introduced by scale from 0 to 5 according to their sensorial performances and physical stability during shelf life (see Table 7Table 7). Here, a value of 0 illustrates that the components are relatively stable during the shelf life, while 5 means that there are extreme unacceptable deteriorations. The setting of scale is based on the current shelf life testing standards in Nutricia.

Table 7 Scale of sensorial attributes and physical stability performances

Components	Sensorial attributes/Physical performances	Scale
Protein+Fat	No creaming/sedimentation	0
	Barely creaming/sedimentation	1
	Slightly creaming/sedimentation	2
	Moderate creaming/sedimentation	3
	Very creaming/sedimentation	4
	Extreme creaming/sedimentation	5
Sugar	No color/flavour change	0
	Barely color/flavour changes	1
	Slightly color/flavour changes	2
	Moderate color/flavour changes	3
	Very color/flavour changes	4
	Extreme color/flavour changes	5

The target values of sensitive vitamins, total amount of unsaturated fatty acids and functional components (EPA, DHA and UMP) refer to the nutrient label claims on the packaging. The setting of this value already takes into account the potential losses during processing. And this value illustrated the desired component amount

levels at the end of the shelf life which are the target levels Nutricia would remain with the help of packaging and logistics.

The variation of vitamins and unsaturated fatty acid is presented quantitatively by the variation index (VI):

$$\text{Variation Index} = \frac{Value\ at\ the\ end\ of\ shelf\ life - Original\ value}{Original\ value} * 100\%$$

If VI is over 0, it means that the components increase during the storage and transport, which is a rare phenomenon for sensitive components that easily get degraded or oxidized. If VI is below 0, it means that the components decrease during shelf life. The lower the VI is, the more unstable the component is, and it deserves attentions to define the reason behind.

4.1.1.3 Data references

Data references need to be attached with hyperlinks in the protocol file to specify the reference documents. It is due to the fact that 1) nutrient variation testing and sensorial & physical testing are conducted in different departments. If there is any unusual situation, the data references are the key to access the responsible teams for investigation; 2) the shelf life testing in the food industry are based on batches and reference documents can help trace back to the specific batch. By comparing the variation data of different batches, both the packaging team and other teams are able to receive useful insights regarding raw material, processing, supply chain management and so on.

4.1.2 **Application of the product mapping protocol**

The aim of building up the mapping protocol is to help choose a product which shows a severe instability during shelf life. With the calculation of variation index and quantitative description of sensorial and physical changes, it is easy to define the most sensitive product.

Herby is an example of three AMN products with diverse characteristics to explain how the mapping protocol works. Please note that the basic information and target values in the following table are real values from product development specifications but the variation values and data references are not real data but only for demonstration. For better understanding, the original table with all the information in one row is separated into three sub-tables (Table 8).

Table 8 The product mapping protocol examples

			Basic Info													
PDS Number	Product Name	Flavour	Volume	Current shelf life(month	pH											
1005518	Souvenaid	Cappucino	125ml	12	6.2											
1005193	Diasip	Strawberry	200ml	12	6.8											
1005926	Calogen	Neutral	500ml	12	5.6											
			Sensitive Vitamins													
			Vitamin A (μg-RE/100ml)		Vitamin B1(mg/100ml)		Vitamin B9(μg/100ml)		/itamin B12(μg/100ml		Vitamin C(mg/100ml)		Vitamin D3(μg/100ml)		Vitamin E(mg-α-	
PDS Number	Product Name	Flavour	VI	Target	VI	Target	VI	Target	VI	Target	VI	Target	VI	Target	VI	Target
1005518	Souvenaid	Cappucino	-25.2	160	-21.9	0.15	-5.7	320	**-29.5**	2.4	**-53.9**	64	-2.1	0.70	-7.1	32
1005193	Diasip	Strawberry	-13.3	82	**-45.1**	0.40	-1.2	38	-2.6	0.65	**-30.7**	15	-6.2	1.2	-0.2	2.5
1005926	Calogen	Neutral	/	0	/	0	/	0	/	0	/	0	/	0	/	0
			Unsaturated fatty acid(g/100ml)						unctional Componen		Other components		Data references			
			Total		EPA		DHA		UMP(mg/100ml)		Protein + Fat	Sugar				
PDS Number	Product Name	Flavour	VI	Target	VI	Target	VI	Target	VI	Target						
1005518	Souvenaid	Cappucino	-2.7	2.6	-1.9	0.24	-0.8	0.96	-2.1	500	2	2	shelf life report -2017			
1005193	Diasip	Strawberry	-3.8	3.3	/	/	/	/	/	/	1	**5**	shelf life report -2009			
1005926	Calogen	Neutral	**-63.9**	44.7	/	/	/	/	/	/	**3**	0	shelf life report -2012			

As can be seen from the protocol, these three products are from the same family and with same shelf life of 12 months. The pH of Diasip is almost neutral (6.8) while Souvenaid (6.2) and Calogen(5.6) are relatively acidic. The sensitive components which result in great losses in shelf life distinguish from others with high variation index (marked with red circle in Table 8) and are defined in Table 9.

Table 9 The defined sensitive components

PDS Number	Product Name	Flavour	Sensitive components	VI/scale
1005518	Souvenaid	Cappuccino	Vitamin B12	-29.5
			Vitamin C	-53.9
1005193	Diasip	Strawberry	Vitamin B1	-45.1
			Vitamin C	-30.7
			Sugar	5
1005926	Calogen	Neutral	Unsaturated fatty acid	-63.9
			Protein+fat	3

Then, by checking the Table 4 in 3.1.5 the influencing factors and potential critical effects of variation of above components are clearly mapped out as Table 10 shows (key parameters are marked with red circle).

Table 10 The influencing factors and critical effects of variation of the defined sensitive components

Factors which influence component stability						Factors which are affected by sensitive component variation							
			pH		Sensitive Components	Sensory Attributes			Physical Stability				Nutrients
Temperature	O_2	Light	Acid	Alkaline	Vitamins	Color	Flavour	Ordour	Viscosity	Creaming	Sedimentation	Crystal Formation	Degradation
x	xx	xx	o	xx	Vitamin B1								x
x	xx	o	o	o	Vitamin B12								x
o	xx	o	o	x	Vitamin C								x
					Unsaturated fatty acid								
xx	xx	x	o	o	ω-6, EPA, DHA		x	x					
					Other components								
xx	o	o	o	o	Protein +Fat				x	x	x	x	
xx	o	o	o	o	Sugar	x	x						
very sensitive	xx					Related to the phenomenon			x				
slightly sensitiv	x												
stable	o												

By following the protocol, it is apparent that vitamin B12 and vitamin C are sensitive components of Souvenaid and oxygen is the main influencing factor which may result in the degradation of these two vitamins. For Diasip, vitamin B1, vitamin C and sugar are critical components which may get affected by oxygen, light, pH increase over 7 and high temperature. The potential deteriorations include nutrient degradation and changes in color and flavor. For Calogen which contains no vitamins but unsaturated fatty acids, the temperature and oxygen are the significant influencing factors and it can be assumed that the potential critical effects include flavor and ordour changes as well as the physical instability like viscosity increase and creaming.

Table 11 Product mapping results

Product	Sensitive components	Influencing factors	Critical effects
Souvenaid	Vitamin B12	O2	Degradation
	Vitamin C	O2	Degradation
Diasip	Vitamin B1	O2	Degradation
	Vitamin C	O2	Degradation
	Sugar	Temperature	Color/flavour changes
Calogen	Unsaturated fatty acids	Temperature, O2	Flavour/ordor changes
	Protein+fat	Temperature	Viscosity increase, creaming, sedimentation, crystal formation

As mentioned in the beginning of this chapter, the original intension was to use this protocol to choose a representative product with severe issues during shelf life regarding the sensitive component variation. However, due to the lack of critical data like shelf life testing reports, and in agreement with Nutricia, Diasip Strawberry 200ml is selected instead as the representative product for supply chain research. This is because 1) 200ml is the most frequently produced volume format of AMN; 2) the Diasip Strawberry's production schedule was able to fit within this project's timeframe.

4.1.3 **Key shelf life influencing factors of the representative product**

According to available data, the shelf life of Diasip strawberry 200ml is 12 months. The pH is 6.8 which is over 5, so this product goes through the heat treatment of pasteurization and UHT before filling. These characteristics represent

the majority of AMN liquid products. The level of sensitive vitamins and unsaturated fatty acid is on average (compared to 94 AMN aseptic oral nutrition products), which makes Diasip a practical representative because the research on storage and transport can provide a general reference for other products with similar levels of components.

According to a previous internal study (Nijssen, 2004), temperature and oxygen are the key influencing factors of Diasip Strawberry during shelf life. However, the current equipment in Nutricia is not applicable to precisely measure the residual oxygen in headspace to detect the oxygen permeation during supply chain; thus, temperature becomes the main research focus. With storage temperature over 25 °C for a certain period, the potential critical effects include spoilage, vitamin degradation, unsaturated fatty acid oxidation, sensorial attributes change like darker color and blander strawberry flavour, physical instability like sedimentation and creaming. With low temperature under 0 °C for a certain period, it may result in crystal formation and gelling (Cornelly et al., 2014). In summary, **0°C to +25°C** is the suggested temperature range for storage and transport.

Therefore, for supply chain research, temperature control in warehousing and during transporting deserves particular attention.

4.2 Packaging system and Supply chain evaluation of representative product

Focusing on the representative product, this part first describes the product characteristics and its impacts on the packaging system. Then, the description of the current packaging system components and their respective requirements is given. Afterwards, the physical flow of current supply chain is presented, and interactions between packaging system and logistics are discussed based on packaging-related logistics activities in the manufacturer and DC. In addition, the structure of representative routes is introduced along with their different lead times. Ultimately, all the above results are summarized for further discussions.

4.2.1 **Product characteristics and impacts on packaging system**

This product has high viscosity, once there is any leakage, the sticky content will result in negative effects like contamination on every packaging level and affects the consumer experience. Moreover, the retail price of Diasip is 12.13 euros per

pack which contains four 200ml bottles, resulting to 3.03 euros per bottle. The high price makes it hard to bear a certain amount of leakage and damage regarding the economic losses in supply chain.

There are 3 parts of the product: the bottle which contains the product, aluminum foil to seal the bottle, and the cap to provide rigid protection for product. The general shape of the primary packaging is an irregular cylinder with a neck (Figure 8). This design manages to save production costs because it fits with the extrusion blow molding process. Moreover, the curves along the bottle makes it easy to hold, especially practical for elderly customers. However, the irregular shape raises certain extent of space waste during transportation compared to regular cylinder-shaped or cube-shaped bottles.

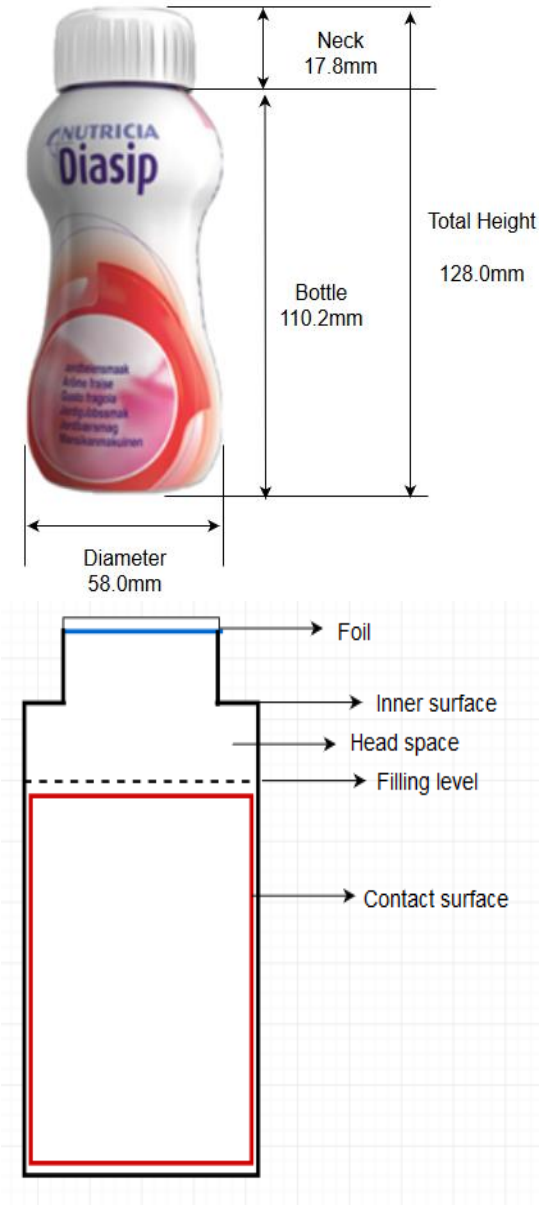

Figure 8 Primary Packaging of Diasip 200ml

The weight and general dimensions regarding the height and diameter determine the amount of bottles that can be loaded to a pallet and transporters, due to the weight and volume limit. The weight also affects the availability of handling activities in all supply chain actors. The packaging volume determines the material usage and cost. The product volume determines the filling level during the filling

process at the manufacturer, as well as the contact surface which is the area that package and product directly come in contact with each other, and is related to substance migration (Figure 8). The space between filling level and foil is the headspace, within which the residual oxygen is highly related to vitamin degradation and sensorial attributes deterioration regarding oxidation. Theoretically, 3-5% residual oxygen within headspace is allowed, but in reality is slightly higher than 5%, according to a previous study (Kim, 2016). The packaging constitutes a 6-layer structure with different types of plastics to provide oxygen, moisture and light barriers. These materials determine the cost for manufacturer and provide rigidity to bear long-distance transportation; however, they also require special concern during storage and transport because the oxygen barrier is sensitive to humidity. Before entering the filling process, the primary package goes through the sterilization process under 170°C peroxide and hot air. This heat treatment results in slight changes (normally, shrinkage) of the packaging dimension, thus affecting the stackability of other packaging levels. The heat treatment may also accelerate the chemical and physical substance migration between packaging and product. More details are presented in Appendix 3.

4.2.2 **Packaging system components and requirements**

4.2.2.1 Primary packaging

As detailed illustrated in 4.2.1, the primary packaging of Diasip is a 200ml plastic bottle with 6-layer structure and the plastic sleeve which includes labeling information. The total weight is 233g (including packaging and product). The packaging barriers are required to be strong enough to provide rigidity for the inside product to bear long-distance transport. And they also provide sufficient protection to reduce oxygen and light permeation. This is because 1) once the packaging got misshaped, it is no longer attractive to customers even though the inside product is intact; 2) oxygen and light may penetrate through weak barriers and thus affect the product quality. In this way even though the packaging is intact, the product inside is no longer acceptable for consuming. On the other side, the barriers should also be well designed to reduce material cost and to enhance recyclability.

Table 12 Packaging system description

Package level	Description	Weight	Volume	Actors involved
Primary	200ml multi-layer plastic bottle with plastic sleeve	233g	$3.38x10^{-4}m^3$	Manufacturer, Distributer, Retailer, Customer
Secondary	4 bottles of products loaded in a card paper cluster	950g	$1.719x10^{-3}m^3$	Manufacturer, Distributer, Retailer
Tertiary	6 secondary packaging loaded in a corrugated board box	5.9kg	$1.392m^3$	Manufacturer, Distributer, Retailer
Pallet	63 or 81 or 99 tertiary packaging loaded in a EU pallet according to pallet pattern	Min: 396.7kg Max: 609.1kg	Min: $1.06m^3$ Max: $1.59m^3$	Manufacturer, Distributer

4.2.2.2 Secondary packaging

Secondary packaging is a card paper cluster containing 4 primary packaging **(**

Figure 9) which is also the display packaging in retailer outlets. The card paper groups the bottles inside relatively firmly to resist the fluctuation during transport. And it is a suitable packaging material regarding cost, light-weight and recyclability. Meanwhile, it also prevents primary packaging from unwanted contaminants like dust. The disadvantage of this secondary packaging is that moisture decreases the mechanical strength of card paper; once there is any leakage or the packaging is exposed to a humid environment, the protection level will decrease accordingly, or it may even stick to the primary packaging.

Figure 9 Secondary packaging

4.2.2.3 Tertiary packaging

The tertiary packaging is a corrugated board box which contains 6 units of the secondary packaging, weighing 5.9kg. Corrugated box is a rather economic material and is easy to produce and to recycle. Meanwhile, it provides protection for primary and secondary packaging regarding mechanical damages and potential contaminations (e.g., leakage from other products). A key point to address regarding tertiary packaging is the handleability. The current weight is friendly for operators to pick, and there are 2 holes on the box for gripping. The disadvantage of the corrugated board is similar to card paper, which can be easily contaminated and damaged by the leakages (Figure 10).

Figure 10 Leakage on corrugated board box

4.2.2.4 Pallet

It is convenient to use the EU Pallet as the transport unit in Europe because the majority of European countries adjust their logistics system to the EU pallet. Three pallet patterns are applied to fulfill demands of various customers, with minimum 39.24% and maximum 58.86% fill rates regarding the space usage in the transporter (45 ft wide high cube pallet truck or container). The pallet is wrapped with shrink film in order to sustain the stability and to resist potential contaminations and damages like moisture during storage and transport. The material of pallet in this case is wood, which is friendly for recycling.

Figure 11 The wooden EU pallet

More detailed information of packaging system is presented in Appendix 4.

4.2.3 **Supply chain description**

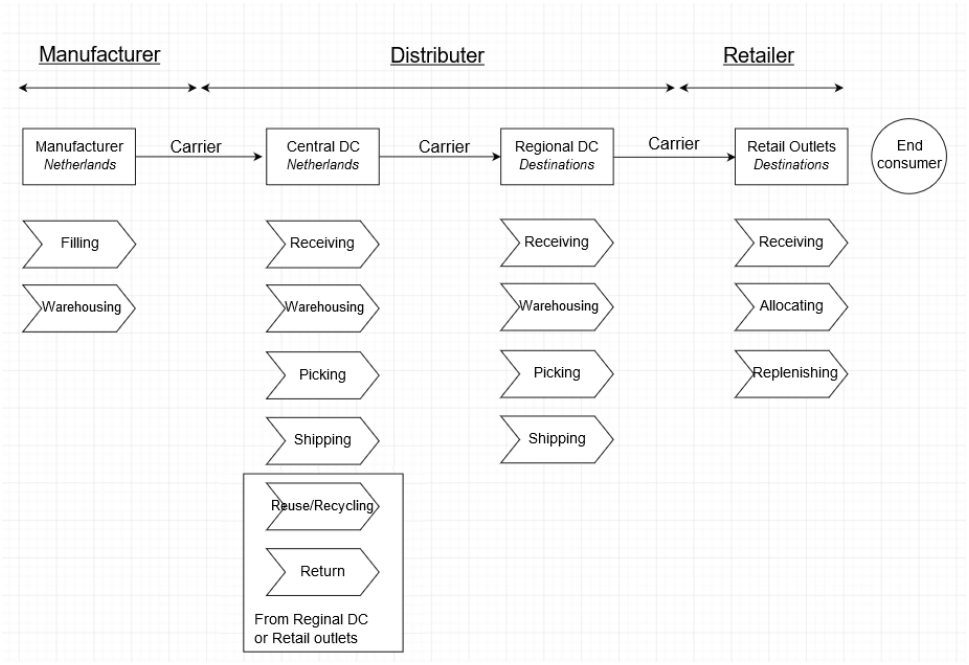

Figure 12 Supply chain structure

The general structure of supply chain is presented in Figure 12 with main logistics activities in each actor. The manufacturer (Netherlands) is in charge of production. After filling and packing processes, the finished goods are transported to central

DC (Netherlands). Central DC in Netherlands and regional DC in destination countries cooperate with each other for multi-level distribution; the detailed delivery routes and their respective structure will be explained in 4.2.6. There are 2 types of customers in this case, household customers and retail outlets like elderly homes, pharmacies and hospitals. This study mainly focuses on the latter.

In this part, the interactions between packaging system and supply chain in manufacturer and distributer are studied through packaging-related activities in these 2 actors, in order to define the requirements on packaging from a logistics point of view. The lead time of representative routes are calculated, storage and transport conditions of each route are introduced, then compared with current shelf life and storage requirements regarding sensitive components of Diasip, in order to ultimately determine the improvement opportunities.

4.2.4 **Packaging-related logistics activities**

Packaging-related logistics activities in manufacturer and central DC are illustrated in flowchart with detailed explanation in text. They are attached in Appendix 5 from page 69 to page 79. Then the critical points in terms of the inefficiency spaces and unnecessary or excessive activities are identified and discussed.

4.2.4.1 Logistics activities at the manufacturer

Activities at manufacturer including filling and warehousing requests huge capital investments regarding packing equipment and warehouse management, etc. Majority of activities are accomplished automatically, but a few steps like packaging material input, quality control/check, and warehousing involve labor. The high level of automation makes it hard to change the activities, otherwise it may result in further investment. One noteworthy detail is the overhang after palletization, which means that the stacked goods exceed the edges of pallets (Figure 13). Overhang may affect the stability of pallets during storage and transport, especially when facing outside forces. Stretch films are applied to enhance the stability, sealing tape is also utilized when there are damages on small part of stretch films. Further suggestions need to be addressed with integration of logistics activity mapping in central DC.

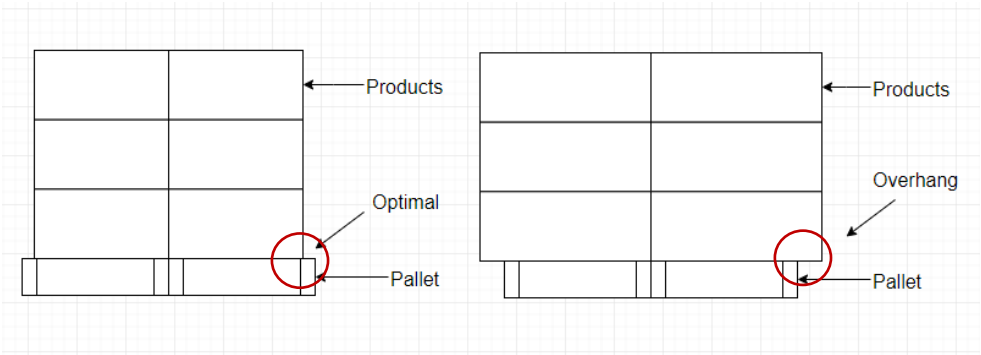

Figure 13 Overhang on pallet

4.2.4.2 Logistics activities at central DC

Operational efficiency is the key point deserving discussion in DC regarding value-adding. Nutricia takes great efforts towards this. Standardized pallet labels are used throughout the whole supply chain to enhance universal information communication and traceability. And for the whole pallet orders, EPT (electric pallet transport) operators are assigned to conduct storing and picking in one ride. Meanwhile, as can be seen from the flow charts above and as is clearly illustrated in Appendix 5, the majority of logistics activities are labor-intensive, especially the repacking and picking processes. These activities require huge investments in training operators, operation schedule arrangement and most importantly, require a high degree of handleability of the packaging. For example, the corrugated box is desired to be easy to open in order to ease manually repacking process, which means the sealing glue is not desired to be too strong, otherwise the repacking efficiency will be reduced accordingly. But the potential tradeoff is that the packaging will be less robust and may be accidently open during the picking process or transport; this will result in decrease of operational efficiency and possible leakage.

On the other hand, many packaging materials are wasted during the repacking process, with pallet labels and stretch films removal and application in almost every process. It would be optimal to avoid repacking if every product is packed in requested packaging at the manufacturer. However, the volume of repacking orders only makes up a small percentage. Moreover, the repacking requests change from time to time and it is not applicable to add new packing lines in the manufacturer to fulfill these requests considering the potential investments.

In addition, the inefficient stackability of the pallet is also an issue of significance in central DC. In some cases, the customer places the order of several boxes of products (Figure 14). These boxes cannot fill a full pallet and the customer also requests not to stack pallets in transporters. In the end, it results in a great space waste and low fill rate.

Figure 14 The space waste on pallets

For returned goods, many time are wasted during round trip delivery. Sometimes there are only few time left before due by date when the returned products arrive at central DC. In the end, it is hard to resell the returned goods but dispose them.

4.2.4.3 Summary

The issues in manufacture and central DC regarding the interaction between packaging system and logistics can be summarized in following bullet points:

1) Overhang of pallets
2) Operational efficiency, which is affected by labor-intensive repacking and picking processes and the degree of handleability of packaging system
3) Packaging material waste in many processes
4) Inefficient stacking of pallets
5) Unable to resell returned orders due to shelf life limitations

4.3 Lead time

4.3.1 **Introduction**

Lead time in this study is the sum of planning, production and warehousing time in manufacturer, warehousing, transport time between logistics points and rotation time in retail outlets (the time between products arriving at retailer and products are sold to customers). It varies depending on orders, SKU etc. In this section the average value of the representative product (Diasip Strawberry 200ml) is illustrated which represents the average lead time of AMN 200ml PB products.

Planning time illustrates the time from receiving the order until starting production. It normally takes 8-9 weeks in this case. Production time refers to the time which is required to finish producing one batch of products. It takes 1 day for the representative product production. After production the finished products are directly transported to central DC in most cases. The transport takes **1.5 days** in average depending on the transporters and the delivery routes. Afterwards the products are stored in central DC for **23 days** due to the time-consuming logistics activities mentioned in 4.2.5 and inventory concerns. Next, lead times start to differ depending on the different delivery routes.

There are two routes of transportation from central DC to next logistics points, serving different countries within or outside Europe. The **G4 route** serves four countries including Netherlands, Belgium, Germany and France. The **G38 route** is designed for in total 38 countries to deliver products to countries within Europe or to the oversea countries like Brazil. The supply chain structures of G4 countries are similar and relatively simple, it is practical to summarize the overall conditions by calculating the average lead time value of the G4 area. The supply chain structures of G38 countries are relatively complicated compared to G4 areas and varies from one country to another. Regarding their supply chain structures and lead times, it is interesting to compare 1) G4 and G38 areas; 2) different G38 countries. Also, regarding the regional logistics contact availability, ultimately the selected routes are the routes with accessible information.

In the end, representative delivery routes studied in this research include all G4 countries (Netherlands, Germany, Belgium, France) and three G38 countries (UK, Italy, Brazil). The logistics system and respective lead times are introduced in the following sections.

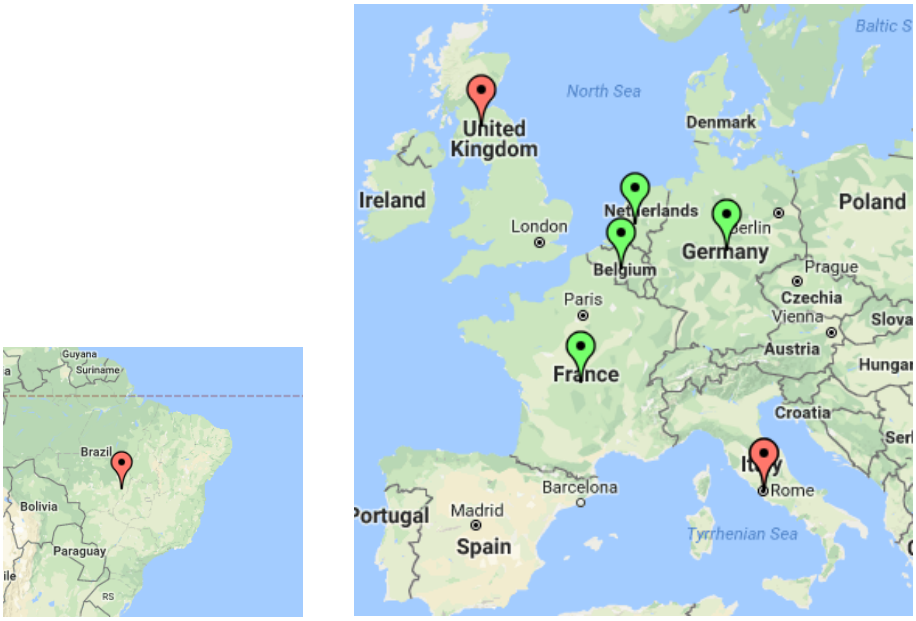

Figure 15 Representative routes studied in this project.

Green - G4 countries, Red - G38 countries

4.3.2 **Lead times of representative routes**

G4 Route (Netherlands, Germany, Belgium, France)

Orders that follow G4 route are directly delivered to end customers or firstly are delivered to CBU hubs which serve like transition stops in which pallets are re-allocated into sub-routes in short time in destination countries. Then products are delivered to the end customers (hospital, pharmacy, elderly home or patients' home), or are delivered to wholesaler for downstream distribution (Figure 16).

On average it takes **2 days** to delivery in G4 route. Netherlands, Germany and Belgium follow next day delivery, so 2 days are spent. Delivery time in France varies from 2 days to 5 days according to destination areas. Delivery time could be prolonged if the customers are not available on delivery day to pick up orders and orders are returned to upper logistics stops.

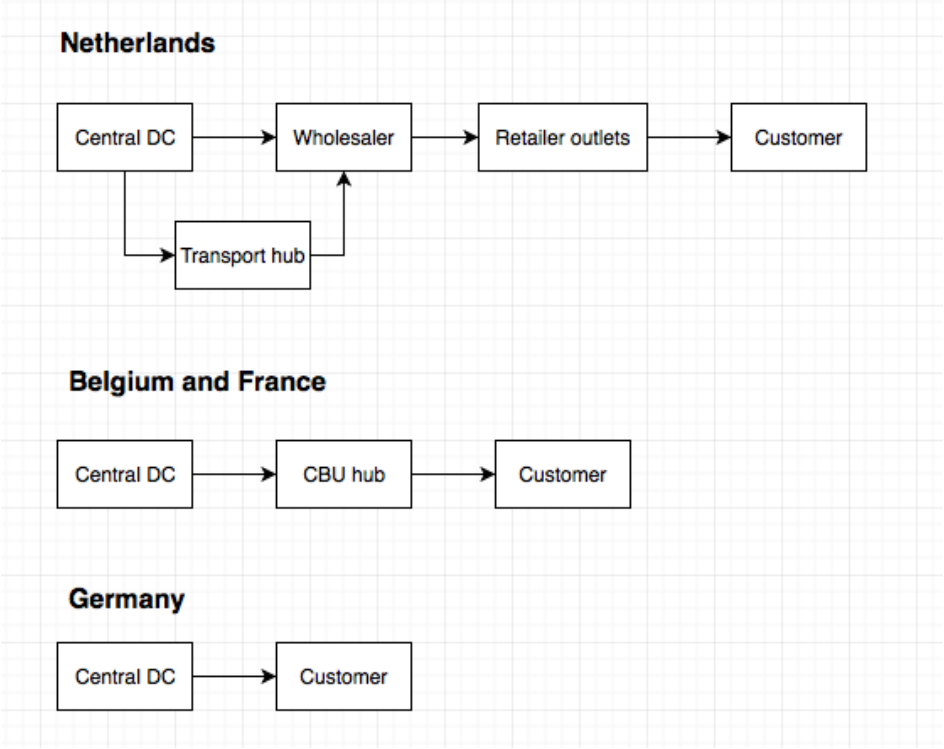

Figure 16 Delivery routes of G4 countries

G38 Route

Orders that follow G38 route are firstly delivered to regional DC in destination countries where the similar logistics activities like repacking and re-allocating are addressed as in central DC (Venlo), then products are delivered to wholesalers or individual customers through different sub-routes. In total it takes **84 days** for UK route after departing from central DC until the products are sold in retailer outlets or delivered to patients' home. Brazil route takes **111 days,** Italy route takes **60 days** and the retail outlets of both countries are mainly hospitals.

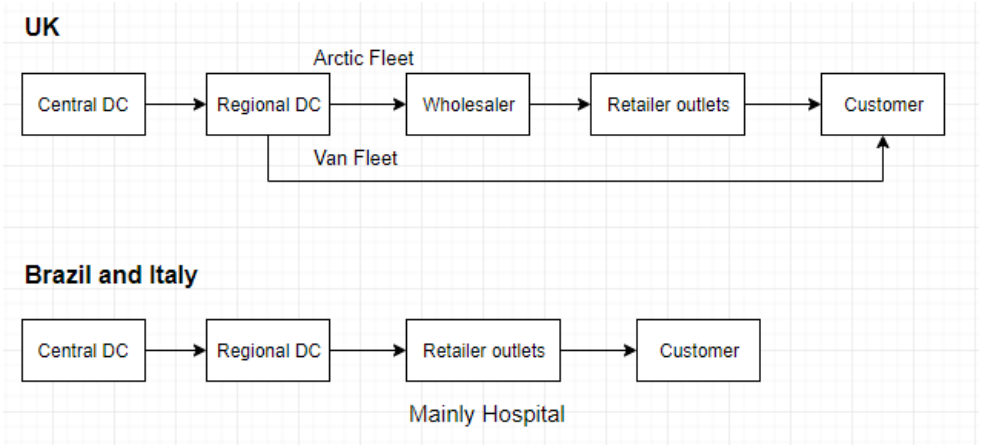

Figure 17 Delivery routes of G38 countries

Detailed information regarding the time and transporters between each logistics stop of all representative routes are introduced in Appendix 6 for deeper understanding.

4.3.3 **Summary of lead time**

On average, the lead time of G4 route is **26.5 days**, UK requires **107 days**, Brazil requires **134 days** and Italy takes **60 days**. If the same batch of products are delivered to end customers following the above routes, due to the different lead times it can be assumed that the sensorial attributes and nutrient contents will differ.

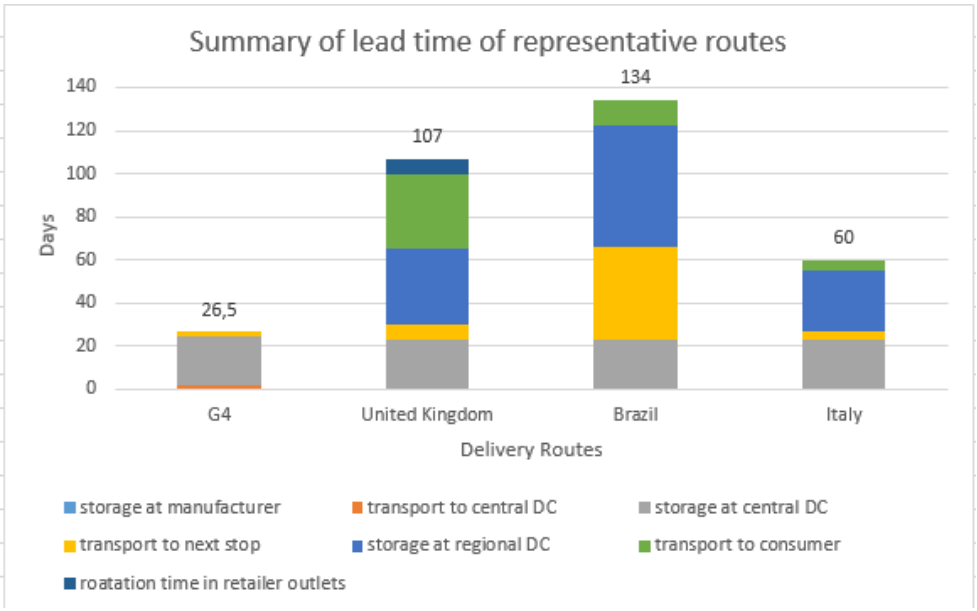

Figure 18 Summary of lead time

In G4 route, the **storage time at central DC** takes the majority of time of lead time, this is due to the time-consuming repacking and picking process and inventory management according to order requests.

In G38 route, considering UK, storage at both central and regional DC takes up to 58 days. This is also due to the labor-intensive logistics activities in DC. The transport from regional DC to customers also is time-consuming and it takes 35 days. In Brazil, the oversea shipping from central DC to local DC and storage in regional DC takes over 98 days, which implies the improvement space regarding decreasing delivery time and storage time. In Italy, both the storage in central DC and in local DC takes the majority of the lead time, respectively 23 days and 28 days. But it deserves investigation since there is no repacking process in Italian local DC and 28-day seems quite long to finish receiving, warehousing and picking.

When comparing the in-country delivery time of UK and Brazil (green bar of Figure 18Figure 18 Summary of lead time), it is interesting to notice that the delivery time of UK (35 days) is longer than the time of Brazil (12 days) even though Brazil is a bigger country regarding land area. This is because that the various delivery approaches in UK by boat or truck (Figure 17) affect the delivery time and during public holidays like bank holiday the delivery is postponed

accordingly. In Brazil, truck is the only delivery approach and the retail outlets are mainly hospitals. It makes the delivery straightforward and more efficient.

4.4 Temperature control in storage and transport

Temperature is the key factor that influences shelf life. Even with same lead time, different storage and transport temperature conditions may lead to different sensorial and nutrient performance of products. In this part, temperature control in central DC, CBU hub and regional DC as well as in transporters (truck, container and ship) of G4 and G38 routes are illustrated. Detailed introductions of each delivery route are attached in Appendix 7 to provide supplemental insights.

Table 13 Summary of storage and transport temperature control

Storage		Temperature	Transport		Transporter	Temperature
Central DC warehouse	Venlo, NL*	+15°C to +25°C	Manufacturer to central DC	NL	Truck/Container	**No control**
G4 hubs	NL	Not controlled but not exceed 26°C	Central DC to G4 customers	NL	Truck	**Not controlled** but not exceed 26°C
	BE	+15°C to +25°C		BE	Truck	+15°C to +25°C
	FR	+5°C to +25°C		FR	Truck	+5°C to +25°C
	DE	No hub		DE	Truck	<+25°C, not always controlled
G38 regional DC warehouse	IT	+5°C to +25°C Oil products: +18 °C	Central DC to G38 regional DC	IT	Truck	**No control**
	UK	+2°C to +25°C		UK	Container	**No control**
	BR	Around +25°C		BR	Ship	<+25°C
			G38 regional DC to in-country stops	IT	Truck	**No control**
				UK	Arctic/Van fleet	**No control**
				BR	Truck	<+25°C

*NL: Netherlands, BE: Belgium, FR: France, DE: Germany, IT: Italy, UK: United Kingdom, BR: Brazil

As summarized in Table 13, the storage temperature of most representative routes is controlled within the suggested range +25°C as mentioned in 4.1.3. Only the Netherlands has lack of control, and orders are directly delivered to customers

without staying in the hub for German route. According to the Dutch logistics team, the trucks need to stay in the garage for one day after loading. The temperature could be extreme, but even in warmest days the temperature did not exceed +26°C. However, temperature varies from time to time and with exposure to strong sunlight during hot hours, the temperature inside trucks will increase severely. This information requires confirmation by previous monitoring records or further real-time datalogger tracking.

Transport temperature control in Belgium and France is within the suggested range and in Germany most of the cases is controlled. For Netherlands there is no control for transport which needs further work regarding the fact that it takes 3.5 days on road and the temperature could be pretty high in hot seasons. Transport temperature control of Brazil route is well-monitored because the transporters are refrigerated and temperature is controlled within +25°C. However, the humidity control regarding artic shipping requires special concern because the oxygen barrier of primary packaging is sensitive to humidity. There is no control of the transporter (from central DC to local DC and in-country delivery) in Italy and United Kingdom which could be a severe issue since the temperature in Italy is over +26°C for 4 months from June to September according to 30-year tracking data (Figure 19. World Meteorological Organization, 2018). And it takes maximum 6 weeks for in-country transport within UK and the temperature could reach a high level during this time.

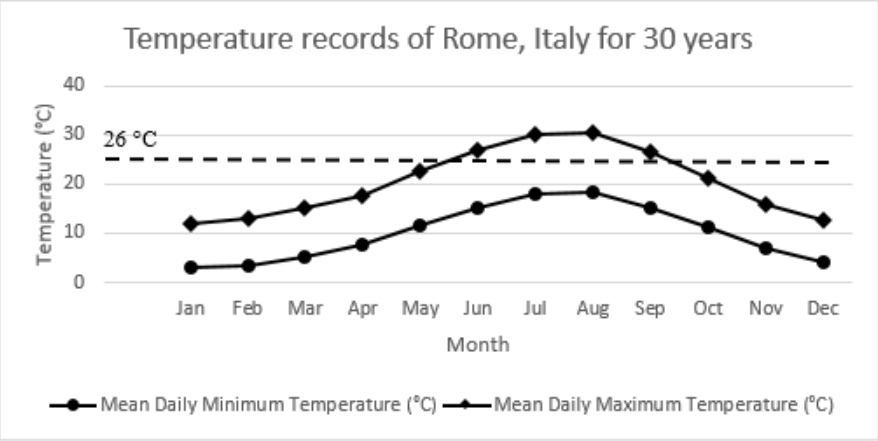

Figure 19 Temperature records of Rome, Italy for 30 years

(World Meteorological Organization, 2018)

4.5 Summary of lead time and temperature control of storage and transport

The defined improvement spaces are summarized into following bullet points:

1）**Lead time**

- G4 route: long storage time at central DC

- G38 route

United Kingdom: long storage time at central DC and regional DC, long transport time from regional DC to customers

Brazil: long storage time at regional DC and long oversea transport time from central DC to Brazilian regional DC

Italy: long storage time both at central DC and regional DC

2）**Temperature control**

- Storage temperature control: no control for overnight storage in Netherlands

- Transport temperature control: no control in Netherlands, Italy and United Kingdom

3）**No humidity control** in ocean shipment of Brazilian route, the humidity may affect the performance of the oxygen barrier of the primary packaging.

5 Conclusions and suggestions for future work

Packaging plays an important role in shelf life considering the protection against mechanical forces and decreasing component variation. And the product performances during shelf life are highly resulted from the nature of the product. In this research, a practical product mapping protocol is proposed to select one representative product for supply chain study based on the product's sensitivity. It should be noted that although the representative product was ultimately not chosen through the protocol (due to certain issues pointed in 4.1.2), the proposed protocol is still a valuable tool that can be used for similar studies later on. Then the lead time and temperature control of storage and transport in representative routes are the main focuses of the supply chain research. Based on the above information, this study is carried out to define the improvement spaces of current packaging and logistics system of a Nutricia plastic-bottled liquid oral nutrition product.

5.1 Conclusions

This thesis is based on the following research questions and this chapter shows the summary of the answers of these questions.

- What are the requirement of the product's packaging system and logistics, regarding storage and transport in supply chain?

- What are the critical points of storage and transport conditions throughout the product's supply chain and are there any potential improvement opportunities for improvement?

5.1.1 **Requirements of packaging and logistics from product development and supply chain aspects**

According to 4.1.3, the requirements from the representative product towards packaging are:

- Storage and transport temperature within 0°C to +25°C

- Strong oxygen barrier

- Short lead time

Optimal temperature control aims at decreasing the degradation of sensitive vitamins and oxidation of unsaturated fatty acid as well as guarantee the sensorial attributes and physical stability. Oxygen barrier in this case requires condition control in supply chain because the barrier is sensitive to humidity, with long time exposure to humidity the barrier strength could reduce and oxygen permeation rate will increase accordingly. Regarding lead time, even under the optimal conditions, longer storage or transport time are related to more vitamin loss and deterioration of sensorial performance. In this case long-distance transport and logistics activities in distributer are time-consuming and affect the lead time to a great extent.

5.1.2 **Improvement areas of the current packaging system and logistics**

By summarizing the insights from packaging system and logistics evaluation based on the representative product, the critical improvement spaces are defined:

Table 14 Improvement areas of packaging system and logistics

	Improvement areas	**Supply chain points**
Packaging system	Overhang in pallets	Manufacturer
	Handleability of tertiary packaging (corrugated box)	Central DC
	Fill rate	Transporter
Logistics	Multiple verification processes	Central DC
	Packaging material waste	Central DC
	Lead time reduction	
	Lack of humidity/temperature control	Humidity -- whole supply chain Temperature – NL/UK/IT

- The **overhang in pallets** may affect the stability of pallets during storage and transport, especially when facing outside forces. The stretch films and sealing tapes currently applied in the supply chain are not be enough to enhance the stability. Lock pattern stacking should be a solution and the corresponding investment and cost should be discussed.

- The packaging-related logistics activities require the consideration about **handleability of tertiary packaging** (corrugated box) in this case. For example, the glue of corrugated box should not be too strong to affect the repacking

efficiency and not be too weak to increase risks of leakage during transport. The balance between the robustness of the packaging and handling friendliness needs to be defined quantitatively to enhance operational efficiency.

- The current **fill rate** regarding the space usage in truck is 39.24% minimum and 58.86% maximum depending on different pallet patterns. For some orders, the customer only request several boxes of products placing on a pallet without stacking in the transporter. In this case the fill rate is even lower. Adjustment of palletization and stackability could be addressed to increase the fill rate for maximizing space usage with negotiation with customers.

- Multiple **verification processes** are conducted in DC to verify the information of orders which is labor-intensive and time-consuming. To increase the operational efficiency, the application of automatic technology in packaging should be discussed to define the tradeoffs between cost and benefits.

- Considering the **packaging material waste** during repacking, the volume of repacking and the wasted packaging levels need to be defined for further discussion of practical solutions.

- The **lead time** in different routes varies **from 26.5 days to 134 days**. If the orders get returned, the lead time will be even longer and there is less time left for due by date. The discussion should be addressed to define the possibility of improvement of packaging according to different delivery routes with different lead times. For example, stronger packaging barriers could be applied to products with longer lead time to provide more protection.

- The **lack of humidity control** of storage and transport could affect the oxygen barrier and result in oxidation especially in overseas ship transport. The influence of humidity on the oxygen barrier of during the representative routes needs to be specified to detect the necessary of applying humidity control.

- There is **no temperature control** of Netherlands CBU hub and transporters of Netherlands, United Kingdom and Italy. According to the information provided by relevant colleagues, the temperature does not reach to a high level. However, the actual situation needs to be verified.

5.2 Potential implementation of the product mapping protocol

As illustrated in 4.1, this protocol can be used as a decision-making tool to define the sensitive components according to their variation during shelf life. The component variations are presented in a quantitative way, and cover the degradation of vitamins and unsaturated fatty acid as well as the sensorial and physical performances. This allows the researcher to organize the data in a logical approach and to have a clear perception of the product stability. After defining the sensitive components, relevant influencing factors of these relatively sensitive components regarding storage and transport and potential critical effects of component variation are precisely presented in the Table 4 in 3.1.5. It allows the researchers to determine the main focuses of the following supply chain researches. This protocol can be implemented in both academic research and industry projects. When there is limited time and resources, researchers can select one representative product and several sensitive components by applying this mapping protocol then conducting supply chain research on the main influencing factors, with high priority of the defined sensitive components. The supply chain research results can later be applied to other products with same packaging and similar product composition/contents. It is a practical approach to fully take advantage of available data while minimizing costs.

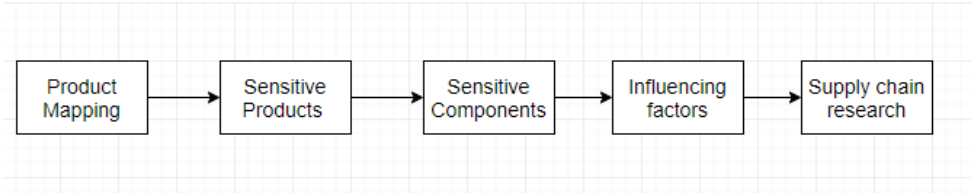

Figure 20 The mapping protocol implementation steps

5.3 Future work

5.3.1 **Research scope expansion**

Given the 20-week limit of a master thesis project, this study only covers one representative product and 7 representative routes. In the future work the research

scope could be expanded to more aseptic products of Nutricia and more distribution routes. Furthermore, with the better understanding of aseptic products and plastic bottle packaging, the research scope could be expanded to products with retort process and other types of packaging. It would be interesting to compare the performances of different primary packaging filled with the same product (e.g., Tetrapak packaging and plastic bottle). Also, the sustainability and recycling system regarding packaging could be studied in the future.

5.3.2 **Shelf life testing**

To verify the deviation of the key sensitive components of the representative product during shelf life, the shelf life testing which covers the whole claimed shelf life is desired. The shelf life testing should cover both nutrient degradation, sensorial attributes and physical stability performances. And it is reasonable to test several batches of products and to calculate mean values in order to obtain reliable conclusions. Moreover, it would be an optimal idea to test all aseptic products of AMN and to input these data to the mapping protocol to build a comprehensive database for further researches.

5.3.3 **Supply chain verification**

Due to time and resource limits, the information on lead time, warehousing and transportation conditions in foreign countries outside Netherlands as well as the warehouse temperature within Netherlands were acquired through semi-structured interview via email. The actual situation may be different and should thus be verified in future work via on-site visits or data logger monitoring.

Moreover, due to equipment limitation, relevant experiments are not conducted after the critical points of supply chain are defined. The relevant experiments should be addressed to understand the influences of storage and transport on packaging system and product. For example, researchers can collect the products of the same batch but from different supply chain points and measure the residual oxygen within the headspace.

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Appendices

Appendix1 Face-to-face interview

A.1 Exploration Stage

During this stage, the aim is to interview key Nutricia employees—who come from 5 teams: packaging, technology, product development, sensory, and specification divisions—who have relevant working experience or have cooperated with the packaging team previously. This is done to collect insights about how to determine the sensitive components of products that require special concern on packaging and logistics, taking into account various inputs from different teams.

After interviewing one colleague from the sensory team and two colleagues from the specification team, a message was received that these two teams' working domains are not relevant to this project. Instead, the shelf life team was the better option to contact because this team is in charge of testing the products' physical and sensorial changes during the shelf life. This information on physical and sensorial changes is related to sensitive components, which thus makes it relevant to this project. In the end, a total of 19 key contacts from 4 teams including packaging, technology, PD and shelf life team were interviewed during the exploration stage with a total of 15 hours of interview time, wherein each interview lasted from 0.5 hour to 1.5 hours, or 1 hour on average.

The interviews in the exploration stage follow the interview guideline of 3-step strategy and it is explained in detail in Figure A.1.

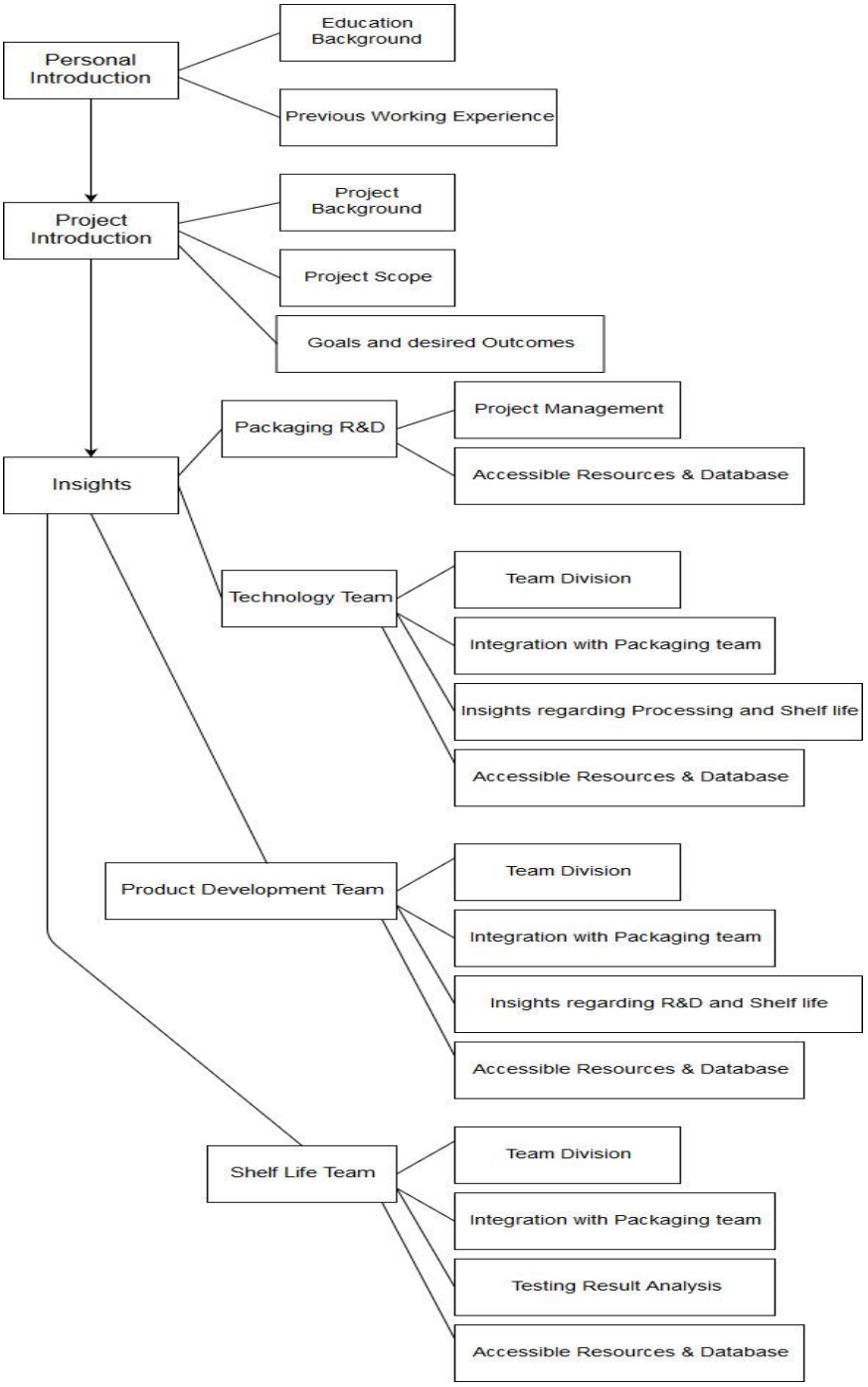

Figure A.1 Interview guideline of exploration stage

To begin with, a personal introduction including author's education backgrounds and previous working experience is addressed to effectively let the interviewees have a clear perception of the interviewer. Afterwards, the project backgrounds, scope and research questions are explained to illustrate the motivation of organizing the interview. In the end, the topics are led to specific domains concerning the different responsibilities of each team.

For packaging team, project management is the main focus. For example, how to efficiently communicate with other teams to acquire desired data based on previous experience; what are the available resources and databases that are related to the product mapping; what types of information the packaging team prefers to obtain to understand the requirements of AMN products regarding the sensitive components. Besides, the accessible resources and databases are important for the author to collect valuable data.

For the other 3 teams, 4 topics are designed as the main focuses. First, team division regarding specific responsibilities of the team is well explained with ongoing projects as detailed examples, it allows the author to have a broad view of the working scopes of the interviewee. Based on the particular domains each team is enrolled in, the professional insights about the how to build a reliable approach to link product sensitive components and packaging are requested. The insights include key contact recommendation as mentioned above, previous reports that are relevant to this project and key components that normally require more attention due to their interaction with packaging, etc. At the end, recommendation of useful internal database and resources is provided, and several databases are offered with access authority as well.

A.2 Clarification stage

Based on the information gathered in exploration stage, a mapping protocol which serves as the approach to define the sensitive components of products that requires special concern on packaging and logistics is proposed. Then the interview steps into clarification stage which includes 2 rounds of follow-up interviews with different focuses.

A.2.1 First round Follow-up interviews

To ensure that the protocol is fairly accurate and to check whether there is any missing information that is needed by these 4 teams, a first round of follow-up interviews is conducted. In total, 4 colleagues from different teams were

interviewed, with a total of around 2 hours of interview time. As illustrated in Figure A.2, both positive and negative comments are welcomed for improvement.

A.2.2 Second round Follow-up interviews

Thanks to the practical suggestions received in the first round of follow-up interviews, the mapping protocol is improved with a clearer scope and motivation. To specify some details regarding information accuracy, the second round of follow-up interview is held with 3 colleagues from 3 teams, and in total 2 hours was devoted. Important suggestions were provided that enables the author to remove the unreliable data from over 5 years ago and adjust the mapping parameters based on actual production situations.

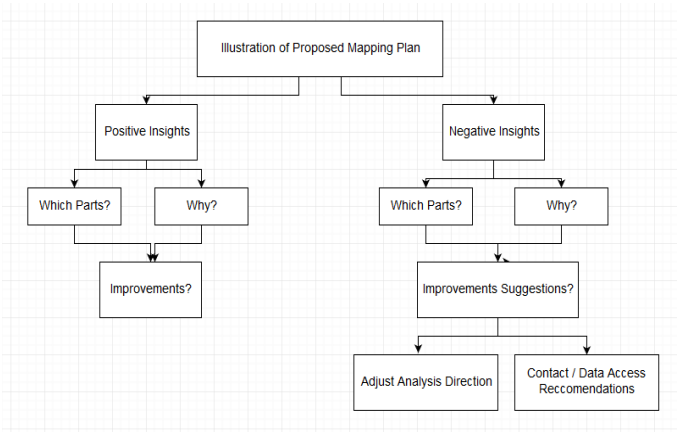

Figure A.2 Guideline of follow-up interview in the first round

Appendix 2 Semi-structured interview questions via email

The emails regarding delivery route, lead time and transporter are sent to key contacts of logistics planning team in each country with the following questions:

1) Once the products arrived local warehouse, in average how long the products will be stored in warehouse before they are distributed to next point?

2) Before our products are sent out for next point, is there any repacking process is requested in local warehouse?

3) In average, how long it takes to transport one batch of products from local warehouse to the next point and which type of transporter we are using?

4) If there is any contact who has the information of rotation time in our end customer in UK, it would be totally appreciated to have you share their contact detail.

The emails regarding warehouse and transport condition control are sent to key contacts of logistics quality control team in each country with the following questions:

1. What parameters are controlled in our local warehouse (e.g., temperature) and how we manage to control them (fans, air conditioners etc.)?

2. For transporters which deliver our products from local warehouse to next point, is there any parameter are controlled within transporters to ensure our product safety and quality? If so, how do we control these parameters?

Appendix 3 Product characteristics and its impacts on packaging system

Table A.1 Product characteristics and its impacts on packaging system

Product characteristics	Description	Impact on packaging system
Price	12.13 euros / 4 bottles 3.03 euros / bottle	High value product, prevent it from bear a certain amount of leakage and damage
Content	High viscosity Sensitive components	Negative effects and contamination risks considering leakage Shelf life: 12 months Storage: ambient temperature (25°C)
Sterilization	Before entering filling process, the primary package goes through the sterilization under 170°C peroxide and hot air	Heat treatment results in packaging dimension slightly changes (normally shrinkage) thus affects the stackability of secondary and tertiary packaging Heat treatment accelerates the chemical and physical substance migration between packaging and product
General shape	Irregular cylinder with a neck	Saves production costs due to the easy extrusion blow moulding process compared to other shapes Certain extent of space waste regarding the irregular shape
Dimension(1)	Height 128.0mm Diameter 58.0mm	Decides the amount of bottles can be loaded to pallet and transporters due to the volume limit
Package Volume	237ml	Decides the cost and material use
Product Volume	200ml	Decides the filling level, contact surface and majority part of product weight
Headspace	37ml	Affects product shelf life regarding the residual oxygen within headspace that related to component oxidation Decides the fluctuation area of product that related to leakage risks
Weight (2)	233g	Related to availability of handling activities in manufacturer and DC

		Decides the amount of bottles can be loaded to pallet and transporters due to the weight limit
Packaging Material	Plastic 6-layer structure Oxygen barrier: EVOH Moisture barrier: HDPE	Decides the packaging cost for manufacturer Durable, less requirement of protection from the secondary package Rigidity enables the product to bear long distance transportation Provides protection against oxygen and light to guarantee the product quality EVOH is sensitive to humidity thus requests special concern during transportation and storage
Inner Surface(3)	23791.25mm^2	Decides the area that package and product potentially contact and related to substance migration
Contact Surface(4)	18301.12mm^2	Decides the area that package and product directly contact and is related to substance migration
Residual oxygen after filling(5)	1.11-1.85ml	Affects product shelf life regarding components oxidation resulting from inner forces
oxygen permeation rate(6)	<0.002tbd(cc/bot/day)	Affects product shelf life regarding components oxidation resulting from outside forces

(1) Hereby the dimensions refer to the total height (neck+bottle) and the biggest diameter of the bottle; all the data illustrate the nominal value after sterilization.

(2) Hereby the weight refers to the total weight of product and package

(3) Hereby the inner surface refers to the sum of the inner surface of bottle (23055.83mm^2) and foil (735.42mm^2).

(4) Hereby the contact surface illustrates the partial inner surface of bottle that contacts product when the bottle stands still.

(5) Hereby are the ideally theoretical value that after filling process, there are 3%-5% oxygen residue within headspace. The equation is headspace(ml)*3% or 5% = residual oxygen(ml).

(6) Hereby the value illustrates the maximum tolerance of oxygen permeation per day, it depends on packaging material property.

Appendix 4 Packaging system characteristics

Table A.2 Packaging system characteristics

Package level	Characteristics	Value
Primary package	Dimension	Height 128.0mm Diameter 58.0mm
	Volume*	3.38x10-4m3
	Weight	233g
Secondary package	Primary package per secondary package	4
	Dimension	115x115x130 mm3
	Volume*	1.719x10-3m3
	Weight	950g
Tertiary package	Primary package per tertiary package	24 (4 x 6)
	Overall dimensions	364x243x136mm3
	Volume*	12029.47cm3
	Weight	5.9kg
Loading Carrier	Stackability (Depending on pallet patterns)	A: 9x9 B: 7x9 C: 11x9
	Tertiary packages per pallet	81(9x9) 63(7x9) 99(11x9)
	Dimension of a single EU pallet	1200x800x144 mm3

Dimension of products after stack**	A: 1093x729x1230mm3 B: 1093x729x958mm3 C: 1093x729x1502mm3
Dimension of pallet after stack	A: 1200x800x1380mm3 B: 1200x800x1108mm3 C: 1200x800x1652mm3
Volume of pallet after stack	A: 1.32m3 B: 1.06m3 C: 1.59m3
Primary package per pallet	A: 1944 B: 1512 C: 2376
Weight of stacked products on pallet	A: 477.9kg B: 371.7kg C: 584.1kg
Weight (including pallet and stretch foil)	A: 502.9kg B: 396.7kg C: 609.1kg
Pallets per truck	33
Total primary package per truck	A: 64152 B: 49896 C: 78408
Fill rate***	A: 48.87% B: 39.24% C: 58.86%

Appendix 5 Packaging logistics activities in supply chain

A.5.1 Logistics activities in manufacturer

A.5.1.1 Packaging logistics activities in filling process at manufacturer

The mapping flowcharts follow the beneath symbol explanation.

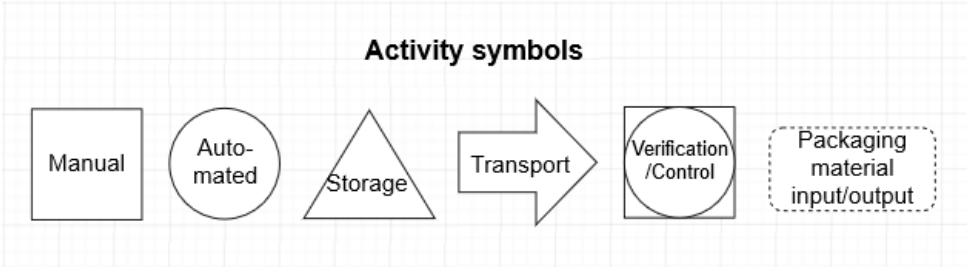

Figure A.3 Symbols of logistics activity mapping

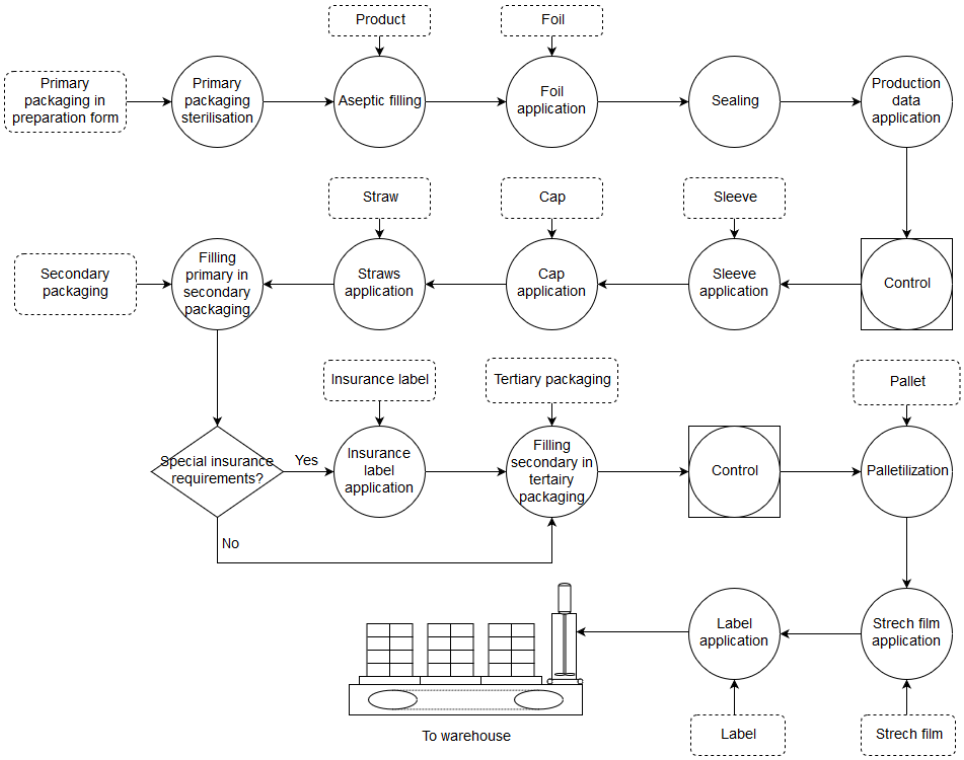

Figure A.4 Packaging logistics activities in filling process at the manufacturer

Before the primary packaging enters the system, it requires some preparation including primary packaging input from packaging production line, packaging position adjustment to help the primary packaging fit in the filling line and moil remove & recycle—keeping the moil until the primary packaging entering the filling process helps guarantee the hygiene of inner surface of the primary packaging, and the removed moils are collected and cut into small pieces for reuse. Then the primary packaging will enter the chamber, where sterilization, aseptic filling, and foil application are conducted.

Firstly, the primary packaging goes through the packaging sterilization under 170°C peroxide and hot air because it is important to ensure the aseptic condition of the inner surface of the package which will directly come in contact with the product. It will also affect the product quality regarding microbiology. Another reason is that there is no retort process to sterilize the product-filled package afterwards. Once the primary packaging is sterilized, it is then ready to meet the product for aseptic filling under the nitrogen atmosphere. Henceforth, the product and the primary packaging are considered as an inseparable and unified single unit. After filling, the aluminum foil seal is applied to the primary packaging following 2 steps. First, the foil is preheated under 225°C with infrared heat lamp and gets fixed with 3 spots on the packaging. Then, the foil is fully fixed with glue and a certain amount of pressure. Once the foil is completely fixed, the primary packaging then goes through the sealing process under 215°C to make sure that the lip of the bottle is fully covered tightly with aluminum foil. For traceability, the data of production line are printed on the foil. Then an automatic check is conducted to ensure that all the bottles are firmly sealed to avoid the potential contaminants.

In the next step, the sleeves—which contain all the required product information—are applied after an automatic confirmation process that scans the QR code on the sleeves, ensuring that the right sleeves match the right product. After application, products also undertake 85°C steam for a few seconds to let the sleeves shrink and be firmly applied on the surface of primary packaging. The following step is cap application. After this step, the products will enter the packing line where the straws are attached on the primary packaging, 4 primary packaging units (2x2) are filled into the secondary packaging, the card paper cluster. If the products will be delivered to countries that request special insurance requirements, the special labels will be attached on clusters before the secondary packaging are filled into tertiary packaging which is the corrugated box. If not, 6 units of secondary packaging will be filled into the tertiary packaging directly. Before palletization,

there is a manual control point which allows staffs to randomly fetch a box of packed products twice per hour to ensure that all the elements of packaging (e.g. straw) are in the right position with the right product information (e.g. flavor, volume), and all relevant supply chain information like SKU code and production date are correct. After the confirmation, the tertiary packaging will be loaded onto EU pallets, and in total 3 types of pallet patterns are used for this product depending on delivery destinations. Then the stretch film is wrapped around it, following the rule that there should be more layers of film attached to the bottom of the pallet and less on the top, in order to enhance the stability. Afterwards, the pallet label—containing the SKU, quantity, due-by date, batch number, and location information—is attached on the surface of stretch film, and the whole pallet will be loaded on the conveyer belt that links the packing line and warehouse, and will wait for further transport.

A.5.1.2 Packaging logistics activities in the warehousing process at manufacturer

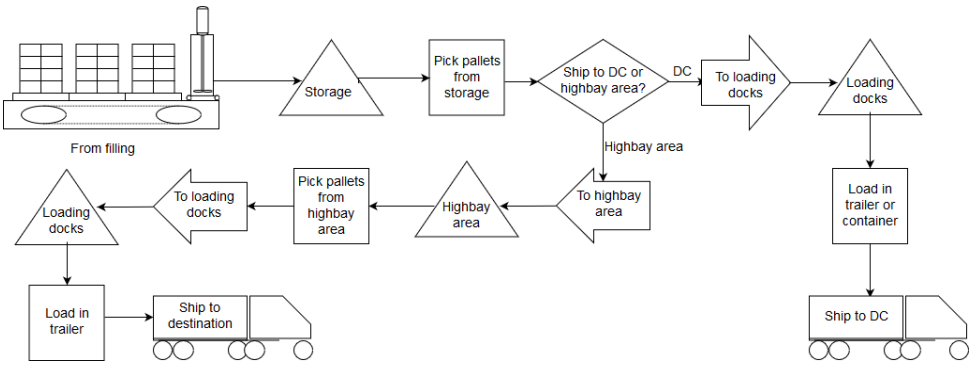

Figure A.5 Packaging logistics activities in warehousing process at the manufacturer

An automatic guided vehicle (AGV) links the filling process and warehouse by carrying 3 pallets each time from the conveyer belt to the warehouse, following a set route. After arriving at the warehouse, the pallets are temporarily stored and wait for picking. Warehouse operators who drive the high bay truck will first scan the code on the pallet with portable devices to define the destination, then carry transport the pallets to targeted locations within the manufacturer warehouse. Normally, 99% of the pallets will be sent to central DC, which is located in Venlo, Netherlands, for further distribution.; These pallets will be first placed in loading

docks and then will be loaded in trucks (weekdays) or containers (weekends) that head to central DC. The other 1% of the pallets will be stored at the warehouse in a high bay area for different purposes (e.g., quality control) for a certain period, varying from several days to several months.; Then, those pallets will be picked by highbay trucks and transported to loading docks, and then are shipped to destinations by truck or container.

To clarify, the pallets that are temporarily stored in high bay area are not stacked, but are placed in separated slots of the high bay shelves.

A.5.2 Logistics activities in central DC

A.5.2.1 Packaging logistics activities in the receiving process at central DC

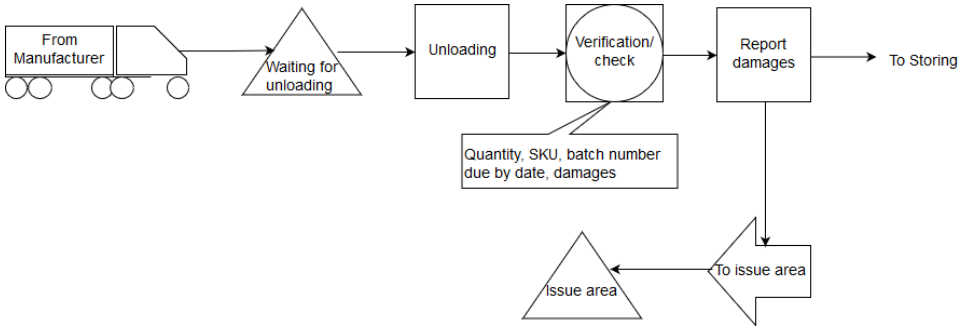

Figure A.6 Packaging logistics activities in receiving process at DC

Once the transporters which carry the finished products arrived at DC, they need to wait in the unloading area. After receiving the request, unloading operators will unload the pallets with EPT (Electric pallet truck) from trucks or containers to inbound area. During this process, the operators will verify the quantity, SKU, batch number, due by date of the products as well as the damages. The intact pallets will be transported for storing after operators scanning the pallet label which is includes the assigned storage information, attached in manufacturer. If there is any damage of the pallet, the operators are empowered with a certain degree of freedom to deal with the damages. If there is only one layer or less than one layer of pallet is damaged, operators can report the damage and scrap the damaged parts; if there are more than one layer of pallet are damaged, operators need to report the damage, block the pallet in the system, transport the pallet to issue area and let corresponding team to propose practical solutions depending on the specific situation.

A.5.2.2 Packaging logistics activities in the storing process at DC

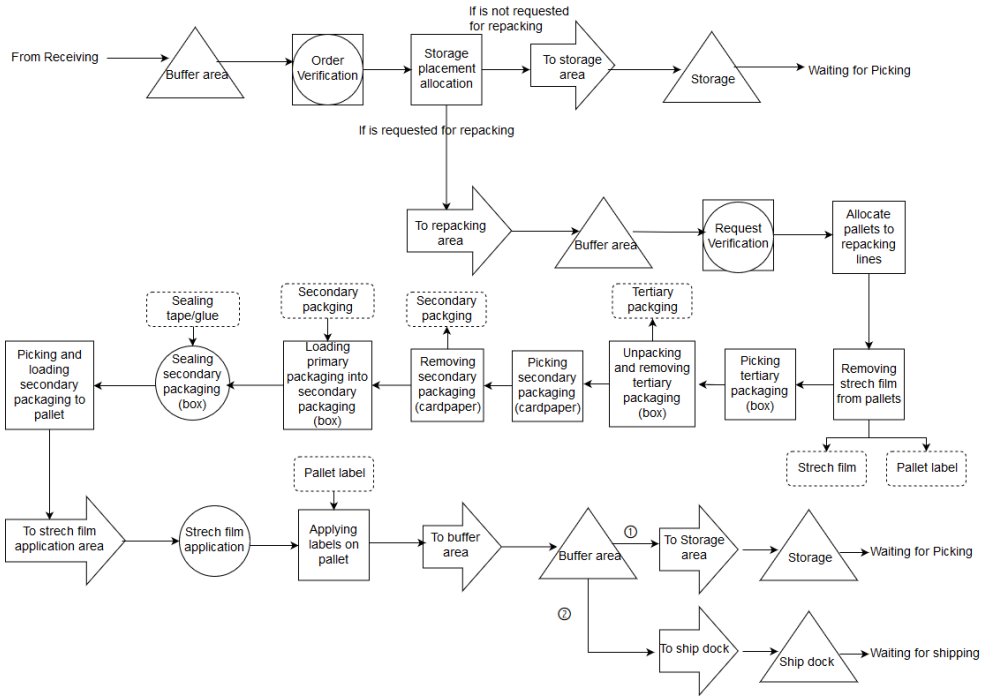

Figure A.7 Packaging logistics activities in storing process at DC

The received pallets will be stored in buffer area temporarily, then the operators will verify the order request and place the pallets in different areas according to the instructions from DC warehouse management system. If the order requests the whole pallets, these pallets will be directly transferred to storage area and be stored until the picking request is addressed. For urgent orders, pallets are directly transported to shipping dock for delivery.

If the order requests repacking, then the pallets will be transferred to repacking area which is located in one floor upstairs out of the receiving area. After verification of the repacking requirements, operators will allocate the pallets to corresponding repacking lines. There are various repacking lines to meet customers' demands, to simplify, hereby only one of the repacking processes, which is often applied to 200ml AMN PB products, is illustrated. After allocating pallets to repacking line, operators will first remove stretch films and pallet labels

to pick out the tertiary packaging (corrugated box). Then unpack and sit aside the corrugated box for further use. Afterwards the secondary packaging (card paper clusters) will be removed, and the primary packaging (bottles) are placed without card paper cluster in the original corrugated boxes which are removed in previous step, at this point, corrugated box becomes the secondary packaging and the pallets become the tertiary packaging. This repacking process often is conducted when customers request mixed flavors of products. Overall, the volume of repacking orders makes up tiny proportion regarding orders without repacking requests.

Afterwards, the boxes will be sealed and loaded to pallets. The pallets will be applied on stretch film with an automatic machine, afterwards the pallets labels are attached to illustrate the SKU information. After shortly storage at buffer area, repacked pallets will be transferred to storage area and wait for picking; or will be directly transferred to shipping dock and wait for shipping.

A.5.2.3 Packaging logistics activities in the picking process at central DC

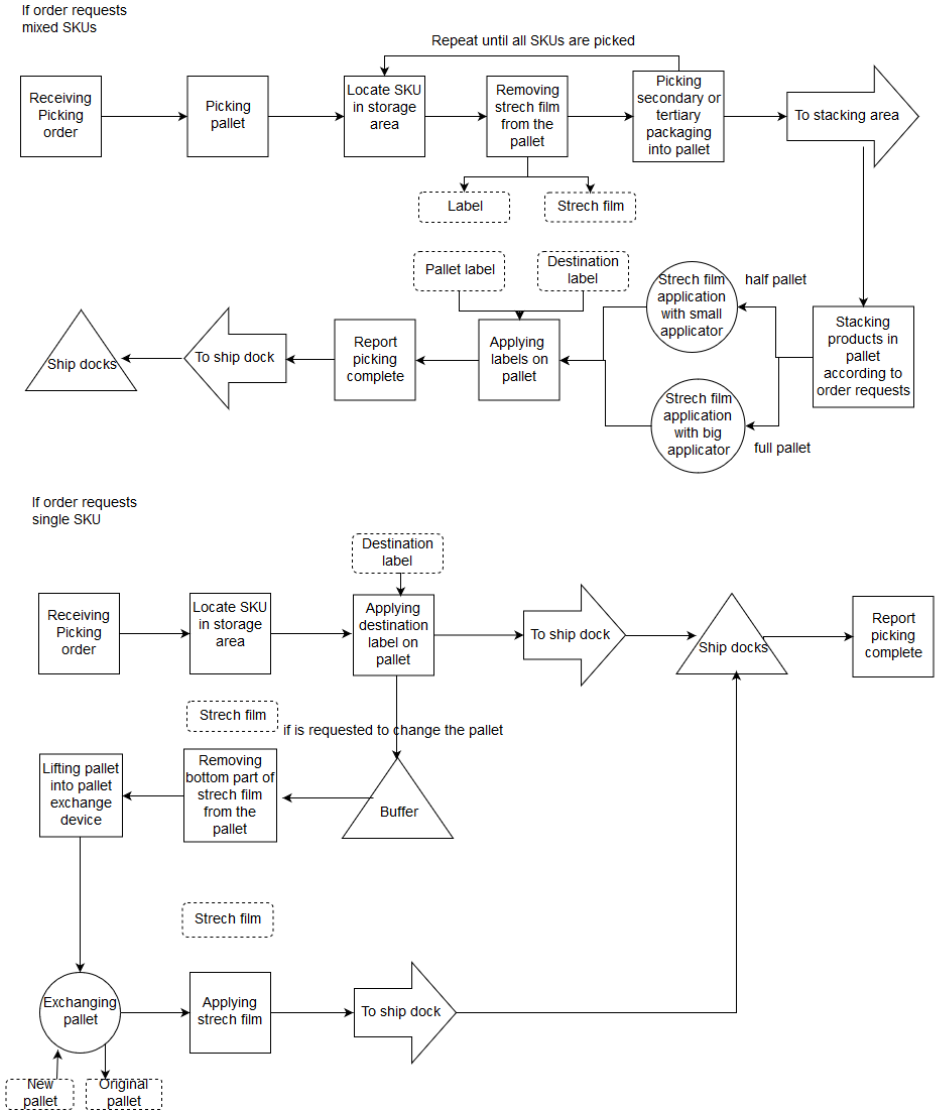

Figure A.8 Packaging logistics activities in picking process at DC

After a certain period of storage, it enters picking process. There are 2 types of picking requests according to the demands from clients.

The first type of picking request is the mixed SKUs. Once operators received the order, order information including the pallet type (EU/UK/others), SKU storage location etc. will be loaded in their portable devices. According to the request, operators will first pick the required pallets according to shipping destination, then

will locate SKUs in the right location in storage area and confirm by scanning the barcodes with their portable devices. The stretch film and pallet label will be removed from the pallet to allow operators to pick the requested SKUs and to load the mixed SKUs on the pallets. Then the pallets will be transferred to stacking area and let the operators working in this area stack the SKUs according to order requests. If the requested SKUs only make up half of the pallet, operators will apply stretch film with a small application machine which requires certain amount of manual operation; if the stacked SKUs make it full pallets, the stretch film will be applied with a big automatic stretch film application machine. After the application of stretch film, pallet label and destination label will be applied on pallets to ensure traceability; afterwards the pallets are transported to shipping docks and are waiting for shipping.

Another type of picking request is the single SKU, which means that the whole full pallet only contains one single type of products no matter they are repacked or keep the original packaging. In this case, there is no need for operators to pick an empty pallet first, operators will directly locate the pallets loaded with single SKU in the storage area, apply destination labels, report that this picking order is finished and then transport them to shipping docks. When pallets arrived at shipping dock, if there is no special requirement, operators will leave the pallets in shipping docks for upcoming shipping process. If the original pallets not align with the destination pallet requirement (e.g., original pallets are EU pallets, the destination requires UK pallets) or there are defects on the pallets (damages, nails sticking out), pallets need to go through a pallet exchanging process. To begin with, the bottom part of the stretch film will be removed to free the original pallet; next the pallet will be lifted into the pallet exchange device, then the device will turn the pallet for 90 degrees, this allows operators to remove the original pallet and place the new one. In this way, the pallet is successfully changed. Afterwards, operators need to manually apply stretch film to fix the products on the new pallets and transport pallets to shipping dock for upcoming shipping process.

A.5.2.4 Packaging logistics activities in the shipping process at DC

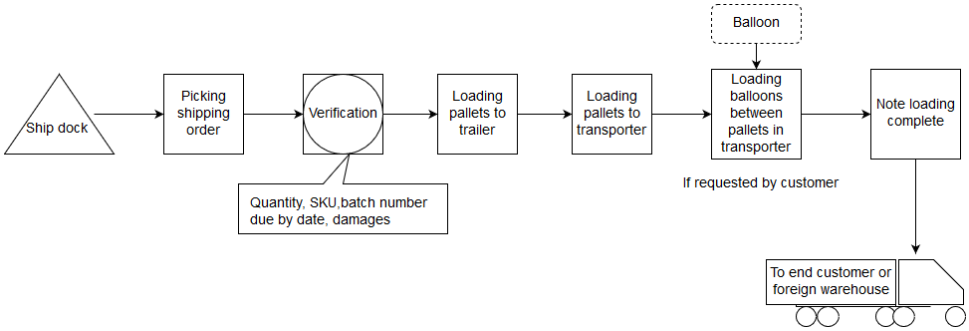

Figure A.9 Packaging logistics activities in shipping process at DC

After the temporary storage at ship dock, the pallets are ready for shipping. Operators will firstly verify the shipping information such as quantity, destination, SKU, according to shipping order; then load 2 to 3 pallets to EPT according to EPT's capacity, in the end load theses pallets to transporters via EPT. To fix the pallets firmly in transporters without space for shaking, inflated balloons are placed between pallets to make up the gaps. These balloons are only placed when it is requested by the order, especially for long-distance oversea transportation. In this way, potential fluctuations are reduced to decrease the damages during transportation. In the end, operators report that the loading process completes, then the transporters will leave for next logistics points.

A.5.2.5 Used packaging material activities at DC

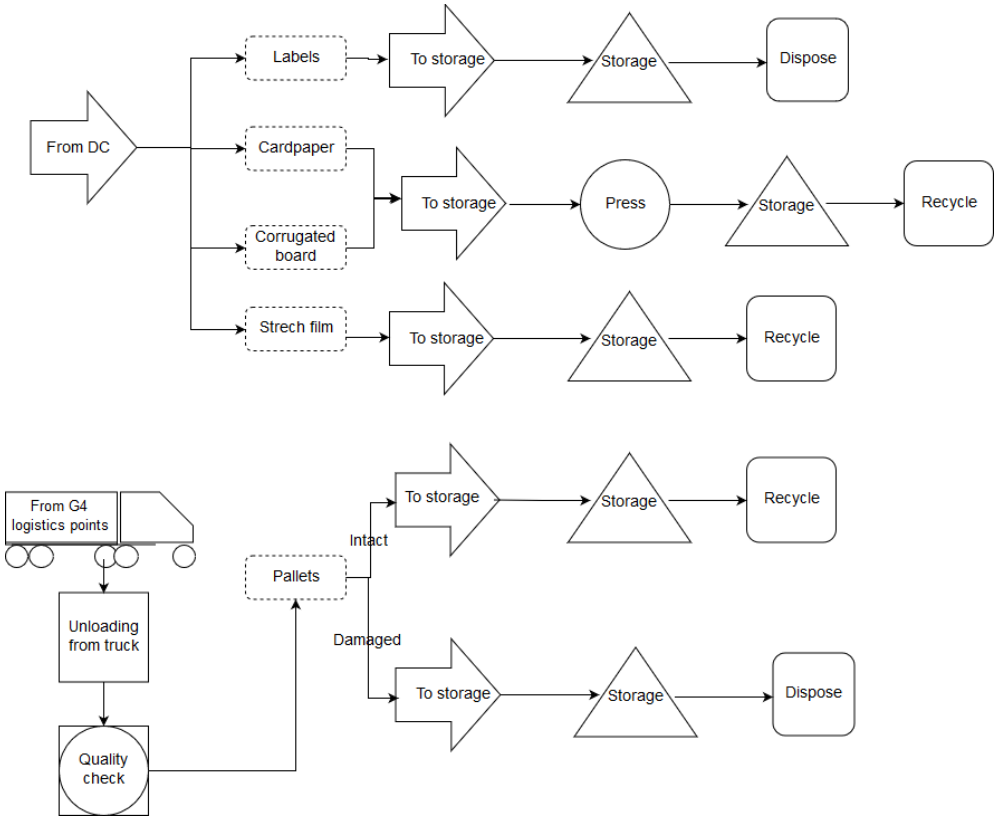

Figure A.10 Used packaging material activities at DC

There are two main approaches to recycling or reusing the used packaging materials.

Within DC, pallet label and stretch film are applied and removed at almost every process. Used stretch films are firstly placed in recycle bins, then are collected together and transported to storage area for recycling. Unfortunately, it is not available to reuse labels but dispose them because they contain both paper, ink and plastics, and it is hard to separate them. For card paper and corrugated board which are mainly removed during repacking process, they are also firstly placed in recycle bin and then go through a press process, in the end they will be recycled. All these recycle work are handled by an external company.

For pallets which are shipped to G4 area (Netherlands, Belgium, Germany, France), once they finished their mission and get empty, they are delivered back to central DC in Venlo. After the quality check, the intact pallets will be stored and wait for reuse within DC, the damaged pallets will be stored and wait for an

external company to dispose, in the meanwhile the new pallets will be replenished. For G38 routes (38 trading countries in or out of Europe), pallets are reused within local warehouses or reginal DC.

A.5.2.6 Return products activities at DC

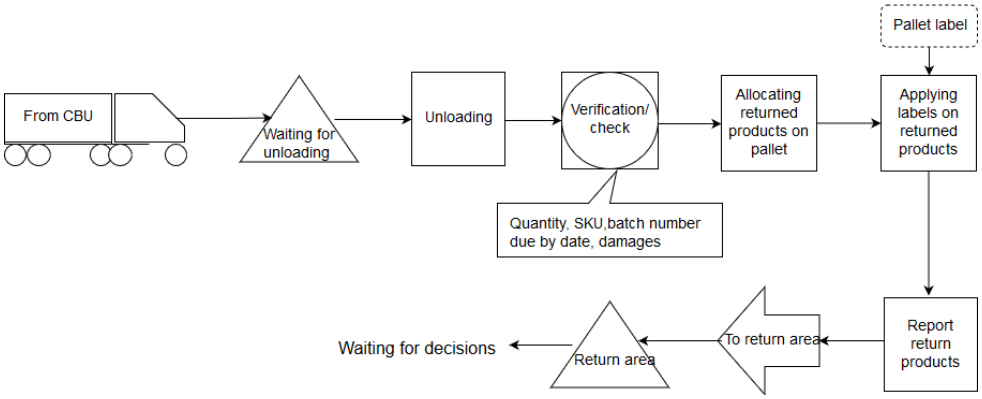

Figure A.11 Return products activities at DC

Return process is similar to receiving process. Due to various reasons, certain amount of products are returned from different logistics stops to central DC. After unloading, operators will verify and report the information of returned products including quantity, SKU, batch number, due by date and so on. The returned products could be in the unit of pallet, box or single bottle, these products will be allocated on pallets with a pallet label attached. Afterwards pallets are stored at return area for future decisions from logistics team.

Appendix 6 Lead time of representative routes of Diasip Strawberry 200ml

A.6.1 Planning time

Planning time illustrates the time from receiving the order until starting production. The manufacturer receives orders from central planning team, then planning team in manufacturer will arrange the production via ordering packaging material, raw material from supplier as well as schedule the production line regarding availability. In average, it takes **8-9 weeks** from receiving the orders until production starting.

A.6.2 Production time

Production time refers to the time which is required to finish producing one batch of products. Generally speaking, the liquid product production includes preparation, filling, packing and cleaning. The production time depends on the volume of the batch and the production line speed. For the selected representative product and selected batch, the production (filling and packing) takes 12 hours. Considering the preparation works before production and cleaning works after production, **1 day** is a reasonable assumption for production time.

A.6.3 Storage time in manufacturer(Zoetmeer)

When the production is finished, 99% of the products will be loaded in the trucks/containers instantly and departure to central DC (Venlo). The left 1% will be temporarily stored in manufacturer warehouse for a certain period of time which varies from several days to several weeks, due to the various purposes (e.g., quality control). Therefore, the storage time in manufacturer can be assumed as **0 day**.

A.6.4 Transport time from manufacturer(Zoetmeer) to central DC(Venlo)

The distance between manufacturer and central DC is 174 miles, there are two types of transporters, truck and container, which transport finished products from manufacturer to DC. On average one batch of production takes **1.5 days** to arrive at central DC.

The majority of products are transported by truck. Trucks go directly to central DC after production, and therefore products arrive at the same day or the day after. Containers goes to Rotterdam first, then get loaded on a barge which heads to central DC, this route takes 3 to 4 days for transportation. As the truck route is the main approach, on average 1.5 days is the reasonable transportation time from manufacturer to central DC.

A.6.5 Storage time at central DC (Venlo)

On average, once products are delivered to DC, they will be stored in the warehouse for **23 days** before these are shipped to next logistics stops. This is due to the fact that products need to go through several logistics activities in DC like verification, repacking and re-allocating on pallets before warehousing; also, the storage time depends on various factors like inventory and planning etc.

A.6.6 Transportation time from central DC (Venlo) to end customers

There are two routes of transportation from central DC to next logistics points, serving different countries within or outside Europe. G4 route serves four countries including Netherlands, Belgium, Germany and France. G38 route is designed for in total 38 countries to deliver products to countries within Europe or overseas.

A.6.6.1 G4 Route (Netherlands, Germany, Belgium, France)

Netherlands

Majority of orders are directly sent to the warehouse of wholesalers where orders are re-distributed for downstream retailer outlets. Some orders are transported to the hub of transporter first, where orders are mixed with different goods for delivery, then are delivered to wholesaler. On average, it takes 2 days to arrive at wholesaler from central DC.

Germany

Due to the fact that central DC, Venlo, is quite close to the Germany border, orders are directly delivered from Venlo to end customers. Orders are picked up at day 1 and delivered next day, so 2 days is the delivery time for German route.

France

Orders are firstly transported to CBU hub in France which takes maximum 1 day, then delivered to customers which takes 1-5 days according to destinations, 60%

orders are delivered within 1 day, 30% arrives in 2 days, 10% takes 3-5 days, it would take longer if customers are not available on the delivery day and orders are returned to hub.

Belgium

Similar to French route, orders are transported to CBU hub first, then are delivered to customers. In total 2 days are spent from Venlo to Belgian customer.

A.6.6.2 G38 Route

Italy

The average delivery time to Italy is **4 days** by multimodal route, if the customer requests delivery by direct truck, orders arrive in 1 day. Afterwards the orders are stored in local DC for **2 to 4 weeks**, **no repacking** is addressed here. The in-country delivery takes 5 days on average by truck to the retail outlets. More than 60% retail outlets are hospital and it can be assumed that the products are consumed in short time.

UK

The average transport time from central DC to regional DC in United Kingdom is **7 days** by container, then products are stored around **3 to 5 weeks** on average. Repacking also is addressed according to order requests, then it takes another **3 to 5 weeks** to arrive wholesaler or homeward customers depending on seasons of year, changes of logistics cost or SKU, and delivery route. 60% orders are delivered to wholesaler via artic fleet for further distribution in boxes or pallets, 40% orders are directly delivered to individual customers via van fleet in boxes or primary and secondary packaging. In wholesaler, it normally takes **1 week** for selling products for next retailer outlets.

Brazil

On average, it takes **43 days** to delivery from central DC in Venlo to regional DC in Brazil via ship. Then products are stored for 56 days in DC and afterwards delivered to customers, mainly hospitals. From regional DC to hospital, orders are transported by truck, 80% orders take 14 days to arrive, the rest 20% take 2 days, in average it takes **12days**.

Appendix 7 Temperature control of storage and transport

A.7.1 Temperature control of storage

1)Central DC warehouse

The temperature is strictly controlled and recorded in DC warehouse. There is no control of the temperature outside the warehouse, normally it ranges from -10°C to +15°C. And the temperature inside the warehouse is strictly controlled and monitored, on average it ranges between **+15°C to +25°C**, depending on the outside temperature. During the warm days, the automatic temperature control system will activate fans and air exchangers inside the warehouse in the morning or night to blow cool air into the warehouse for cooling down. If the temperature is over 30°C for over 48h, an alarm will be activated and the emergency will be reported for prompt solutions from logistics quality control team. The heating system is the same as cooling system, during the cold seasons, heaters are automatically set on to warm up the warehouse, if the temperature is below 0°C for 8 hours, which is beyond the acceptable range, the alarm will be also activated.

2)CBU hub of G4 route

For G4 route, Netherlands includes the warehousing process in wholesaler or transporter hub, Belgium and France need to stay overnight in CBU hub, Germany does not contain warehousing process because orders are directly sent to customers. In Netherlands, orders are picked up at day 1 and delivered to wholesaler at day 2, this implies that trucks are loaded and remain in garage for next day delivery. In this case the temperature in garage can be extreme, but according to previous testing, even in the warmest summer, the temperature did **not exceed 26°C**. In Belgium, temperature is controlled within **+15°C to +25°C**, in France the range is **+5°C to +25°C**.

3)Regional Warehouses of G38 route

Temperature within Italy warehouse is managed with air conditioner or heater, and is controlled within **+5°C to +25°C**. For oil products, there is a special storage room where the temperature is kept around +18 °C to avoid oxidation. In UK, the storage temperature is monitored and maintained between **+2°C to +25°C**. in Brazil, it is controlled within **+25°C**.

A.7.2 Temperature control in transporters

For transporters that transport products from Venlo to next logistics stops, the chilling system and datalogger are only applied when it is requested by corresponding CBU. It is desired to maintain the transportation temperature within between **+15°C to +25°C** to guarantee the product quality and safety.

For G4 route, truck is the common transporter, temperatures inside trucks of Netherlands, Belgium and France are controlled exactly the same as warehouse temperatures. In Germany, it is **within +25°C** but the temperature is not always controlled in every step within in-country delivery.

For G38 route, temperature control differs depending on transporters and countries. In Italy, truck is the transporter, which is not applied with chilling system but the temperature does not arrive to high level because of the application of cohibented truck. In UK, no chilling system is applied to transporter (artic fleet or van fleet) either, if the order is a full batch, the delivery will be accomplished within 2 days and in this case products stay in transporters less than 8 hours. In Brazil, transport temperature is controlled around **+25°C** with chilling system both for overseas shipment from Netherlands to Brazil and in-country transport via truck.