

# Transport of Temperature Sensitive Goods in Europe: Definition, Limitations, Flow Analysis and Case Studies



Tayssa Rytter



## Preface

The present report is part of the ERA-NET project TESS - Intermodal Solutions for Trans-European Temperature-Sensitive Shipments, a trans-national project that brings together leading research institutes from Sweden, Austria and Switzerland. The Swedish partners are all members of the Swedish Intermodal Research Centre (SiR-C) funded by the Swedish Road and Rail Administrations. The project is also funded through the EU 6<sup>th</sup> Framework Programme.

The entire project consortium has participation from the following five organisations:

- KTH (Royal Institute of Technology), Stockholm, Sweden, (Project Co-ordinator)
- TFK (Transport Research Institute) Borlänge, Sweden
- HGU (School of Business Economics and Law at Göteborgs University) Göteborg, Sweden
- HERRY Consultant, Vienna, Austria
- ETH (Institute for Transport Planning and Systems), Zurich, Switzerland

TESS started in 2008 and will be completed during 2010. The project focuses on the Scandinavia - Italy transport corridor and the bearing idea is to bring together actors from the whole supply chain to develop a model case for international intermodal temperature sensitive shipments.

The forthcoming report presents the results of a partial study, performed by TFK Borlänge that comprises the first working package of the project. The aim was to identify and analyse barriers and possibilities for transport customers to use intermodal transport for temperature sensitive shipments. Besides desk research a main part of the study involved interviews with Swedish retailers and transport companies working in the international market. In conclusion, TFK Borlänge therefore would like to thank the representatives from these companies for their time and effort taking part in interviews as well as supporting with data statistics.

Borlänge, Sweden in december 2009

TFK – Transportforskningsgruppen i Borlänge

Anna-Lena Elmquist  
Managing Director

TFK – TransportForsk

Peter Bark  
Managing Director

## Reading Instructions

In order to improve the readability of the report an attempt has been made to view the connection between the different chapters and each WP task. Please bear in mind that the different tasks are not all together separable and that the report therefore gains on being read as a whole.

Chapter 1 - 5 deals with task 1.1 (*Parameters, Criteria and Indicators for Analysis of Transnational Networks for Transport Sensitive Shipment – Theoretical Approach*) and task 1.2 (*Identification and Analysis of Supply Chain Networks for Temperature Sensitive Shipments*). To some extent the initial chapters also relates to task 1.6 (*Identification and Categorization of Barriers Towards International Intermodal Transportation of Temperature Sensitive Goods*).

Chapter 6 gives an overview of the market's perspective according to task 1.2 and 1.3 (*Development of Model for Analysis of International Networks for Temperature Sensitive Shipments*).

Chapter 7 deals with task 1.3 (see above), task 1.5 (*Transport System gap Analysis*) and task 1.6 (see above).

Chapter 8 seizes existing intermodal services according to task 1.4 (*Intermodal Transport Services – “state-of-the-art”*) throughout the ARE-train and Bring Frigosacandias shuttle train between Denmark (Padborg) and Italy (Verona).

Chapter 9 summarizes main outcomes and conclusions from WP 1 all together and also points out remaining project activities.

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## Summary

Every commodity has a limited lifetime. Some will degrade sooner than others, regardless of “how” they have been processed, stored or preserved. To allow those commodities to reach the market, the process of deterioration must be delayed somehow. Many factors can aid the preservation of perishables, like temperature, relative humidity and controlled atmosphere.

Freight transport demand in Europe has grown during the past decades, especially concerning temperature sensitive goods. Concurrently, road transportation has also increased, because it is one of the most important and widely employed means of distribution of such goods. Due to increasing congestion of road transport in and between urban areas and the search for a sustainable transport system, intermodal transport (road/rail) is an attractive option.

The present study is part of a project called *TESS: Intermodal Solutions for Trans-European Temperature Sensitive Shipments* and comprises its first segment or work package. The bearing idea of the project is to bring together actors from the supply chain to develop a model case for international intermodal temperature sensitive goods. The focus of the project is a corridor between Italy and Scandinavia.

The first working package of the project aims to identify and analyse barriers and possibilities for transport customers to use intermodal transport for temperature sensitive shipments. A shift from road to intermodal solution requires changes along the entire cold chain. This report is divided as follow:

- Literature review;
- Interviews (identification and analyses of supply chain networks); and
- Case studies (existing practice).

The literature review was used as a tool to set parameters, criteria and indicators for the carriage of Temperature Sensitive Shipments (TSS). The requirements are different for different groups of foodstuff:

1. Fresh foodstuffs (for example, fruit, vegetables);
2. Chilled foodstuffs (for example prepared vegetables, butter, milk, meat) and;
3. Frozen foodstuffs (meat, poultry, and ice cream).

The shipment of foodstuff could be exposed for different hazards which must be considered by the design of the transport procedures:

- Physical hazards: physical contaminants (foreign bodies).
- Chemical hazards: residues, contaminants and food additives.
- Biological hazards: bacteria, toxins, viruses, parasites and prions.

Chapter 5 gives a comprehensive overview of the demands on the supply chain for different groups of foodstuff.

The interviews with Swedish retailers were important to identify the first break points in Sweden, as well as get information about imported flows (volumes, origin, and type).

The volume imported is a critical factor for the implementation of an intermodal solution that attends Swedish retailers. If the amount of TSS imported is not enough to provide daily train departures but, nevertheless, is close to the necessary volume, maybe a mixed load solution should be considered. Further investigation is though required.

The case studies presented successful examples of an intermodal solution. The Arctic Rail Express (ARE-train) delivers fish products from Narvik to Oslo and carries dairy products in the other direction. The other case study is BringFrigoscandia's intermodal transport solution for foodstuff between Scandinavia and Italy. An express train (which is also shuttle) covers the distance Verona (Italy) – Padborg (Denmark) transporting frozen, chilled and fresh goods three times a week.

Both cases concern express freight trains and cover a long distance. The main incentives given for the use of intermodal transport were: speed, costs, time reliability (better than road transport), environmental friendliness and infrastructure.

This research will continue and its next steps are: delimitation in the flow analyses (Italy-Scandinavia); identification of possible backloads; study of equipments for TSS carriage and determination of possible solutions for TSS intermodal transport.



# 1. Introduction

Every commodity has a lifetime. Some will degrade sooner than others, regardless of “how” they have been processed, stored or preserved. To allow those commodities to reach the market, the process of deterioration must be delayed somehow. Many factors can aid the preservation of perishables, like temperature, relative humidity and controlled atmosphere.

The demand for Temperature Sensitive Shipments (TSS) improved considerably, increasing the need for road transport. The volume of traffic has risen sharply over the last years, overloading the road infrastructure and threatening the supply chain efficiency. Additionally, fuel costs and road tolling makes a migration from road freight to intermodal freight (road/rail) an interesting choice that would meet environmental goals.

This present study is part of a project called *TESS: Intermodal Solutions for Trans-European Temperature Sensitive Shipments*. The bearing idea of the project is to bring together actors from the supply chain to develop a model case for international intermodal temperature sensitive goods. The focus of the project is the corridor between Italy and Scandinavia.

This paper comprises the first part of the TESS project. The purpose of this segment is to identify and analyse barriers and possibilities for transport customers to use intermodal transport. This segment is divided as follow:

- Literature review (parameters, criteria, requirements and indicators for the carriage of temperature sensitive goods);
- Interviews (identification and analyses of supply chain networks); and
- Case studies (existing practice).

In the literature review, the first step taken was to define what a TSS is, followed by the scope of the project, i.e. which products would be considered in the research. Once they were determined, the next step was to describe them and establish requirements, criteria and parameters for their carriage, keeping their best quality until they have reached the final consumer.

Interviews were necessary to identify the supply chain network. The ambition is to interview all the actors in the supply chain. Retailers in Sweden were the starting point and the aim of these interviews is to locate the storages/terminals and cross docking facilities, as well as the volumes imported within a year. The flow analysis is a preliminary one, since some information is still missing. Further reports will contain a full analysis.

This paper also seizes existing practice, i.e. companies that are already using intermodal solutions in order to transport their TSS. The main results of these case studies will be the selection of a set of possible answers concerning loading unit concepts, loading techniques and information supply systems during transportation, as well as, possible backloads.

Before approaching the literature review, the background of the project, its hypothesis and methodology will be highlighted.

## 2. Background

Freight transport demand in Europe has grown during the past decades, especially concerning temperature sensitive goods. Concurrently, road transportation has also increased, because it is one of the most important and widely employed means of distribution of such goods. Due to increasing congestion of road transport in and between urban areas and the search for a sustainable transport system, intermodal transport (road/rail) is an attractive option.

In order to become competitive again in this market segment, rail faces some major challenges, due to its specific characteristics.

Distance and time are important factors of competitiveness for intermodal transport. The greater the physical space between origin and destination, the more likely freight can be damaged throughout the transportation process. An efficiently shipment's transport requires time and coordination and every delay can produce negative consequences in general, and particularly, if the cargo is perishable.

The cold chain must be considered when dealing with TSS because it is one of the most important ways to preserve perishable products and deliver them to market in good condition. According to Rodrigue and Craig (2006), cold chain refers to the transportation of TSS along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of this shipment. From the moment they are produced until they are finally consumed, the maintenance of a high standard quality is essential. The quality of a temperature sensitive commodity depends not only on its manufacturing, but also on how it is handled throughout the cold chain, especially during transportation.

According to Heap (2006), the cold chain requirements for success are: adequate products temperatures, adequate transport equipment, products quality, adequate pre-shipment handling, adequate packaging, pre-cooling, air circulation, temperature control, air freshening, prevention of cross-contamination from other cargoes, prevention of insect infestation, journey time, time without refrigeration and retail sale.

Transport costs for road transport through Europe tend to increase as a result of enhanced fuel prices and driver costs. It is also supported by the introduction of road tolling in Central Europe, which, in the long run, tends to extend even to peripheral countries, including Sweden. Moreover, road transport through Central Europe is increasingly facing quality problems due to gridlock on the motorway network.

Furthermore, consumers are becoming more and more aware of environmental aspects, making the shift from road to rail additionally interesting for retailers. This is of special relevance since many companies have adopted an environmental friendly "farm-to-table" policy. Consequently there is a mutual interest from all stakeholders – producers, retailers, transport companies (especially railways) and the public in general – to find solutions, which enable rail to re-enter this market.

### 3. Hypothesis

The present project deals with the hypothesis that it is feasible to establish intermodal (road/rail) transport solutions for TSS, in a way that fulfils the quality requirements of transport customers.

### 4. Methodology

In order to prove the veracity of the hypothesis mentioned in section 3, some issues must be taken into account:

1. The present transport system's design for TSS;
2. Market's perspectives;
3. Market's logistical requirements;
4. TSS actors and their roles;
5. Seasonal fluctuations;
6. Possible scenarios;
7. Transport solutions;
8. Compatibility of cargoes;
9. Critical factors for success;
10. European logistical networks and functional requirements from these on intermodal solutions;
11. Organisation of international intermodal transport solutions;
12. Solutions for transport-related information handling and exchange;
13. Flexibility and economy of production systems with geographically and seasonally varying demand.

The aim of the literature review was to determine the existing material regarding TSS and to ascertain a guideline to the project. This part of the methodology is fundamental to acquire the necessary knowledge about a TSS and learn about previous researches on the subject. Once the TSS products included in the research were chosen, it was possible to determine who would be interviewed.

Interviews are the most important source of information, especially when a market's perspective is needed. The ambition is to interview the principal actors throughout the TSS supply chain. The start point is Sweden, and interviews were carried out with the three main retailers in the country. The aim of these three interviews was to obtain data from temperature sensitive flows, like origin, volume, transport mode and frequency, as well as who the actors are and how the supply chain is structured.

In addition to the interviews, some case studies were evaluated. Three case studies were selected, in order to exemplify companies currently using intermodal transport solutions in order to deliver TSS. The expected result of the interviews is the selection of possible concepts and techniques concerning loading units and information supply systems during transportation.

The following section of the report goes through the literature review, from a TSS definition to TSS groups and requirements for their carriage.

## 5. Literature Review

In order to define what a TSS is and which are the requirements for an effective transport solution for these commodities, the existing literature was searched and used as a framework to the project. First of all, it was important to define the expression TSS, as well as categorize such products. Since several commodities can be specified as TSS, it was also necessary to determine which products would be part of the research.

The second part of the process was to describe the TSS group chosen in the project and that included: type of products; laws and regulations regarding their carriage; carriage temperature; compatibility of products; packaging.

In the next section definition will be discussed, as well as which TSS will be part of the project.

### 5.1. Definition

In general, a TSS is a commodity that can be spoiled or destroyed if submitted to temperature changes during transportation and, therefore, demands special/specific handling, package and storage.

Several products can be categorized as TSS, such as:

- **Pharmaceutical products:** though European standards for their transport and storage are less severe than those for perishables, both procedures involve carefulness. Medical products must be managed carefully at all times to maintain their cold or frozen state and meet regulatory guidelines. Any weakness or failure at any point in the chain can compromise their integrity, breach security, delay shipments and ultimately result in financial loss or liability. The Good Distribution Practice of Medicinal Products for Human Use cites that vehicles and equipment used to distribute, store, or handle pharmaceutical products should be suitable for their use and appropriately protective of the products to prevent exposure to conditions that could affect their stability and packaging integrity, and prevent contamination of any kind. Vehicles and equipments' design and use must aim to minimize the risk of errors and permit effective cleaning and/or maintenance, in order to avoid contamination, build-up of dust or dirt and/or any adverse effect on the quality of pharmaceutical products being distributed. There should be procedures in place for the operation and maintenance of all vehicles and equipment involved in the distribution process, including cleaning and safety precautions.
- **Live animals:** the distances dealt with in this research and the transport modes (road and rail) used, are not seen as adequate by many animal welfare institutes. The best transport for live animals is by air. The International Air Transport Association (IATA) has created the Live Animals Regulations (LAR), a mandatory standard for international transport of live animals by commercial airlines. Its purpose is to ensure the correct packaging, storing, loading, and transportation of live animal shipments by air. The LAR is endorsed as the official transportation guidelines by: The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Office International des Epizooties (OIE), the European Union, and the U.S. Fish and Wildlife Service.

- **Chemical products:** are highly regulated products and their shipping is controlled by a multitude of national and international laws. Part of those chemicals is categorized as “dangerous goods” and it follows an even more severe regulation.
- **Flowers and plants:** Refrigeration is a critical factor to keep flowers and plants looking fresh. Flowers that will not be in the market immediately and any flowers sold wholesale should be kept in cold storage (Gast, 1997). Cut flowers and potted plants (except for tropical species) should be cooled rapidly to proper temperatures (from 0,5°C to 1,5°C) and maintained at appropriate temperatures, not higher than 5°C throughout the cold chain, with a relative humidity of 90 % - 95 %. They are also sensitive to ethylene and must be kept away from ethylene producers (fruits and vegetables). Poor transportation temperatures levels reduce vase life, increase respiration rates, and increase heat production. Transporting the crop from the field to the consumer takes special precautions. One important decision is whether to transport the material in or out of water. Flowers can either be placed directly into buckets of water containing preservative or dry packed (packed out of water) to be hydrated later. Water combined with preservative compounds maintain the the crop’s hydration, but transporting can sometimes be difficult. Dry packing offers an easier way of transportation, but flowers need to be placed into a cooler or put into water as soon as possible to avoid damage from wilt. Care needs to be taken when packing flowers to keep petal damage to a minimum. Short distance transportation of flowers may allow for the use of buckets with water. Although harder and heavier to transport, flowers will not become water stressed, which could occur with dry packing.
- **Foodstuffs:** the cold chain is the solution used in order to delay the biodegradation process of perishable foodstuffs. The products’ quality can be defined by some parameters and good quality depends on freshness, expected appearance, smell and texture (Pawsey, 1995). Foodstuffs can be divided in three groups and each group requires certain measures to ensure its integrity throughout the supply chain.

The table provided by the United Nations Statistics Division (2002) was used as a support to categorize commodities’ temperature sensitivity (Appendix 1).

The focus of the present project is foodstuffs that are considered temperature sensitive and require strategies to prevent degradation and spoilage.

## **5.2. Food Stuffs**

Foodstuffs can be basically divided in three groups:

1. Fresh foodstuffs (for example, fruit, vegetables);
2. Chilled foodstuffs (for example prepared vegetables, butter, milk, meat) and;
3. Frozen foodstuffs (meat, poultry, and ice cream).

For each group, certain requirements are needed to guarantee its quality and integrity when it reaches the final consumer. Bøgh-Sørensen (2006) mentions three categories of hazards, concerning foodstuffs:

- Physical hazards: physical contaminants (foreign bodies).
- Chemical hazards: residues, contaminants and food additives.
- Biological hazards: bacteria, toxins, viruses, parasites and prions.

Sinclair (1999) mentions that, concerning foodstuffs, it is inevitable that delays will occur between the harvesting of a crop and its utilization. For most fresh fruits and vegetables this intervening period can be crucial to their condition when the stage of consumption is reached. The quality and condition of a perishable commodity is the concern of everyone involved in this production and transportation chain. From the moment it is produced, until it is finally consumed, it is essential to maintain the quality at a high standard. This is complicated by the differing lengths of time in which different products may be maintained in an acceptable condition. The refrigeration process reduces the rate of microbial growth and sometimes even stops it.

Before studying the three groups, the existing requirements for foodstuffs carriage and safety will be highlighted.

### **5.3. Laws, Regulations, Agreements and Standards regarding Food Stuffs**

In Europe, the European Community (EC) has a number of regulations and directives concerning foodstuffs. Created in January 2002, the European Food Safety Authority (EFSA) is responsible to assure a high level of food safety, as part of a comprehensive programme to improve EU's food safety, a high level of consumer protection and restore and maintain confidence in the EU food supply through coherent farm-to-table measures and adequate monitoring.

([http://ec.europa.eu/food/food/foodlaw/principles/index\\_en.htm](http://ec.europa.eu/food/food/foodlaw/principles/index_en.htm))

EFSA's remit covers food and feed safety, nutrition, animal health and welfare, plant protection and plant health. In all these fields, its most critical commitment is to provide objective and independent science-based advice and clear communication grounded in the most up-to-date scientific information and knowledge.

([http://www.efsa.europa.eu/EFSA/efsa\\_locale-1178620753812\\_home.htm](http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_home.htm)).

In Sweden, the Swedish Food Regulations act (SFS 2006:804) aims to assure a high level of protection of human health and consumers' interests in relation to food. The act applies to all stages of production, processing and distribution of food and complements regulations in EC Regulations that have the same aim as the act and which fall within the scope of the Act. The government or the authority appointed by the government may issue regulations and in individual cases decide on prohibitions; usage of products, substances or equipment in the handling of food; food operation personnel's medical examination; and other matters.

([http://www.slv.se/templates/SLV\\_MiddlePage.aspx?id=16413&epslanguage=EN-GB](http://www.slv.se/templates/SLV_MiddlePage.aspx?id=16413&epslanguage=EN-GB))

In Austria, food safety is mainly secured by the Sanitary and Phytosanitary Agreement of the WTO, the International Food Standard and in particular by the Codex Alimentarius by FAO<sup>1</sup> and WHO. A systematic preventive approach to food safety and pharmaceutical safety is based on the Hazard Analysis and Critical Control Points (HACCP) which addresses physical, chemical, and biological hazards as a means of prevention rather than finished product inspection. Within the EC the hygienical standards for foodstuff are based on this background and are resulting in the EC directive EC/852/2004. Further relevant directives on foodstuff are EC/178/2002, EC/882/2004, EC/853/2004 and EC/854/2004.

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<sup>1</sup> FAO - Food and Agriculture Organization

The directive on the hygiene of foodstuffs EC/852/2004<sup>2</sup> comprises also basic instructions for foodstuff transports and its relevant transport equipments.

The ATP agreement – agreement on the international carriage of perishable foodstuffs and on the special equipment to be used for such carriage (1970) is an agreement between signatory countries for cross-border carriage of perishable foodstuffs. Though it provides effective rules for the certification of the refrigerated vehicles used for land and rail transport of certain kinds of foodstuffs, with the purpose of ensuring their safety, there is no overall enforcing authority, and action against non-compliance is regulated by domestic legislation only. The provisions of ATP apply to all carriage, whether by rail, road, or a combination of the two. Both refrigerated and heated vehicles are considered. The ATP agreement deals with just a certain number of perishable foodstuffs.

Panozzo and Cortella (2008) propose an extension to other perishable goods. Among food products not included in the ATP, their suggestion comprises: (1) some widespread foodstuffs like fruits and vegetables, (2) minimally processed ready to use vegetables, (3) ripened cheese and a large number of prepared dishes (sweets with or without creams, cakes, pasta, alone or with filling, cooked foodstuffs, sandwiches and other ready to eat meals, wrapped or unwrapped) not containing meat or milk and normally stored and transported in controlled or modified atmosphere or under vacuum and (4) flowers. They also suggest pharmaceutical products, cosmetics and movie films, but those are not interesting to this research.

OECD, the organization for economic and cooperation development was established in 1961 and comprises 53 standards, which are not mandatory, for fruits and vegetables.

[http://www.oecd.org/document/55/0,3343,en\\_2649\\_33905\\_39595127\\_1\\_1\\_1\\_37401,00.html](http://www.oecd.org/document/55/0,3343,en_2649_33905_39595127_1_1_1_37401,00.html)

UNECE also has its standards for foodstuffs: fresh fruit and vegetables, dry and dried produce, seed potatoes, meat, egg products and cut flowers.

<http://www.unece.org/trade/agr/welcome.htm>

## **5.4. Fresh Food Stuffs**

Fruits and vegetables are the foodstuffs usually transported fresh and their quality can only be maintained after harvest (Bachmann and Earles, 2000). They suffer continuous alterations after harvesting. Some of those changes are desired by customers but others are unwanted, because they lessen the products' quality and even make them inappropriate for consumption. The main biological factors causing those changes are: respiration, evaporation and ethylene (hormone) concentration. The major consideration of the preservation process is the rate at which different products breathe. A lower temperature can control the crop's respiration rate. Consequently, by choosing an environment that will delay the respiratory process, products will be effectively stored.

The higher respiratory rates are, the faster products will degrade. Different commodities vary considerably in their respiratory rates for any given ambient temperature. Relative humidity, product temperature, ambient temperature, atmosphere and air velocity are all responsible for

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<sup>2</sup> Directive on the hygiene of foodstuffs EC/852/2004 of the European Parliament and the Council, 29 April 2004 (OJ L 139, 30.4.2004).

product water loss. The table below displays some examples of commodities and their respiration rates.

**Table 5.1:** Respiration rates of commodities

| Respiratory level | Product  |
|-------------------|--|
| Very low          | Dry fruits and vegetables, nuts, dates                                   |
| Low               | Apples, lemon, grapes, kiwi fruit, garlic, onions, potatoes              |
| Moderate          | Peaches, bananas, cherries, nectarines, carrots, lettuce, tomatoes, figs |
| High              | Strawberries, avocados, cauliflower, raspberries                         |
| Very high         | Brussels sprouts, artichokes, snap beans                                 |
| Extremely high    | Asparagus, broccoli, peas, spinach,                                      |

Source : adapted from AESBUC, 2000.

Sinclair (1999) describes four kinds of deterioration which can affect the quality and appearance of fresh fruits and vegetables:

1. Physical deterioration can be caused in a variety of ways: through manual handling, mechanical handling and attack by insects, the product can deteriorate during harvesting, packing, transporting or any intermediate process.
2. Physiological deterioration: damages caused by exposure to too high or too low temperatures or to direct sunlight, will in due course result in deterioration. Excessive ventilation may result in obvious dehydration, while too little ventilation results in a deficiency of oxygen and a build-up of carbon dioxide. This interferes with the normal process of respiration and can lead to discoloration of internal tissues.
3. Chemical deterioration: any miscalculation in the concentration of chemical preparations used to protect fresh produce from fungal attack may cause injury to the product tissues.
4. Pathological deterioration: a symptom of disease resulting from attack by fungi or bacteria, and frequently rises from the physical, physiological or chemical injuries described above.

Tables 5.2 and 5.3 show fruits and vegetables’ important information, in order to preserve the quality standards until they reach the final consumer (carrying temperature requirements, ethylene’s sensitivity, storage days, ventilation).



Table 5.2: Fruits and vegetables. Part 1

| Commodity                   | Carrying temperature °C | Temperature limits °C | Freezing temperature °C | Ventilation                  | Storage life (days)                              | Sensitivity |                   |            |             |                   |
|-----------------------------|-------------------------|-----------------------|-------------------------|------------------------------|--|-------------|-------------------|------------|-------------|-------------------|
|                             |                         |                       |                         |                              |  | Temperature | Relative humidity | Ethylene   |             | Chilling injuries |
|                             |                         |                       |                         |                              |  |             |                   | production | sensitivity |                   |
| Apple (different varieties) | 0                       | -0,5 / 2              | -1,5                    | Below 3% CO2                 | Storage depends on variety and method of storing | .           | ..                | ...        | ..          | .                 |
| Apricot                     | 0                       | -0,5 / 0              | -1,5                    | Yes                          | 20   | ..          | ..                | ...        | -----       | -----             |
| Avocado                     | 7                       | 4,5 / 12,5            | -0,5                    | Yes                          | 30   | ..          | .                 | ...        | ..          | ...               |
| Banana                      |                         |                       |                         | Maximum possible when cooled |  | ..          | .                 | ..         | ...         | ...               |
| Lacatan                     | 14                      | 14 / 15               | -1                      |                              | 24   |             |                   |            |             |                   |
| Others                      | 12                      | 12 / 13               | -1                      |                              | 24   |             |                   |            |             |                   |
| Cherry                      | -0,5                    | -1 / 0                | -1,5                    | Yes                          | 20   | ..          | ..                | -----      | -----       | -----             |
| Grape                       | -0,5                    | -1 / 0,5              | -1,5                    | Yes                          | 50 / 100   | ..          | .                 | -----      | -----       | -----             |
| Grapefruit                  | 10                      | 4,5 / 16              | -1                      | 1%CO2 max.                   | 40   | .           | ..                | .          | -----       | ..                |
| Kiwi fruit                  | -0,5                    | -0,5 / 0,5            | -2                      | 1%CO2 max.                   | 40   | .           | .                 | .          | ..          | -----             |
| Lemon                       | 10                      | 5 / 16                | -1,5                    | 1%CO2 max.                   | 80   | .           | .                 | .          | -----       | ..                |
| Lime                        | 10                      | 5 / 16                | -1,5                    | 1%CO2 max.                   | 50   | .           | .                 | .          | .           | ..                |
| Mango                       | 9                       | 7 / 10                | -1                      | Yes                          | 20 / 40  | ..          | ..                | ..         | ..          | ...               |
| Melon                       |                         |                       |                         |                              |  | ..          | ..                | ..         | .           | ..                |
| Honeydew                    | 10                      | 10 / 21               |                         | Yes                          | 90   |             |                   |            |             |                   |
| Cantaloupe                  | 3                       | 2 / 4,5               |                         | Yes                          | 15   |             |                   |            |             |                   |
| Water                       | 10                      | 4,5 / 10              |                         | Yes                          | 15   |             |                   |            |             |                   |
| Orange                      | 4,5                     | 3 / 7                 | -1 / -0,5               | 1%CO2 max.                   | 40 / 50  | .           | .                 | .          | -----       | ..                |
| Papaya                      | 7                       | 4,5 / 10              | -1                      | Yes                          | 20 / 30  | ..          | ..                | ...        | ..          | ...               |
| Peach                       | -0,5                    | -1 / -0,5             | -1,5                    | Yes                          | 30   | ...         | ..                | ...        | ...         | -----             |
| Pear                        | -0,5                    | -1 / -0,5             | -1,5                    | 3%CO2                        | 60 / 150   | ..          | ..                | ...        | ...         | -----             |
| Pineapple                   | 8,5                     | 7 / 10                | -1                      | Yes                          | 30   | ..          | .                 | .          | -----       | ...               |
| Plantain                    | 12                      | 12 / 13               | -1                      | Max.                         | 24   |             |                   |            |             |                   |
| Pomegranate                 | 0                       | 0 / 2                 | -3                      | Yes                          | 30   | .           | .                 | .          | -----       | -----             |
| Tangerine                   | 4,5                     | 3 / 7                 | -1,5                    | 1%CO2 max.                   | 40   | ..          | ..                | .          | -----       | ..                |

Adapted from Sinclair (1999) and Mercantila Publishers (1989)

- Insensitive/ no ethylene production.
- Not particularly sensitive/ insignificant ethylene production.
- Sensitive/average ethylene production.
- Very sensitive/ high ethylene production.

**Table 5.3: Fruits and vegetables. Part 2**

| Commodity             | Carrying temperature °C | Temperature limits °C | Freezing temperature °C | Ventilation | Storage life (days) | Temperature | Relative humidity | Sensitivity         |             | Chilling injuries |
|-----------------------|-------------------------|-----------------------|-------------------------|-------------|---------------------|-------------|-------------------|---------------------|-------------|-------------------|
|                       |                         |                       |                         |             |                     |             |                   | Ethylene production | sensitivity |                   |
| <b>Artichoke</b>      |                         |                       |                         |             |                     | ••          | ••                | -----               | -----       | -----             |
| Globe                 | 0                       | -0,5 / 4              | -1                      | Yes         | 14 / 20             |             |                   |                     |             |                   |
| Jerusalem             | 0                       | -0,5 / 4              | -1                      | Yes         | 60                  | ••          | ••                | -----               | -----       | -----             |
| <b>Asparagus</b>      | 0                       | 0 / 1                 | -0,5                    | Yes         | 20                  | ••          | ••                | -----               | •           | -----             |
| <b>Aubergine</b>      | 7                       | 7 / 10                | -0,5                    | Yes         | 14                  | •           | ••                | -----               | •••         | •••               |
| <b>Beans (French)</b> | 0                       | 0 / 7                 | -0,5                    | Yes         | 20                  | •••         | •••               | -----               | -----       | ••                |
| <b>Beetroot</b>       | 0                       | 0 / 1                 | -0,5                    | Yes         | 60 / 90             | •           | ••                | -----               | -----       | •                 |
| <b>Cabbage</b>        | 0                       | 0 / 1                 | -0,5                    | Yes         | 20                  |             |                   |                     |             |                   |
| Head pointed          |                         |                       |                         |             |                     | •••         | ••                | •                   | ••          | -----             |
| Red                   |                         |                       |                         |             |                     | ••          | •                 | •                   | ••          | -----             |
| White                 |                         |                       |                         |             |                     | •           | •                 | •                   | ••          | -----             |
| <b>Capsicum</b>       | 6,5                     | 7 / 10                | -0,5                    |             | 20                  | ••          | •••               | •                   | •           | ••                |
| <b>Carrots</b>        | 0                       | -0,5 / 0,5            | -1                      | Yes         | 70                  | ••          | ••                | •                   | ••          | -----             |
| <b>Cauliflower</b>    | 0                       | 0 / 1                 | -0,5                    | Yes         | 30                  | ••          | •••               | •                   | ••          | -----             |
| <b>Celery</b>         | 0                       | 0 / 1                 | -0,5                    | Yes         | 60 / 90             | •••         | ••                | •                   | •••         | -----             |
| <b>Chicory</b>        | 0                       | 0 / 1                 | -0,5                    | Yes         | 14 / 20             | ••          | ••                | -----               | -----       | -----             |
| <b>Cucumber</b>       | 7                       | 7 / 10                | -0,5                    | Yes         | 14                  | ••          | •••               | •                   | •••         | •••               |
| <b>Garlic</b>         | 0                       | 0 / 1                 | -0,5                    | Yes         | 150                 | •           | •                 | -----               | -----       | -----             |
| <b>Ginger</b>         | 12                      | 10 / 13               |                         | Yes         | 150                 |             |                   |                     |             |                   |
| <b>Leek</b>           | 0                       | 0 / 1                 | -0,5                    | Yes         | 60                  | ••          | ••                | -----               | ••          | -----             |
| <b>Lettuce</b>        |                         |                       |                         |             |                     |             |                   |                     |             |                   |
| Iceberg               | 0                       | 0 / 1                 | -0,5                    | Yes         | 40                  | ••          | •••               | •                   | ••          | -----             |
| Others                | 0                       | 0 / 1                 | 0                       | Yes         | 20                  | •••         | •••               | •                   | ••          | -----             |
| <b>Marrow</b>         | 7                       | 7 / 10                | -0,5                    |             | 60                  |             |                   |                     |             |                   |
| <b>Onions</b>         | 0                       | 0 / 1                 | -0,5                    |             | 30 / 120            | •           | •                 | •                   | •           | -----             |
| <b>Peas in pod</b>    | 0                       | 0 / 1                 | -0,5                    |             | 7 / 120             |             |                   |                     |             |                   |
| <b>Potatoes</b>       |                         |                       |                         |             |                     | ••          | •                 | •                   | ••          | •                 |
| Ware                  | 7                       | 4,5 / 10              | -0,5                    |             | 60+                 |             |                   |                     |             |                   |
| Seed                  | 4,5                     | 1,5 / 7               | -0,5                    |             | 150                 |             |                   |                     |             |                   |
| Sweet                 | 12,5                    | 12,5 / 15,5           | -1                      |             | 120                 | •           | •                 | -----               | -----       | •••               |
| <b>Pumpkin</b>        | 10                      | 10 / 12,5             | -0,5                    |             | 60 / 190            | •           | •                 | -----               | -----       | ••                |
| <b>Rhubarb</b>        | 0                       | 0 / 1                 | -0,5                    |             | 15 / 30             | ••          | •••               | -----               | -----       | -----             |
| <b>Salsify</b>        | 0                       | 0 / 1                 | -1                      |             |                     |             |                   |                     |             |                   |
| <b>Squash</b>         | 10                      | 7 / 12,5              | -0,5                    |             | 60 / 90             | ••          | ••                | -----               | -----       | ••                |
| <b>Tomato</b>         |                         |                       |                         |             |                     | •••         | •                 | ••                  | ••          | •••               |
| Green                 | 12,5                    | 10 / 15,5             | -0,5                    |             | 20                  |             |                   |                     |             |                   |
| Firm ripe             | 7                       | 7 / 10                | -0,5                    |             | 14                  |             |                   |                     |             |                   |

Adapted from Sinclair (1999) and Mercantila Publishers (1989)

--- Insensitive/ no ethylene production. • Not particularly sensitive/ insignificant ethylene production. •• Sensitive/average ethylene production. ••• Very sensitive/ high ethylene production.

## 5.5. Chilled Food Stuffs

Chilled foods are those which have been submitted to chilling process and afterwards are kept at chill temperatures. They must be carried at temperatures between about  $-1.5^{\circ}\text{C}$  and  $+5^{\circ}\text{C}$ . The following products can be found as chilled foods (Mercantila Publishers, 1990): chilled fresh meat, chilled meat products, manufacturing meat, chilled poultry, chilled fish, lightly and semi-preserved fish products, live fish, chilled dairy products, margarine, eggs, prepared meals, prepared salads, prepared raw vegetables.

**Table 5.4:** Chilled foodstuffs

| Commodity            | Carrying temperature<br>°C | Temperature limits<br>°C | Freezing temperature | Ventilation | Storage days | Sensitivity |       |
|----------------------|----------------------------|--------------------------|----------------------|-------------|--------------|-------------|-------|
|                      |                            |                          |                      |             |              | Temperature | Odour |
| <b>Bacon</b> (1)     | -1                         | -2 / 4,5                 |                      | No          | 30           | •••         | ••    |
| <b>Beef</b> (1)      |                            |                          |                      |             |              |             |       |
| Chilled              | -1,5                       | -1,5 / 0                 |                      | No          | 40           | ••          | ••    |
| Quarters             | -1,5                       | -1,5 / 0                 |                      | (2)         | 70           | •••         | ••    |
| Packaged             | -1,5                       | -1,5 / 0                 |                      | No          | 70           | ••          | ••    |
| <b>Butter</b> (1)    | 0                          | -1 / 4,5                 |                      | No          | 30           | ••          | •••   |
| <b>Cheese</b> (3)    | 2                          | 0 / 10                   |                      | Yes (4)     |              | ••          | •     |
| <b>Cream</b> (1)     | 0                          | -1 / 0,5                 |                      | No          | 10           | •••         | ••    |
| <b>Eggs</b> (shell)  | 0                          | -1 / 0,5                 | -3                   | Yes         | 180          | •••         | •••   |
| <b>Fats</b>          | 0                          | -1 / 4,5                 |                      | No          |              | •••         | ••    |
| <b>Fish</b> (1)      |                            |                          |                      |             |              |             |       |
| Iced                 | -0,5                       | -1,5 / 0                 |                      | No          | 14 / 20      | ••••        |       |
| Salt                 | -0,5                       | -2 / 4,5                 |                      | No          | 150          | ••••        |       |
| <b>Game</b> (1)      | 0                          | -1,5 / 0                 |                      |             |              | •••         | ••    |
| <b>Ham</b> (1)       | -0,5                       |                          |                      |             |              | •••         | ••    |
| <b>Lamb, mutton</b>  | -1,5                       | -1,5 / 0                 |                      | No          | 30           | •••         | ••    |
| Packaged             | -1,5                       | -1,5 / 0                 |                      | No          | 70           | ••          | ••    |
|                      | 0                          | -1,5 / 4,5               |                      | No          | 180          | •••         | ••    |
| <b>Margarine</b>     | 0                          | -1,5 / 0,5               |                      | No          | 180          | •           | ••    |
| <b>Meat products</b> | -0,5                       | -1,5 / 0,5               |                      | No          |              | •••         | ••    |
| <b>Milk</b>          |                            |                          |                      |             |              | ••••        | •••   |
| Pasteurised          | 0                          | -0,5 / 1                 |                      | No          | 14           |             |       |
| Sterilised           | 0                          | -0,5 / 1                 |                      | No          | 30           |             |       |
| Concentrated         | 0                          | -0,5 / 1                 |                      | No          |              |             |       |
| <b>Pork</b> (1)      | 1,5                        | -1,5 / 0                 |                      | No          | 14           | •••         | ••    |
| Salt                 | 4,5                        | -1 / 7                   |                      | No          | 120          |             |       |
| <b>Poultry</b> (1)   | -1                         | -1,5 / 1,5               |                      | No          | 14           | ••••        | ••    |

Source: adapted from Sinclair (1999) and Mercantila Publishers (1990).

- (1) May also be carried as frozen cargo, in which case transport conditions for frozen cargo should be followed.
- (2) On longer voyages an atmosphere of 10 % CO<sub>2</sub> may be called for, and is maintained by injection.
- (3) Temperatures may vary with the type of cheese and whether or not it is required to ripen during the voyage.
- (4) Ventilation is not required, but an atmosphere containing high levels of CO<sub>2</sub> could develop. The level should be checked before the space or cooler is entered and if necessary should be reduced by ventilation.

Sensitivity to temperature • Relative robust to temperatures above the required storage and transport.

••••• Product must be maintained at the required temperature.

Sensitivity to foreign odours • Little or no sensitivity towards foreign odours.

••• extreme sensitivity towards foreign odours.

Table 5.4 displays the requirements for chilled products' carriage. According to Heap (2007), refrigerated transport of chilled foods must be seen as a total operation involving movement

of goods from a fixed place to another (storage). The author also mentions that even the finest transport equipment cannot compensate for poor handling at loading, wrong packaging and stowage or inadequate cooling. This applies for every temperature sensitive commodity.

The next section describes frozen foods.

### 5.6. Frozen Food Stuffs

Mercantila Publishers (1990) mentions the necessity of distinguishing between frozen foods and deep (or quick) frozen foods. While the first one must be kept at a steady temperature of -10° C (or -12° C) or colder, the second one must be kept at -18° C or a lower temperature.

These products can be named among deep frozen foods: (1) deep frozen meat (Deep frozen meat includes beef, veal, pork, lamb, venison and game. Meat is marketed and transported in several forms: frozen carcasses and primal cuts – sides, legs, etc – frozen retail cuts, frozen mince including hamburgers. ATP maximum internal temperature is currently -18 °C), (2) deep frozen poultry, (3) fish, (4) fruits and concentrated juice and (5) vegetables. The table below presents information about deep frozen foodstuffs:

Table 5.5: Deep frozen foodstuffs

| Commodity                        | Ideal temperature | Temperature limits | Carrying temperature | Ventilation | Storage life | Sensitivity |       |
|----------------------------------|-------------------|--------------------|----------------------|-------------|--------------|-------------|-------|
|                                  |                   |                    |                      |             |              | temperature | odour |
|                                  | -25° C            | -- /-12° C         | -18° C               |             |              |             |       |
| Retail packed minced beef        |                   |                    |                      | No          | (2)          | •••         | ••    |
| Retail packed minced pork        |                   |                    |                      | No          | (2)          | •••         | •     |
| Retail packed minced beef, lamb  |                   |                    |                      | No          | (2)          | •           | •     |
| Manufacturing meat               |                   |                    |                      | No          | (2)          | •           | •     |
|                                  | -24° C            | -- /-8° C          | -18° C               |             |              |             |       |
| While chickens                   |                   |                    |                      | No          | (2)          | •           | •     |
| Chicken parts                    |                   |                    |                      | No          | (2)          | ••          | •     |
| Turkey                           |                   |                    |                      | No          | (2)          | •••         | •     |
|                                  | -29° C            | -- / -8° C         | -18° C               |             |              |             |       |
| Fatty fish                       |                   |                    |                      | No          | (2)          | •••         |       |
| Lean fish                        |                   |                    |                      | No          | (2)          | ••          |       |
| Shrimps                          |                   |                    |                      | No          | (2)          | ••••        |       |
|                                  | -18° C            | -- /-15° C         | -18° C               |             |              |             |       |
| Deep frozen fruits without sugar |                   |                    |                      | No          | (2)          | ••          |       |
| Deep frozen fruits in syrup      |                   |                    |                      | No          | (2)          | ••••        |       |
| Deep frozen concentrated fruit   |                   |                    |                      | No          | (2)          | •           |       |
|                                  | -18° C            | -- / -2° C         | -18° C               |             |              |             |       |
| Deep frozen vegetables in        |                   |                    |                      | No          | (2)          | •           |       |
| Deep frozen asparagus,           |                   |                    |                      | No          | (2)          | •••         |       |
|                                  | -18° C            | -- / -20° C        |                      |             |              | (3)         |       |
| Bakery and confectionary         |                   |                    | -18° C               | No          | (2)          |             |       |
| Ice cream                        |                   |                    | -20° C               | No          | (2)          |             |       |
| Desserts                         |                   |                    | -18° C               | No          | (2)          |             |       |
| Prepared meals                   |                   |                    | -18° C               | No          | (2)          |             |       |

Source: Based on Mercantila Publishers (1990).

- (1) In accordance to the ATP agreement.
- (2) Storage life is directly related to the temperature in which the commodity is kept.
- (3) Due to the great variation between different products it is not possible to indicate the sensitivity to temperature warmer than -18° C.

Sensitivity to temperature • Relative robust to temperatures above the required storage and transport.

•••• Product must be maintained at the required temperature.

Sensitivity to foreign odours • Little or no sensitivity towards foreign odours.

••• extreme sensitivity towards foreign odours.

The three traditional frozen commodities are butter, beef and chicken.

**Table 5.6:** Frozen foodstuffs

| Commodity         | Ideal temperature | Temperature limits | Carrying temperature (1) | Ventilation | Storage life | Sensitivity |       |
|-------------------|-------------------|--------------------|--------------------------|-------------|--------------|-------------|-------|
|                   |                   |                    |                          |             |              | temperature | odour |
| Frozen beef       | -20° C            | -- /-8° C          | -12° C                   | No          | (2)          | •           | •     |
| Frozen chicken    | -20° C            | -- /-8° C          | -12° C                   | No          | (2)          | •           | •     |
| Frozen butter (3) | -20° C            | -- /-8° C          | -10° C                   | No          | (2)          | •           | •••   |

Source: Based on Mercantila Publishers (1990).

- (1) In accordance to the ATP agreement.
  - (2) Storage life is directly related to the temperature in which the commodity is kept.
  - (3) The ATP agreement states that butter’s temperature can gradually rise during transportation if it is intended for immediate further processing at destination.
- Sensitivity to temperature • Relative robust to temperatures above the required storage and transport.  
 •••• Product must be maintained at the required temperature.
- Sensitivity to foreign odours • Little or no sensitivity towards foreign odours.  
 ••• extreme sensitivity towards foreign odours.

The next section discusses requirements, barriers and possibilities for mixing cargoes.

### 5.7. Compatibility of Cargoes

Though the mixing of several commodities in a single load seems to be economically advantageous, serious problems may arise, due to different carriage temperature, transit time, relative humidity, packaging and stowage patterns, emission of undesirable taste or odour-producing substances from the commodities, and emission of significant quantities of the undesirable ripening hormone, ethylene. It is often necessary to keep numerous commodities in the same storage, but it is not a big problem if done for a short-term period, though many authors highlight the risks of cross contamination and spoilage (Mercantila Publishers, 1990; Sinclair, 1989; Keener, 2003; Thompson et al., 2007).

*A priori*, products that are most sensitive to high relative humidity are: onions, potatoes, yams and cape gooseberries and should not be mixed with other commodities that, on the other hand, would dehydrate by evaporation if humidity is reduced.

Concerning odour emissions, citrus fruits, potatoes, onions, leek, celery, garlic and other strong odour producing foodstuffs could spoil other more sensitive products like apples, pears and melons. Moreover, meat, eggs and dairy products readily absorb odours from products like apple and citrus fruits. Bachmann and Earles (2000) recommend that onions, nuts, citrus fruits and potatoes should each be stored separately.

Besides, when dealing with fresh fruits and vegetables, ethylene production and sensitivity must be taken into account. Aubergine, Brussels sprout, celery, banana, cucumber, pear and peach are very sensitive to the hormone. However, fruits like banana, pear and peach also produce significant quantities of ethylene and ventilation of the container or storeroom is necessary.

Another practice that is quite dangerous is the utilization (without preventive measures of cleaning and inspection) of the same equipment for garbage carriage or other contaminant products after food delivery and then the return to food delivery again.

International Product Safety Consultants – IPSC (Keener, 2003) has constructed a product handling and compatibility matrix, ranked from the highest risk of cross-contamination (Category 1 Hazard) to the lowest risk (Category 4 Hazard).

**Table 5.7:** Product handling matrix

|                   |   | BACK-HAULED PRODUCTS |                   |                  |               |  |                |
|-------------------|---|----------------------|-------------------|------------------|---------------|--|----------------|
|                   |   | Dry goods            | Frozen boxed meat | Fresh boxed meat | Fresh produce | Industrial equipment, botanicals and chemicals | Paper products |
| OUTBOUND PRODUCTS | Dry goods                                     | 4                    | 3                 | 2                | 2             | 1  | 4              |
|                   | Frozen boxed meat                             | 3                    | 4                 | 2                | 2             | 1  | 4              |
|                   | Fresh boxed meat                              | 2                    | 2                 | 2                | 2             | 1  | 4              |
|                   | Fresh produce                                 | 2                    | 2                 | 2                | 2             | 1  | 4              |
|                   | Industrial equipment botanicals and chemicals | 1                    | 1                 | 1                | 1             | 1  | 4              |
|                   | Paper products                                | 4                    | 4                 | 4                | 4             | 4  | 4              |

Source: International Product Safety Consultants (IPSC), Inc (Keener, 2003).

National Rural Health Alliance INC. (2007) mentions that separation choices should be made primarily on the temperature requirement of the product and then on sensitivity to odour contamination and ethylene production. They provide a table of recommendations on how to separate products in relation to their volumes to be moved in different load options. Observe that the table refers to road transport.

**Table 5.8:** Separation choices for products during road transportation

| Volume to transport    | Recommended separation   |
|------------------------|--|
| One truck load or less | Partitioned load for frozen (-18 °C) /chilled (+1 °C)/chilling sensitive (+8 °C) or          |
|                        | Partitioned load for frozen (-18 °C)/ non frozen (+5 °C)                                     |
| Two trucks or less     | Frozen (-18 °C) load plus a partitioned load for chilled (+1 °C)/chilling sensitive (+8 °C)  |
| Three trucks or more   | A separate load for frozen (-18 °C), chilled (+1 °C) and chilling sensitive (+8 °C) products |

Source: National Rural Health Alliance INC. (2007)

Based on the literature available, a compatibility matrix was built to be used in the project (appendix 2). The criteria used to determine if products were compatible to be carried in the same loading unit were:

1. Relative humidity;
2. Temperature;
3. Ethylene production;
4. Ethylene sensitivity;
5. Odour production;
6. Odour sensitivity;
7. Need of ventilation.

Notice that packaging was not considered and if the requirements differed for the products in question, they were considered incompatible. However, an effective packaging may solve the problem, if mixed loads are inevitable. But as suggested by National Rural Health Alliance INC. (2007), if mixing loads is the only possibility, then they should be partitioned (regardless the transport mode used). Besides, fresh fruits and vegetables, despite their

packaging (usually mesh bags, plastic bags or paper boxes that allow ventilation) should respect the parameters set for them above and avoid cross contamination. Section 5.8 discusses packaging, its advantages and disadvantages, materials, etc.

## 5.8. Packaging

Packaging is a very important step towards food's quality maintenance. Packaging factors that need to be considered when transporting product include: ventilation, product protection (against contamination, rough handling and dehydration), strength, insulation and labelling. It facilitates handling and distribution, delays deterioration, labels the product and can be a powerful marketing tool (design, colour, etc).

Mercantila Publishers (1990) groups inner packaging in three categories: rigid, semi-rigid and flexible. There are two types of packaging:

1. Inner packaging: usually in direct contact with the product.
2. Outer packaging: normally contains a number of inner packaging.

Inner packaging requirements for chilled and frozen products differ from those for fruits and vegetables.

Mercantila Publishers (1989) points out the inexistence of international standards for fruits and vegetables' packaging, but it should contain, protect and identify the product and the materials used should observe hygiene and non-toxicity standards.

The most important properties of packaging materials to be used for chilled and frozen products are (Mercantila Publishers, 1990):

- **Water vapour permeability:** Permeability to water vapour, called Water Vapour Transmission Rate (WVTR). Concerning chilled and frozen products, WVTR of the packaging material and of the packaging itself should be low or very low. Plastic laminates containing an aluminium foil layer present hardly any water vapour penetration.
- **Gas permeability:** For a number of frozen and deep frozen products it is necessary to use a packaging material with low oxygen permeability in order to prevent or reduce the development of rancidity, an oxidative process.
- **Physical properties:** The packaging material has to withstand the conditions experienced in the cold chain, such as drops, shocks and vibrations. Physical properties comprise several different characteristics such as burst strength, tensile strength, elongation and elasticity. For deep frozen food the material must be able to withstand temperatures as cold as  $-40^{\circ}\text{C}$  without becoming brittle. In some cases, liquid nitrogen or solid carbon dioxide is used as a refrigerant, and the packaging material must withstand temperatures as low as  $-50^{\circ}\text{C}$  or even lower. The trend towards ready-to-eat dishes means that an increasing amount of packaging material as well as withstand extremely cold temperatures must also be able to tolerate high temperatures. Hot fillings are used for some foodstuffs. This means that the food (usually liquid or semi-liquid) is put into the package while still hot, often over  $90^{\circ}\text{C}$ . Obviously, the packaging material must withstand this process.

- **Machinability:** The choice of a potential new plastic affects the quality of the final product. The new material should run on the existing packaging machinery at least the same speed and with lesser failures than the material it is to replace, in order to justify the change, since packaging machines are often very expensive.
- **Migration:** Several countries have legislation on packaging, including maximum permissible limits for migration of additives from the packaging material into the foodstuff.

Outer packaging serves to enclose the product and provides a means of handling. Poor quality packaging will lead to damage. It should withstand: rough handling during loading and unloading, compression from the overhead weight of other cartons, impact and vibration during transportation and high humidity.

Concerning fresh fruits and vegetables, the outer package should also allow adequate air flow (ventilation) so that the commodity in the inner packaging will maintain the desired temperature.

Table 5.10 displays the types of packaging (both inner and outer), materials, products that use these kinds of packaging and some observations.

The literature is rich and detailed concerning food safety and quality standards, aiding to set parameters for transport equipment, logistical requirements and quality control. In order to obtain a market's perspective and a reliable data, it was necessary to interview the actors involved in the supply chain, starting from the end (destination). The three biggest retailers in Sweden were interviewed, but before the results acquired are displayed, the retail's segment will be overviewed.



**Table 5.10:** Types of packaging

| TYPES           | MATERIAL   | INNER/OUTER  | PRODUCTS                                       | OBS  |
|-----------------|------------|--------------|--|--|
| Bags, mesh bags | Paper      | Inner        | Potatoes, onions                               | Prevents air-flow to the product during transit (unless perforated), and can be used to maintain a modified atmosphere around the product.   |
|                 | Plastic    | Inner        | Fruits and vegetables in general               |  |
| Trays           | Plastic    | Inner        | Fresh meat and poultry                         | Fresh meat and poultry are traditionally displayed in trays made of wood pulp or a rigid plastic, sometimes called "foodtainer". The tray is overwrapped with a plastic film with high permeability to oxygen. Fresh fruits and vegetables can also be marketed in this way. |
|                 | Wood pulp  | Inner        | Fresh meat and poultry                         |  |
|                 | Paper      | Inner        | Fruits, vegetables                             |  |
| Boxes           | Plastic    | Inner/ outer | Fruits and vegetables                          | Depends on the size and the plastic material. Packages with a top and bottom that are heat formed from one or two pieces of plastic are known as clamshells. Clamshells are used in items that are easily damaged by crushing.   |
|                 | Paperboard | Outer        | Foodstuffs in general                          | Variable strength, depending on construction and type  |
|                 | Wood       | Outer        | Foodstuffs in general                          |  |
| wrappers        | Plastic    | Inner        | Potatoes, sweet potatoes, apples, onions, etc. | Shrink wrapping is a technology that protects the product from disease and reduce mechanical damage.   |
|                 | Paper      | Inner        | Butter, margarine                              |  |
| Bins            | Wood       | Outer        | Foodstuffs in general                          | Bulk transport of heavy products. Useful for the consolidation of small volumes of mixed product lines which are difficult to stack onto pallets in a stable manner  |
|                 | Plastic    | Outer        | Foodstuffs in general                          |  |
| Crates          | Wood       | Outer        | Foodstuffs in general                          |  |
| Foil            | Plastic    | Inner        |  |  |
|                 | Aluminium  | Inner        | Prepared meals, meat products                  |  |
| Cartons         | Plastic    |              | Ice cream, milk, milk yoghurt                  | Many rigid and semi-rigid plastic packages (trays, boxes, etc) are made by injection moulding.   |

Source: adapted from Mercantila Publishers (1989), Mercantila Publishers (1990) and National Rural Health Alliance INC. (2007)

### Market's Perspective: an Overview

The retail market has changed as a result of many factors: customers' environmental concerns; the increase in the number of single-person households and; the strong desire for good value for money and cheap prices.

People spend less and less time preparing meals, not only demanding prepared and single meals, but also premium and indulgence food (ice cream and confectionery). The environmental concern resulted in healthier foodstuffs (containing fewer artificial additives), ecological production methods and ethical foods (such as organic).

The infrastructure has also changed: small shops that were centrally located were replaced by larger supermarkets situated in peripheral areas. While the small shops were geographically limited concerning their supplies (foodstuffs), the larger supermarket chains import goods from all over the world and are not restricted to foodstuffs. They import other commodities as well, like toys, clothes, house décor, kitchen equipment, DVDs, etc.

Customers are demanding quality standards set by international organisations. Society itself is developing an environmental awareness of its own, reflected not only in the food segment, but also in actions like recycling, using ecological transport alternatives, purchasing ecological products.

Some retailers have also introduced technological services for their customers: the private computer and the internet made possible the online purchase followed by home delivery.

Europe has some of the largest retail markets in the world and from a supply perspective, it is experiencing increasing consolidation. Warehouses and terminals are becoming larger and fewer. Competition is increasing and many retail groups are expanding their presence in other EU countries, as well as other parts of the world.

On the subject of fruits and vegetables, the most important trends are related to health, convenience, pleasure, product variety, organic products and fair trade (Centre for the Promotion of Imports from Developing Countries - CBI, 2008). According to CBI (2008), the EU market for fresh fruits and vegetables is, in general, decreasing in volume. They accredit this fact to a shift in the eastern EU member states from basic products towards more diverse produce and an increase in the availability of other food products. Table 6.1 provides data on the consumption of fruits and vegetables in the EU. Observe that volume is represented in thousand tonnes and volume consumed is equivalent to: *production + imports – exports*.

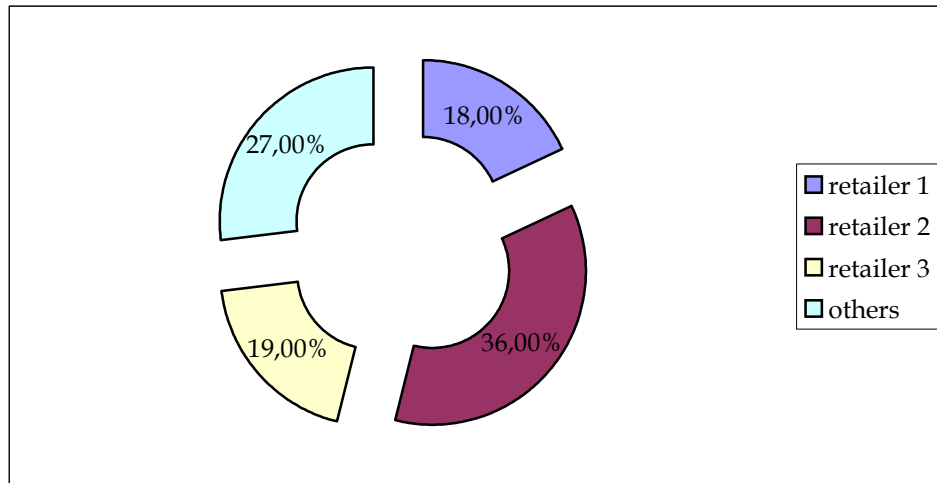
**Table 6.1:** Consumption of fresh fruits and vegetables by EU member countries in 2002-2006 (thousand tons)

| Fruits          |               |               |               | Vegetables      |               |               |               |
|-----------------|---------------|---------------|---------------|-----------------|---------------|---------------|---------------|
|                 | 2002          | 2004          | 2006          |                 | 2002          | 2004          | 2006          |
| <b>Total EU</b> | <b>74 574</b> | <b>80 427</b> | <b>76 576</b> | <b>Total EU</b> | <b>61 790</b> | <b>67 262</b> | <b>61 789</b> |
| Italy           | 16 026        | 18 466        | 17 945        | Italy           | 12 683        | 14 969        | 13 780        |
| Spain           | 12 932        | 14 290        | 13 578        | Spain           | 7 703         | 8 216         | 7 381         |
| France          | 11 902        | 12 776        | 11 280        | France          | 6 798         | 6 869         | 6 179         |
| Germany         | 8 339         | 7 236         | 6 641         | Germany         | 6 268         | 5 848         | 5 465         |
| Greece          | 3 924         | 3 813         | 3 953         | Poland          | 4 882         | 5 480         | 5 028         |
| United Kingdom  | 3 218         | 3 377         | 3 659         | United Kingdom  | 4 035         | 4 243         | 4 581         |
| Poland          | 3 564         | 3 901         | 3 605         | Romania         | 3 391         | 4 153         | 3 662         |
| Romania         | 2 887         | 4 100         | 3 563         | Greece          | 3 126         | 3 399         | 3 087         |
| Portugal        | 2 417         | 2 217         | 2 229         | Belgium         | 2 500         | 2 728         | 2 388         |
| Hungary         | 1 396         | 2 130         | 1 681         | Portugal        | 2 257         | 2 560         | 2 281         |
| Austria         | 1 439         | 1 580         | 1 533         | Netherlands     | 1 628         | 1 804         | 1 746         |
| Netherlands     | 1 154         | 1 022         | 1 475         | Hungary         | 1 624         | 1 766         | 1 260         |
| Czech Republic  | 869           | 922           | 942           | Bulgaria        | 859           | 931           | 709           |
| Belgium         | 793           | 926           | 824           | Austria         | 706           | 712           | 694           |
| Bulgaria        | 862           | 770           | 682           | Czech Republic  | 617           | 608           | 679           |
| Sweden          | 538           | 604           | 614           | Sweden          | 558           | 604           | 619           |
| Denmark         | 374           | 400           | 425           | Slovakia        | 343           | 409           | 434           |
| Ireland         | 189           | 187           | 386           | Denmark         | 387           | 396           | 419           |
| Slovenia        | 389           | 423           | 327           | Finland         | 307           | 319           | 323           |
| Slovakia        | 341           | 284           | 260           | Ireland         | 275           | 267           | 279           |
| Finland         | 240           | 257           | 249           | Latvia          | 183           | 221           | 236           |
| Cyprus          | 220           | 243           | 228           | Lithuania       | 314           | 376           | 183           |
| Lithuania       | 205           | 182           | 170           | Slovenia        | 120           | 145           | 145           |
| Latvia          | 159           | 128           | 146           | Cyprus          | 94            | 90            | 86            |
| Estonia         | 86            | 81            | 80            | Estonia         | 68            | 78            | 65            |
| Luxembourg      | 64            | 64            | 54            | Malta           | 39            | 50            | 54            |
| Malta           | 47            | 51            | 48            | Luxembourg      | 22            | 21            | 24            |

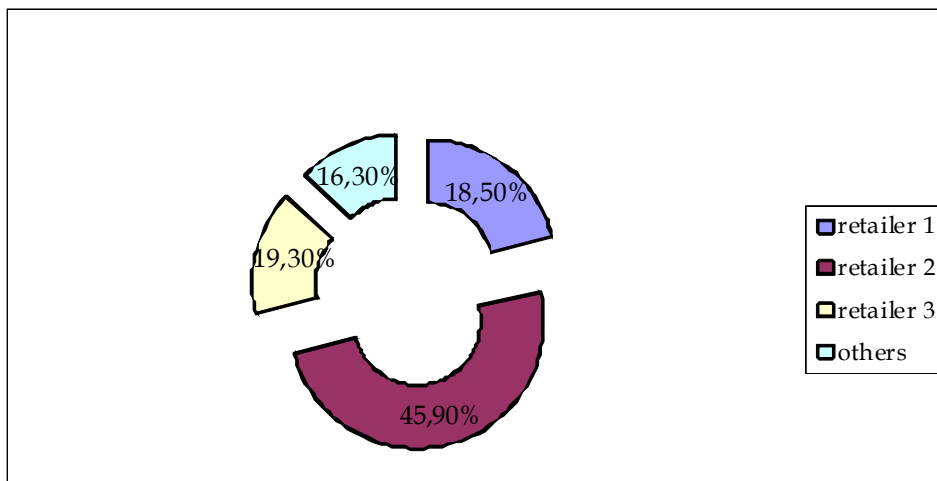
Source: CBI, 2008.

The European fish and shellfish market is characterised by many small and medium suppliers, processors and distributors, but the structure of the trade channel has been changing. It is consolidating, as a result of increased competition and improved logistics in the fish trade (CBI, 2008). In Sweden, the consumption of prepared and preserved fishery products is small, according to CBI (2008), but is increasing, since Swedish demand for health, quality and food safety is high.

Sweden has the highest grade of consolidation and concentration in retailing in the EU. The three largest retailers hold more than three quarters of the market share (CBI, 2008). The Swedish dairy industry is characterized by a great number of manufacturers, which usually deliver their commodities to the three largest retailers (Björklund, 2002). Figures 6.1 and 6.2 show the Swedish market segment in 2001 and 2009.



**Figure 6.1:** Swedish market segment 2001.  
Source: Björklund, 2002.



**Figure 6.2:** Swedish market segment December 2009.  
Source: Fri Köpenskap, 2009.

According to Movement Consulting (2007), “PREMIUM” products have got their breakthrough some years ago in Sweden and are an important reason for the relative growth of the retailers segment. Some factors that justify this phenomenon are:

- Comfort: the increase of chilled prepared meals, competing with deep frozen alternatives and replacing the “home made” meals.
- Health: sugar, fat, additives and other chemicals are being replaced by healthier and, sometimes, more expensive alternatives.
- Environment: ecological and nutritional products have expanded their market’s segment.
- Price: getting more for less is still an important factor when deciding what to purchase.

To have an accurate overview of the Swedish market, interviews were carried out with the largest retailers in the country. The results are displayed in the next chapter.

## 6. Interviews with Retailers in Sweden

In order to analyse the flows imported by retailers in Sweden, products were grouped in five classes:

1. Fresh foodstuffs;
2. Frozen foodstuffs;
3. Chilled foodstuffs;
4. Dry foodstuffs; and
5. Non-food (NF).

The ambition is to interview the actors involved in the TSS supply chain, starting with the three largest retailers in Sweden.

Swedish companies are well aware of environmental issues, and have adopted environmental measures such as: ensure that their suppliers (both national and international) also have ecological policies; prioritization of boat and train, when possible; social responsibility with respect to energy transport and products. The next sections display the results from the three interviews.

### 6.1. Retailer 1

Retailer 1 started operating in Sweden in the middle of the 1900 century. Its environmental policies include: an active work to minimize environmental load caused by packaging disposal, products degradation and transportation; increase its organic products' supply to attend the demand, as well as support the improvement of this market segment; require proof of environmental policies from its' suppliers; and influence environmental improvements through active dialogues with customers, owners, companies and environmental organisations.

The material acquired from retailer 1 is very rich. The data collected includes: volumes for frozen, chilled, dry and NF commodities within a year; frequency of delivery per week and terminals (destination); location of those terminals and total volume delivered by every supplier. Unfortunately, volumes for fresh fruits and vegetables were not obtained.

The company warehouses/terminals are mostly located in Southern Sweden, except for one located in Umeå. This was expected, since the population is more concentrated in the South. These terminals are the first break points of the commodities in the country. The volume imported (in one year interval) translates this fact accurately: just 7,98% of the total volume imported (frozen, chilled, dry and non-food products) by retailer 1 is placed in Umeå's terminal, while the rest is unequally spread in the southern part of the country. Observe that 62,12 % of the total volume is concentrated around the capital, Stockholm (see table 7.1).

**Table 7.1:** Volume imported per terminal (retailer 1)

| TERMINALS    | % TOTAL IMPORTED VOLUME |
|--------------|-------------------------|
| Malmö        | 4,55                    |
| Växjö        | 16,11                   |
| Gothenburg   | 0,95                    |
| Bro*         | 53,6                    |
| Johanneshov* | 8,52                    |
| Västerås     | 8,29                    |
| Umeå         | 7,98                    |

\*Both are located in Stockholm region.

Table 7.2 shows the number of pallets imported by the retailer from European countries in one year.

**Table 7.2:** Number of pallets imported from European countries within a year

| ORIGIN<br>(COUNTRY) | TYPE OF PRODUCT |              |          |               |              |
|---------------------|-----------------|--------------|----------|---------------|--------------|
|                     | Frozen          | Chilled      | Fresh    | Dry           | Non-food     |
| Austria             | 0               | 967          | 0        | 0             | 103          |
| Belgium             | 4 433           | 363          | 0        | 4 283         | 0            |
| Switzerland         | 0               | 0            | 0        | 1 467         | 0            |
| Czech Republic      | 0               | 0            | 0        | 0             | 40           |
| Germany             | 9 039           | 11           | 0        | 31 592        | 4 960        |
| Denmark             | 18 632          | 20 332       | 0        | 110 306       | 23 280       |
| Estonia             | 0               | 0            | 0        | 0             | 419          |
| Spain               | 0               | 251          | 0        | 2 608         | 0            |
| Finland             | 0               | 12 270       | 0        | 3 021         | 431          |
| France              | 0               | 116          | 0        | 7 584         | 0            |
| Greece              | 0               | 0            | 0        | 35            | 0            |
| Hungary             |                 |              |          |               |              |
| Ireland             | 0               | 138          | 0        | 0             | 0            |
| <b>Italy</b>        | <b>0</b>        | <b>3 632</b> | <b>0</b> | <b>30 321</b> | <b>2 842</b> |
| Lithuania           |                 |              |          |               |              |
| Latvia              |                 |              |          |               |              |
| Luxemburg           | 231             | 0            | 0        | 0             | 0            |
| Netherlands         | 6 096           | 6 491        | 0        | 15 077        | 643          |
| Norway              | 786             | 1 890        | 0        | 200           | 1 642        |
| Poland              | 0               | 0            | 0        | 483           | 607          |
| Portugal            | 0               | 0            | 0        | 56            | 976          |
| Slovenia            |                 |              |          |               |              |
| Ukraine             |                 |              |          |               |              |
| United Kingdom      | 1 212           | 6            | 0        | 4 193         | 304          |

If the results are dissociated in groups (frozen, chilled, dry and NF products), it is possible to observe from which countries the largest volumes are originated.

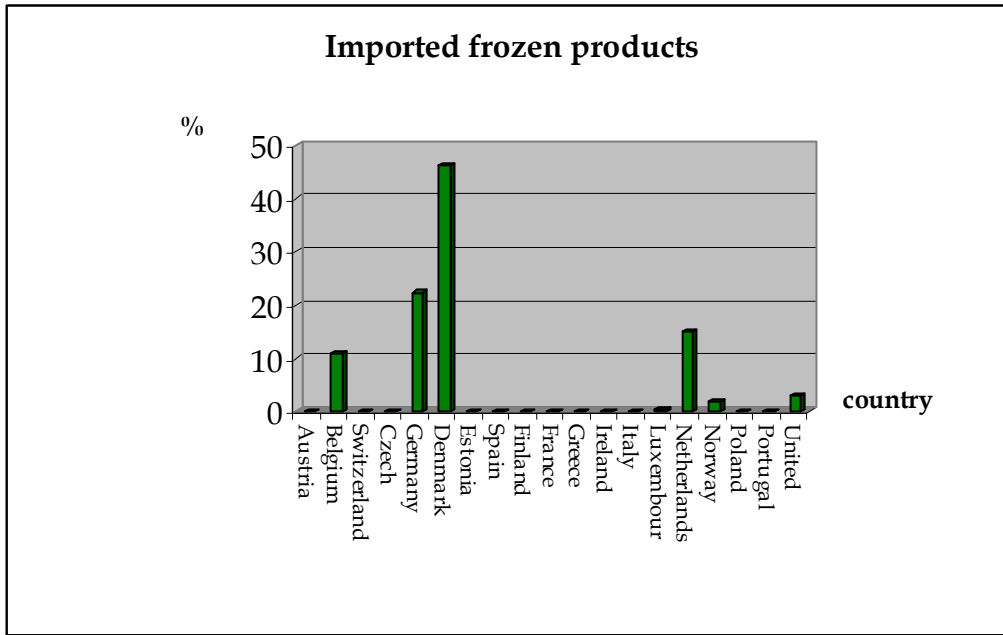


Figure 7.1: Imported frozen products.

The larger frozen volume imported by retailer 1 comes from Denmark, followed by Germany, Netherlands and Belgium (Figure 7.1). Volumes exported by other countries are quite inexpressive, in comparison.

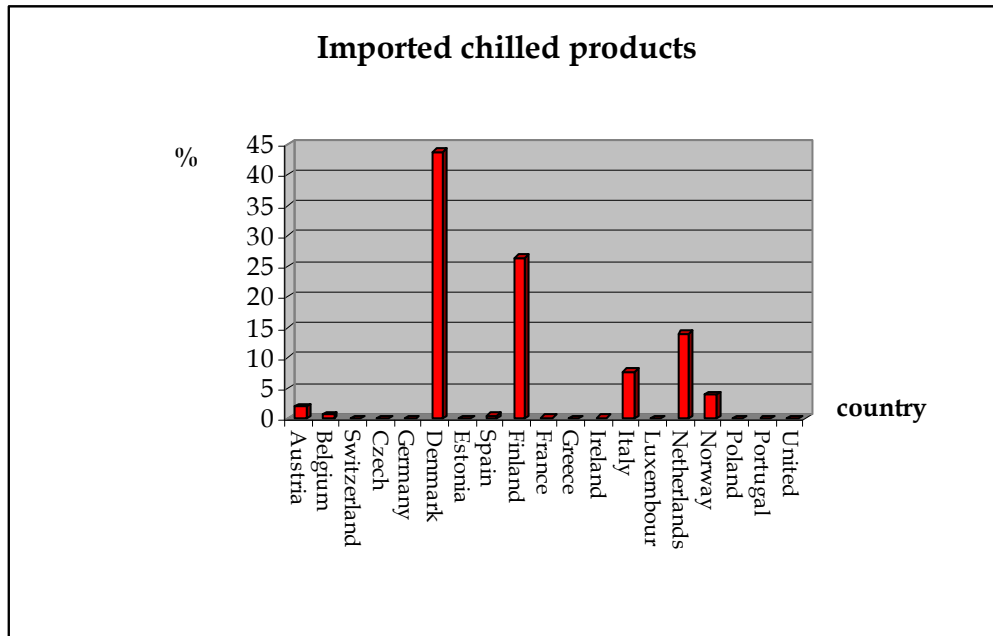


Figure 7.2: Imported chilled products.

Chilled products come primarily from Denmark, followed by Finland, Netherlands and Italy (Figure 7.2). Denmark is, too, responsible for the largest volume of dry commodities. In second and third places are, respectively, Germany and Italy, followed by the Netherlands (Figure 7.3).

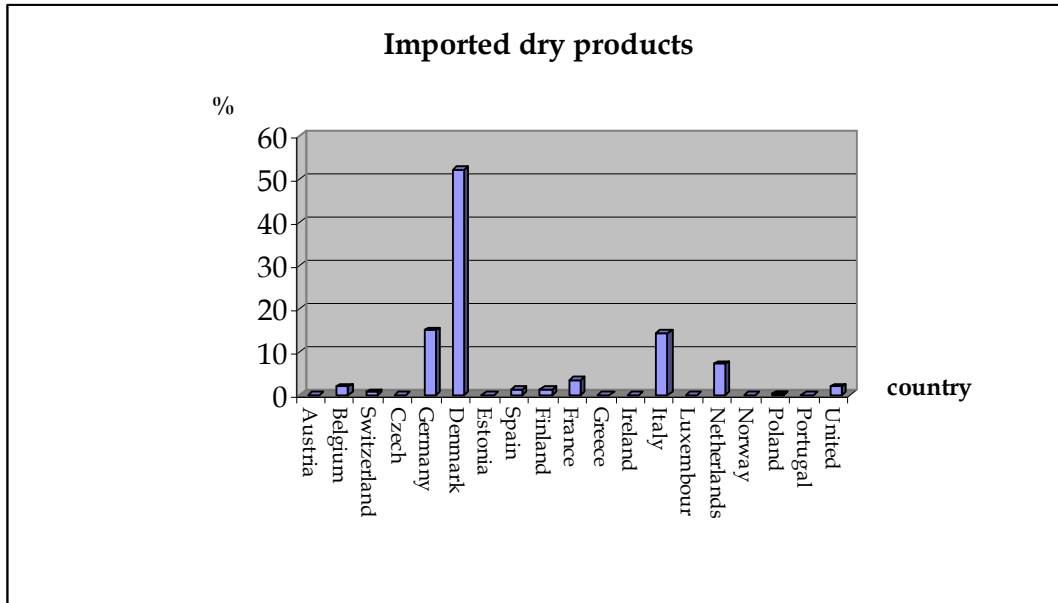


Figure 7.3: Imported dry products.

NF commodities are imported mostly from Denmark, which is responsible for 64,23 % of the total volume imported. Germany, Italy and Norway are, together, responsible for 26,05 % of the total volume imported.

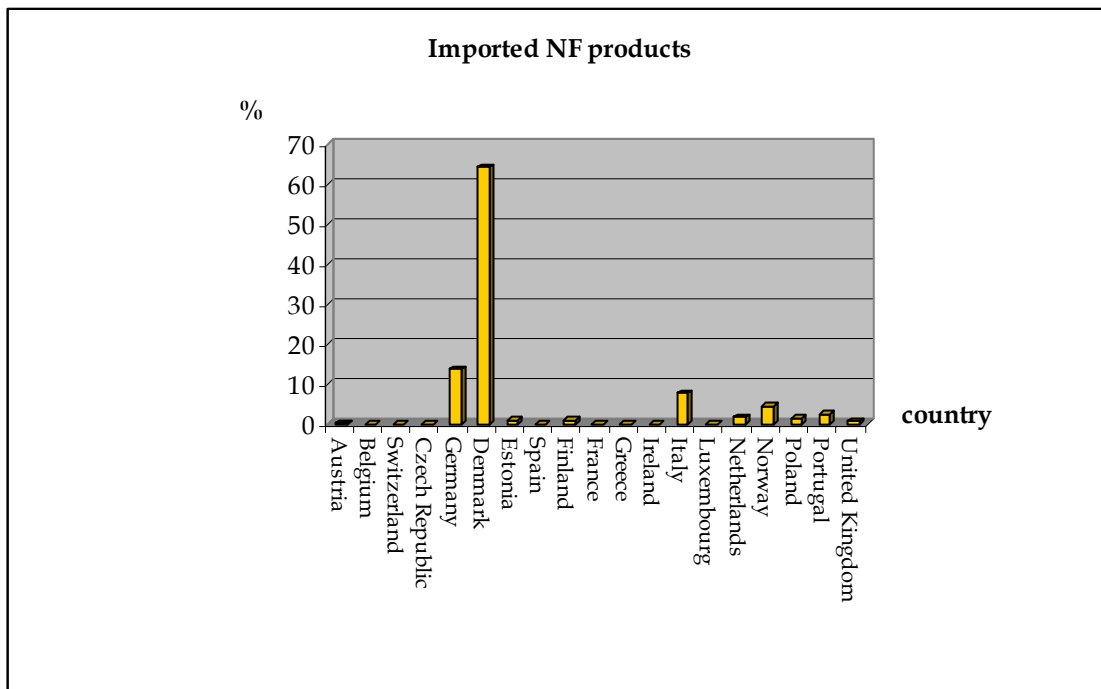


Figure 7.4: Imported NF products.

It becomes clear that, concerning retailer 1, its main suppliers are located in Denmark. Germany, the Netherlands and Italy are also important suppliers, though in smaller scale. It may be correct to assume that, as a near market, Denmark offers lower transport and storage costs than other countries.



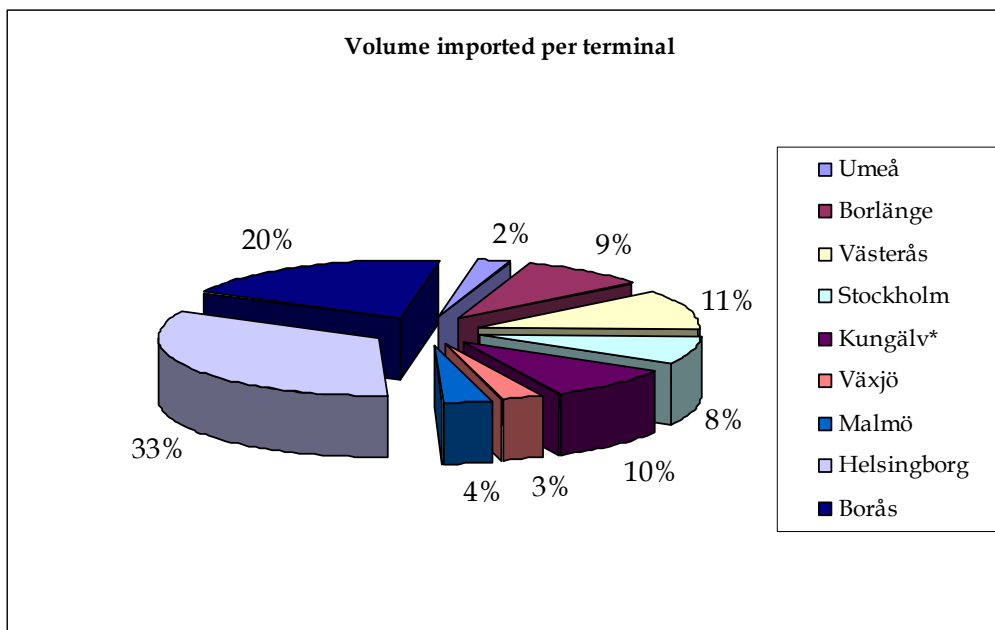
## 6.2. Retailer 2

The company tries to prioritize boat and train instead of trucks. Since 2008, there is a project in development, objecting modal shift (from road to rail, i.e. transporting trucks on trains). The project is being tested.

In order to prevent high emissions of carbon dioxide, the company trains their drivers. The shippers hired by it are also required to show the same environmental concern. When dealing with trucks, the aim is to load them completely and plan the route carefully, with the purpose of decreasing road transport substantially.

The vast information obtained from retailer 2 includes: volumes for fresh (fruits and vegetables), frozen, chilled, dry and non-food (NF) commodities within a year; location of the terminals and total volume delivered by every supplier within a year.

Like retailer 1, the major part of the terminals is located in the south, except for one located in Umeå. Figure 7.5 exemplifies the percentage of total volumes imported placed in each terminal. The terminal (or first break point in Sweden) that receives the main part of the volume is located in Helsingborg, followed by Borås and Västerås.



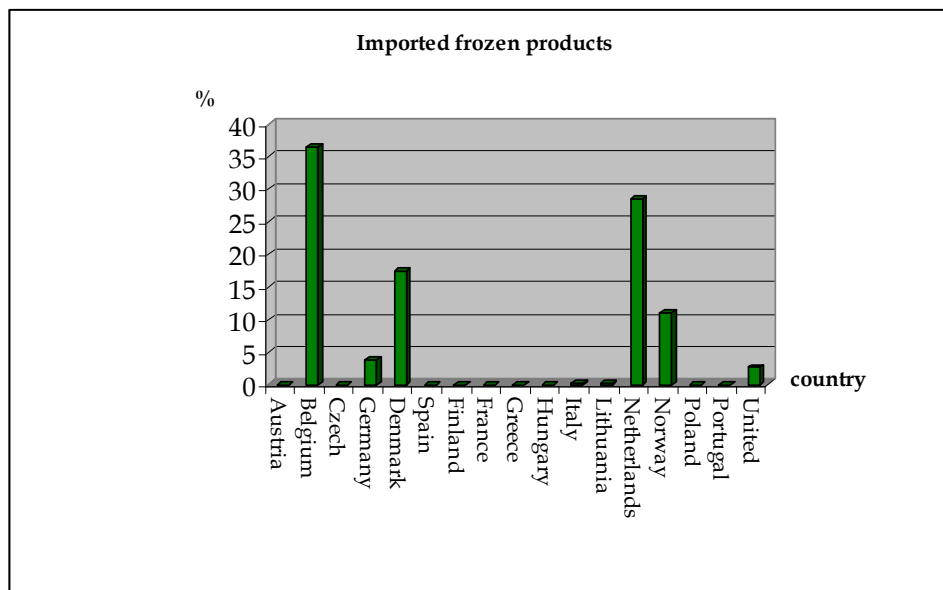
**Figure 7.5:** Volume imported (%) per terminal.  
\* Kungälv is close to Gothenburg.

The number of pallets imported by the retailer from European countries within a year can be seen in table 7.4.

**Table 7.4:** Number of pallets imported from European countries within a year

| ORIGIN (COUNTRY) | TYPE OF PRODUCT |            |               |               |              |
|------------------|-----------------|------------|---------------|---------------|--------------|
|                  | Frozen          | Chilled    | Fresh         | Colonial      | Non-food     |
| Austria          | 0               | 4 400      | 0             | 0             | 0            |
| Belgium          | 17 735          | 316        | 39 554        | 17 590        | 200          |
| Switzerland      | 0               | 0          | 0             | 0             | 0            |
| Czech Republic   | 0               | 1 158      | 0             | 401           | 29           |
| Germany          | 1 843           | 12 208     | 4 061         | 30 340        | 4 007        |
| Denmark          | 8 461           | 28 994     | 4 570         | 56 085        | 8 011        |
| Estonia          | 0               | 0          | 0             | 0             | 5 939        |
| Spain            | 0               | 200        | 127 485       | 17 344        | 55           |
| Finland          | 0               | 4 186      | 21 940        | 6 189         | 2 541        |
| France           | 0               | 3 281      | 21 664        | 19 779        | 287          |
| Greece           | 0               | 641        | 6 370         | 4 023         | 52           |
| Hungary          | 0               | 0          | 652           | 1 739         | 0            |
| Ireland          | 0               | 0          | 0             | 0             | 0            |
| <b>Italy</b>     | <b>62</b>       | <b>142</b> | <b>53 427</b> | <b>79 681</b> | <b>3 391</b> |
| Lithuania        | 52              | 0          | 1 758         | 0             | 0            |
| Latvia           | 0               | 0          | 0             | 0             | 61           |
| Luxemburg        | 0               | 0          | 0             | 0             | 0            |
| Netherlands      | 13 844          | 15 900     | 181 796       | 50 665        | 6 308        |
| Norway           | 5 320           | 0          | 524           | 49            | 0            |
| Poland           | 4               | 0          | 2 026         | 3 491         | 16 116       |
| Portugal         | 0               | 0          | 623           | 147           | 427          |
| Slovenia         | 0               | 0          | 0             | 0             | 122          |
| Ukraine          | 0               | 0          | 0             | 0             | 3 062        |
| United Kingdom   | 1 270           | 0          | 126           | 143           | 5 791        |

Analyzing the commodity groups separately makes possible to establish the greater volumes and their origin (suppliers). Frozen products are mostly imported from Belgium, followed by the Netherlands, Denmark and Norway (Figure 7.6).



**Figure 7.6:** Imported frozen products

Regarding chilled commodities, Denmark is the greater supplier (40,59 %), followed by the Netherlands, Germany and Austria. These four countries alone are responsible for 86,1 % of the total chilled volume imported by retailer 2 (Figure 7.7).

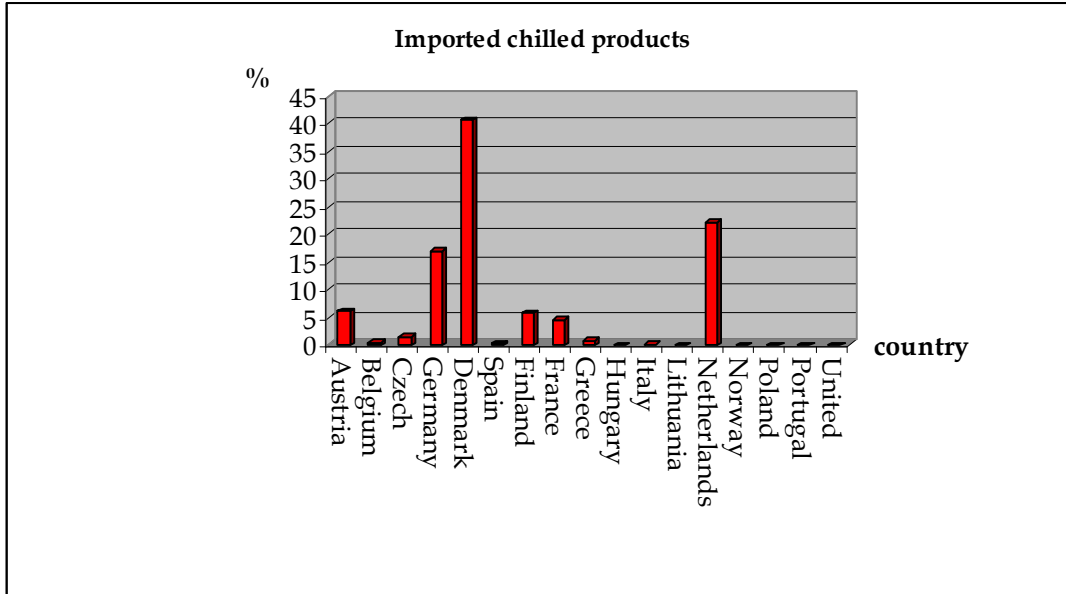


Figure 7.7: Imported chilled products

Italy is the country that exports the greater volume of dry goods to retailer 2 (27,70 %). It is followed by Denmark, the Netherlands and Germany that, together represent 47,66 % of the market segment (Figure 7.8).

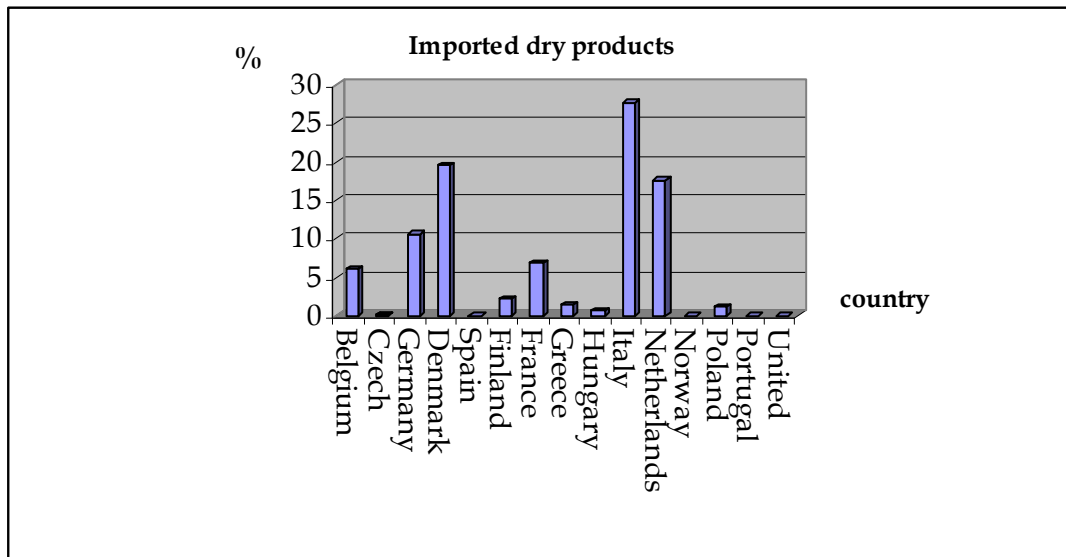
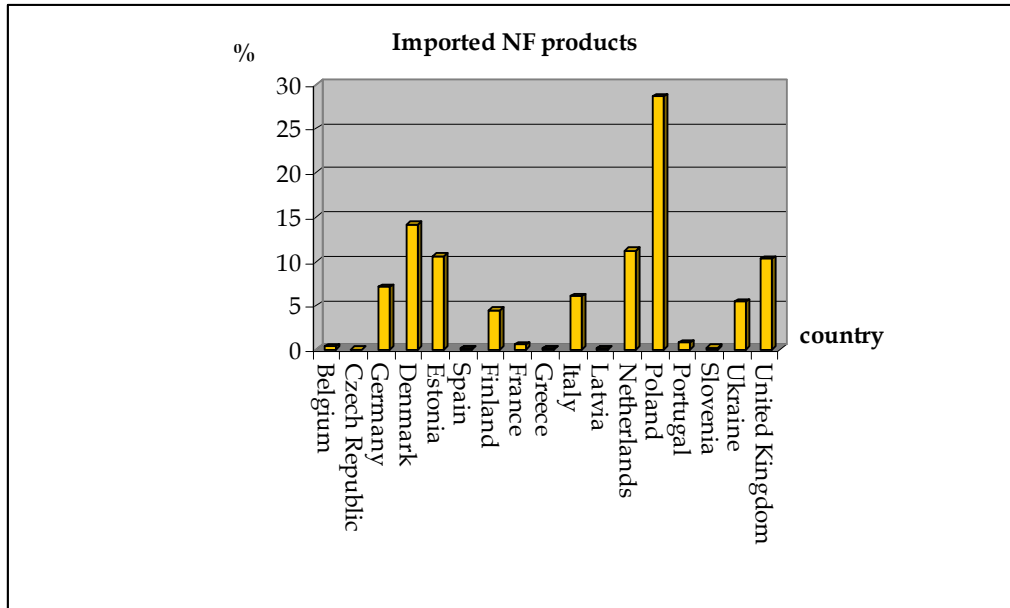


Figure 7.8: Imported dry products

Poland is responsible for 28,58 % of all NF volumes imported by retailer 2. Denmark, the Netherlands, Estonia and United Kingdom also show expressive volumes (Figure 7.9).



**Figure 7.9:** Imported NF products

Table 7.3 (page 34) was provided by retailer 2 and shows fruits and vegetables volumes. Though Sweden represents 29,23 % of all fruits and vegetables acquired by retailer 2, it is known that there are two companies in the country responsible for importing fruits and vegetables and selling them to Swedish retailers. Those two companies are going to be interviewed as well, in order to find out volumes and products imported.

The Netherlands is responsible for 18,51 % of all fruits and vegetables volume but, in fact, 24,54 % of all volume is actually transported from that country to Sweden. It means that fruits and vegetables from Israel, Argentina, Greece, Chile, South Africa, Brazil, Egypt, USA, Colombia, Portugal, United Kingdom and Kenya have their first break point in that country.

Belgium, Denmark, Italy and Poland are the largest suppliers for retailer 2 concerning respectively frozen, chilled, and dry and NF commodities.

**Table 7.3:** Fruits and vegetables imported within a year by Retailer 2  
(in percentage by supplying country)

| Country                 | Supplied by (%) | Transported from (%) |
|-------------------------|-----------------|----------------------|
| Sweden                  | 29,23 %         | 29,23                |
|                         |                 |                      |
| The Netherlands         | 18,51 %         | 24,54 %              |
| Spain                   | 17,02 %         | 17,02 %              |
| Italy                   | 5,67 %          | 5,67 %               |
| France                  | 3,24 %          | 3,24 %               |
| Belgium                 | 3,22 %          | 3,22 %               |
| Israel                  | 1,65 %          | -                    |
| Argentina               | 1,23 %          | -                    |
| Germany                 | 0,83 %          | 0,83 %               |
| Greece                  | 0,83 %          | -                    |
| Chile                   | 0,80 %          | -                    |
| South Africa            | 0,46 %          | -                    |
| Poland                  | 0,46 %          | 0,46 %               |
| Brazil                  | 0,44 %          | -                    |
| Egypt                   | 0,21 %          | -                    |
| Lithuania               | 0,17 %          | 0,17 %               |
| Denmark                 | 0,17 %          | 0,17 %               |
| USA                     | 0,14 %          | -                    |
| Colombia                | 0,12 %          | -                    |
| Portugal                | 0,07 %          | -                    |
| United Kingdom          | 0,06 %          | -                    |
| Hungary                 | 0,04 %          | 0,04 %               |
| Kenya                   | 0,03 %          | -                    |
| Norway                  | 0,02 %          | 0,02 %               |
| Latin America (bananas) | 15,40 %         | 15,40 %              |
| <b>Total</b>            | <b>100,00 %</b> | <b>100,00 %</b>      |

### 6.3. Retailer 3

Retailer 3 maintains a constant focus on quality, with a view to increasing the benefits for customers and company. Important aspects about the company are: the increase awareness of environmental impact and social responsibility with respect to energy, transports and products; and the maintenance of good control of social and environmental responsibility among suppliers. The company complies with Swedish food legislation concerning labeling and traceability.

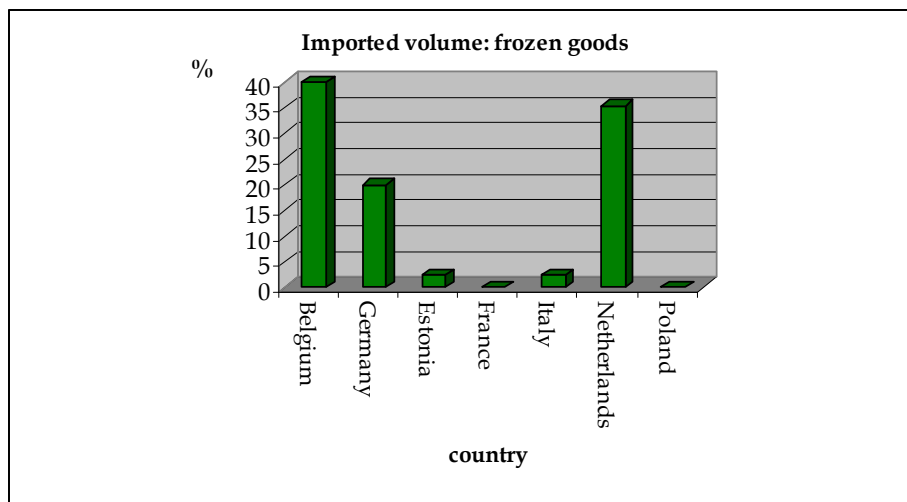
The material obtained from retailer 3 includes: the number of pallets within a year for frozen, chilled and dry products.

Table 7.5 presents the number of pallets imported from European countries within a year.

**Table 7.5:** Number of pallets imported from European countries within a year

| ORIGIN (COUNTRY) | TYPE OF PRODUCT |              |       |               |
|------------------|-----------------|--------------|-------|---------------|
|                  | Frozen          | Chilled      | Fresh | Dry           |
| Austria          |                 |              |       |               |
| Belgium          | 17 000          | 500          |       | 30 000        |
| Switzerland      |                 |              |       |               |
| Czech Republic   |                 |              |       |               |
| Germany          | 8 500           | 5 000        |       | 30 000        |
| Denmark          |                 |              |       |               |
| Estonia          | 1 000           | 800          |       |               |
| Spain            |                 |              |       |               |
| Finland          |                 |              |       |               |
| France           |                 | 100          |       | 12 000        |
| Greece           |                 |              |       |               |
| Hungary          |                 |              |       |               |
| Ireland          |                 |              |       |               |
| <b>Italy</b>     | <b>1 000</b>    | <b>3 000</b> |       | <b>58 500</b> |
| Lithuania        |                 |              |       |               |
| Latvia           |                 |              |       |               |
| Luxemburg        |                 |              |       |               |
| Netherlands      | 15 000          |              |       | 25 000        |
| Norway           |                 |              |       |               |
| Poland           |                 | 1 000        |       |               |
| Portugal         |                 |              |       |               |
| Slovenia         |                 |              |       |               |
| Ukraine          |                 |              |       |               |
| United Kingdom   |                 |              |       |               |

Dissociating the results in groups (frozen, chilled and dry), makes it possible to observe from which countries the largest volumes are originated. Frozen products are mostly imported from Belgium, the Netherlands and Germany (Figure 7.10).



**Figure 7.10:** Imported frozen products

Regarding chilled products, Germany is the greater supplier (48,08 %), followed by Italy and Poland (Figure 7.11).

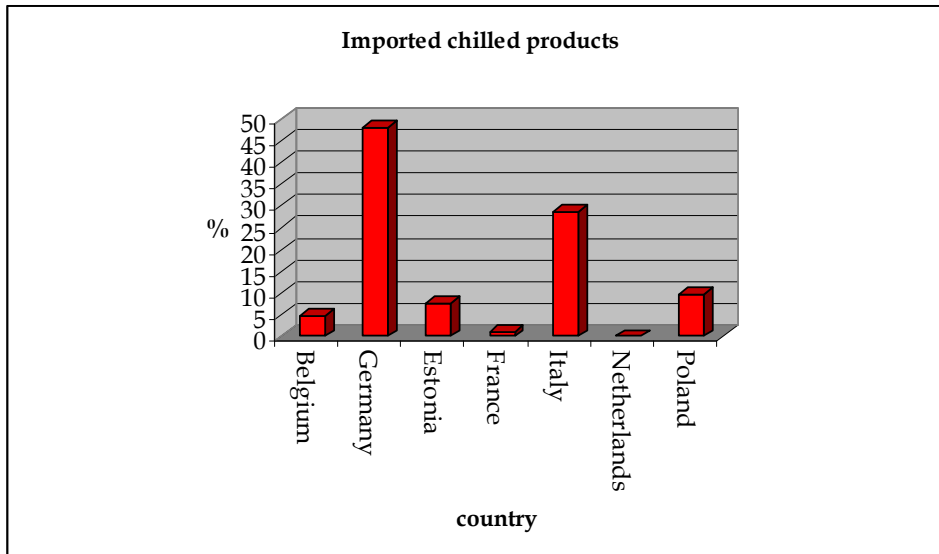


Figure 7.11: Imported chilled products

Italy is the country responsible for the majority of dry commodities (37,62 %), followed by Germany and Belgium (19,29 % each). The Netherlands exports 16,08 % of all dry volume to retailer 3 (Figure 7.12).

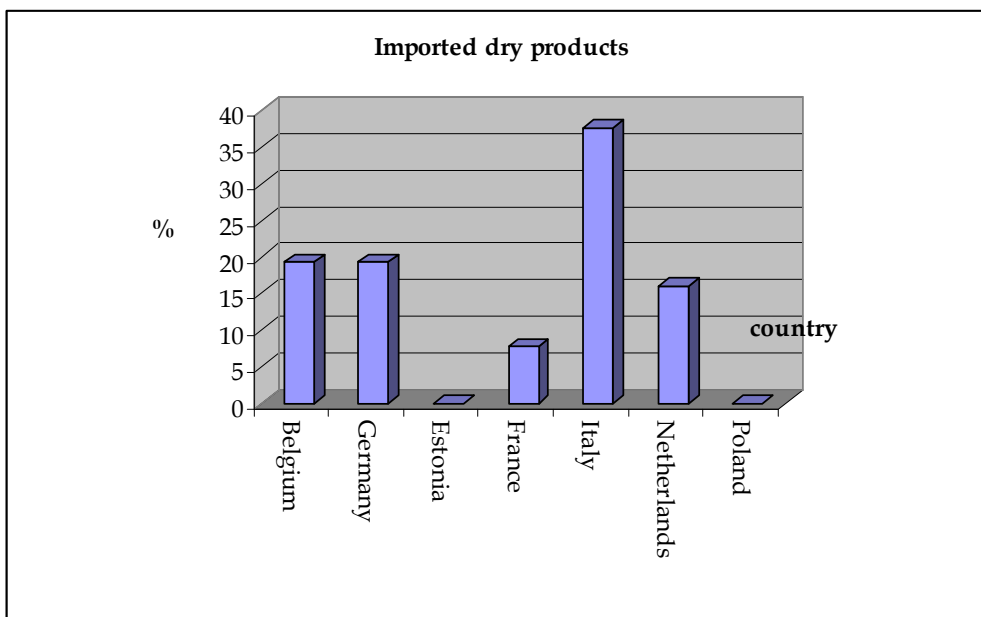


Figure 7.12: Imported dry products

Consequently, the countries exporting the major volumes to retailer 3 are: Italy (29,99 %), Belgium (22,79 %) and Germany (20,87 %). (Figure 7.13)

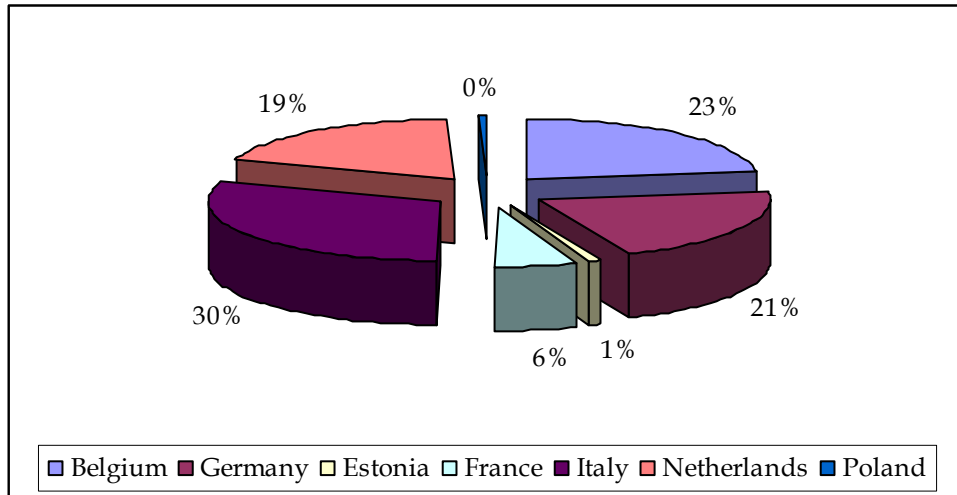


Figure 7.13: volume imported per country

Unfortunately, information regarding fresh commodities and NF products was missing until the conclusion of the present report, as well as volume per terminals and frequency.

Section 7.4 gathers the results from all retailers in order to map the flows imported.

### 6.4. Total Results

In order to map the existing flows from Europe to Sweden, the data collected from retailers 1, 2 and 3 was gathered and analyzed. It becomes clear that most of the terminals are located in Southern Sweden, not only for logistical reasons, but also due to demographical issues.

Table 7.6 ascertains what kind of products is loaded in each terminal (first break points).

Table 7.6: Terminals in Sweden and type of products

| Terminals/products | Fruits & Vegetables | Chilled | Frozen | Dry | NF |
|--------------------|---------------------|---------|--------|-----|----|
| Borlänge           | X                   | X       |        | X   |    |
| Bro                |                     |         |        | X   | X  |
| Jordbro            |                     |         |        | X   | X  |
| Göteborg           |                     |         | X      |     |    |
| Helsingborg        | X                   | X       | X      | X   |    |
| Johanneshov        |                     |         | X      |     |    |
| Kungälv            | X                   | X       |        | X   | X  |
| Malmö              |                     | X       |        |     |    |
| Stockholm          | X                   | X       |        | X   |    |
| Umeå               | X                   | X       | X      | X   |    |
| Västerås           |                     | X       | X      | X   | X  |
| Växjö              |                     | X       | X      | X   |    |
| Borås              |                     |         |        |     | X  |

Figure 7.15 presents results concerning commodities volumes: 44 % of all total volume consists in dry/colonial commodities that are closely followed by fresh products (fruits and vegetables).



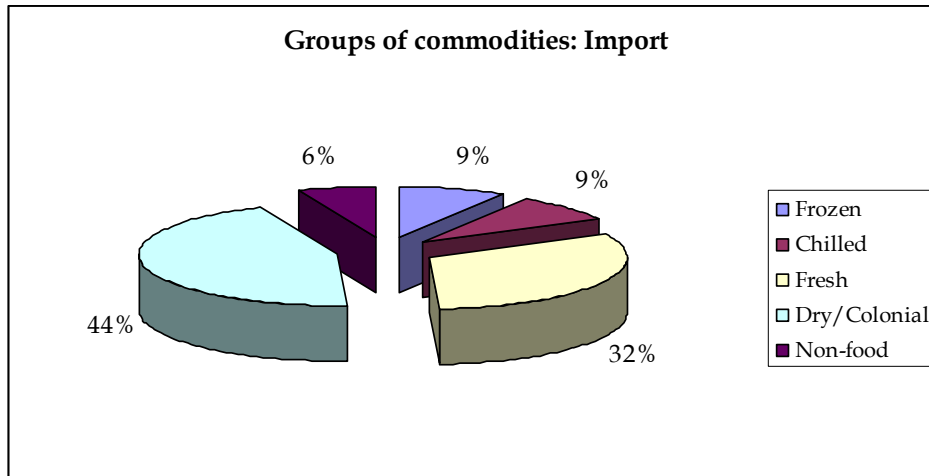


Figure 7.14: Groups of commodities imported to Sweden

The Netherlands is the country with the higher volume of goods (22,86 %, all groups included) exported to Sweden, followed by Denmark (18,91 %). Italy is the third country with the highest exported volumes (16,02 %) to Sweden (Figure 7.16).

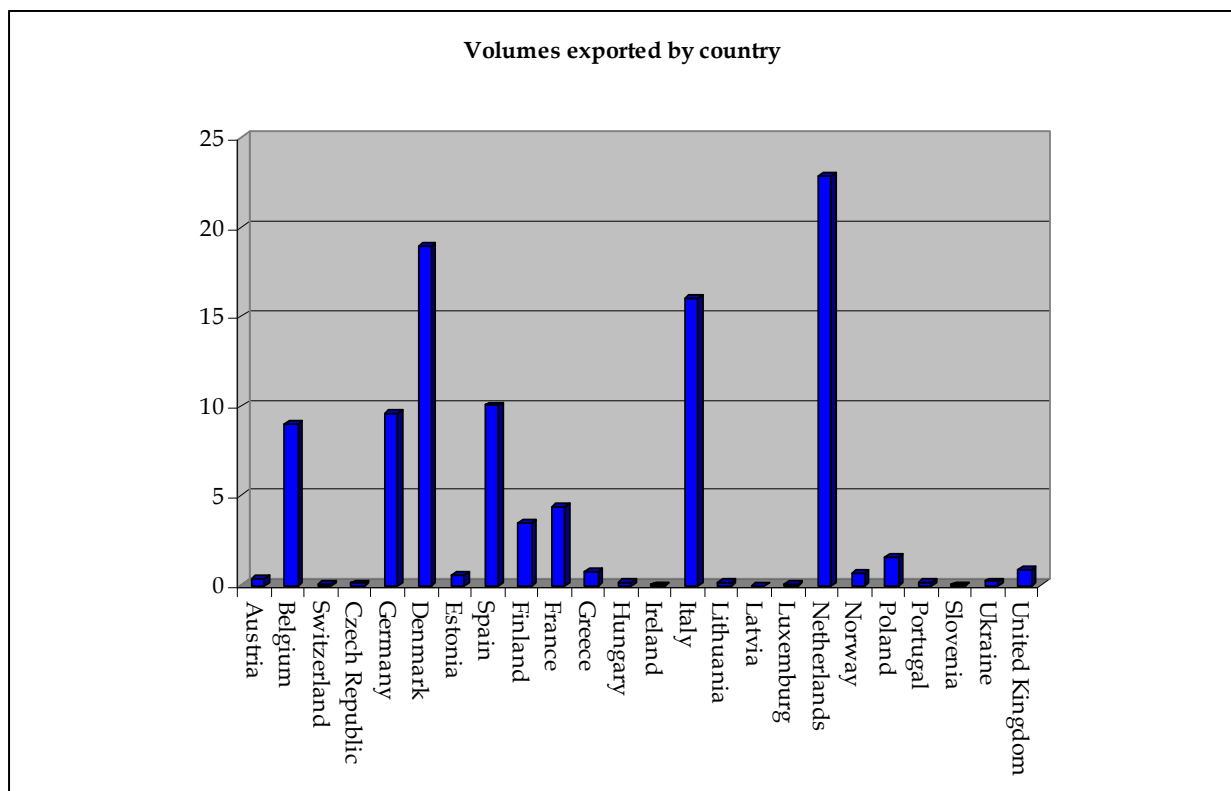


Figure 7.15: Volumes exported by European countries to Sweden (%)

Table 7.7 displays the total number of pallets coming from other European countries. Concerning frozen commodities, the main volumes comes from Belgium, the Netherlands and Denmark (29,78 %, 26,57 % and 20,60 % respectively). Denmark is the major exporter for chilled products (38,45 %) followed by Netherlands (17,45 %) and Germany (13,42 %).

In addition, the Netherlands is responsible for 38,96 % of all fresh volumes imported by Sweden. It may be correct to assume that the Netherlands do not produce all this volume, but

it comes from other countries (South America, Australia, USA, etc) via Rotterdam. The second country exporting fresh goods to Sweden is Spain, with 27,32 % of all volume. Italy is in third place and its exportations represent 11,45 %.

Italy leads the export market to Sweden regarding dry/colonial commodities (25,75 %), followed by Denmark (25,43 %) and Germany (14,05 %) while the NF market has Denmark as a primarily supplier (33,77 %), followed by Poland (18,05 %) and Germany (9,68 %).

**Table 7.7:** Total number of pallets imported from European countries within a year (2008)

| ORIGIN (COUNTRY) | TYPE OF PRODUCTS |              |               |                |              |
|------------------|------------------|--------------|---------------|----------------|--------------|
|                  | Frozen           | Chilled      | Fresh         | Dry/Colonial   | Non-food     |
| Austria          | 0                | 5 367        | 0             | 0              | 103          |
| Belgium          | 39 168           | 1 179        | 39 554        | 51 873         | 200          |
| Switzerland      | 0                | 0            | 0             | 1 467          | 0            |
| Czech Republic   | 0                | 1 158        | 0             | 401            | 69           |
| Germany          | 19 382           | 17 219       | 4 061         | 91 932         | 8 967        |
| Denmark          | 27 093           | 49 326       | 4 570         | 166 391        | 31 291       |
| Estonia          | 1 000            | 800          | 0             | 0              | 6 358        |
| Spain            | 0                | 451          | 127 485       | 19 952         | 55           |
| Finland          | 0                | 16 456       | 21 940        | 9 210          | 2 972        |
| France           | 0                | 3 497        | 21 664        | 39 363         | 287          |
| Greece           | 0                | 641          | 6 370         | 4 058          | 52           |
| Hungary          | 0                | 0            | 652           | 1 739          | 0            |
| Ireland          | 0                | 138          | 0             | 0              | 0            |
| <b>Italy</b>     | <b>1 062</b>     | <b>6 774</b> | <b>53 427</b> | <b>168 502</b> | <b>6 233</b> |
| Lithuania        | 52               | 0            | 1 758         | 0              | 0            |
| Latvia           | 0                | 0            | 0             | 0              | 61           |
| Luxemburg        | 231              | 0            | 0             | 0              | 0            |
| The Netherlands  | 34 940           | 22 391       | 181 796       | 90 742         | 6 951        |
| Norway           | 6 106            | 1 890        | 524           | 249            | 1 642        |
| Poland           | 4                | 1 000        | 2 026         | 3 974          | 16 723       |
| Portugal         | 0                | 0            | 623           | 203            | 1 403        |
| Slovenia         | 0                | 0            | 0             | 0              | 122          |
| Ukraine          | 0                | 0            | 0             | 0              | 3 062        |
| United Kingdom   | 2 482            | 6            | 126           | 4 336          | 6 095        |

Some companies are already using intermodal solutions, successfully, to transport their TSS. Their experience is valuable for the present project, because it makes feasible to establish advantages and disadvantages of this kind of solution that will serve as base to create TESS' own technological, logistical, operational and administrative solutions. The case studies can be seen in section 8.

## 7. Case Studies

In addition to the interviews, some case studies were evaluated. Two case studies were selected, in order to exemplify companies currently using intermodal transport solutions in order to deliver TSS. The expected result of the interviews is the selection of possible concepts and techniques concerning loading units and information supply systems during transportation.

Therefore, it is essential to know matters like:

- Barriers and incentives regarding intermodal transport;
- Demands for intermodal transport between Scandinavia and Central Europe;
- Present design of intermodal transport system concerning offer and demand;
- Existence of additional weaknesses experienced by forwarders while using intermodal transport.

The first case study is the Arctic Rail Express, or ARE-train. This train runs between Narvik and Oslo. It covers 2 100 km in approximately 27 hours. From Oslo to Narvik, the train is loaded with dairy products and runs in the opposite direction loaded with fish.

Bring Frigoscandia is the second case study. The company has a storage for frozen products with 270 000 m<sup>3</sup> (to store 100 000 standard pallets). The company already has an intermodal transport solution between Scandinavia and Italy. GPS and professional temperature monitoring ensures an unbroken cold chain through the entire logistical flow and the company is positive about the solution.

### 7.1. Arctic Rail Express: ARE-train

The Norwegian company CargoNet runs the Arctic Rail Express train (ARE-train) between Oslo and Narvik. This train has many peculiarities like:

- Origin and destination are in Norway, but the train crosses Sweden to reach its destination;
- Average travelling time is 27 hours (2 100 km between origin and destination);
- As the name says it is an express train as has a high priority;
- It is also a shuttle train;
- Locomotive driver changed 7-8 times during the trip;
- Customers are responsible for loading/unloading the train;
- Check points for refrigerants: Boden or Ånge (both in Sweden);
- South-North direction: dairy products;
- North-South direction: fresh fish;
- The train carries just intermodal equipments.

Differently from its Swedish equivalent, Green Cargo, CargoNet does not have load carriers. Its customers are the ones in possession of such equipment (Schenker, Bring Frigoscandia, etc) and for that reason; the company has no access to detailed information about the goods transported, nor responsibility for loading/unloading the train. Therefore, any data about the products must be sought with the customers. Figures 7.1 and 7.2 show the equipment used in ARE-train.



**Figure 8.1:** Swap body used in ARE-train.  
Source: CargoNet



**Figure 8.2:** Semi trailer used in ARE-train  
Source: CargoNet

The table below shows the volume (TEU – twenty feet equivalent unit) carried by ARE-train from 2002 to 2008.

**Table 8.1:** Volumes carried by ARE-train from 2002 to 2008

| YEAR | TEU    | INDEX |
|------|--------|-------|
| 2002 | 25 066 | 100   |
| 2003 | 27 263 | 109   |
| 2004 | 30 078 | 120   |
| 2005 | 35 123 | 140   |
| 2006 | 44 333 | 177   |
| 2007 | 47 002 | 188   |
| 2008 | 48 395 | 193   |

Source: CargoNet

ARE-train is loaded in both directions, with dairy products from Oslo to the north and fresh fish from Narvik to the south. Fish (salmon and codfish) from different parts of northern Norway are conveyed in terminals specially suited to attend fish delivery. The fish industry is tied to season variations as well as an increase of demand around a holiday, for instance.

Moreover, supply and demand are affected by market changes of price, as well as other goods. According to CargoNet, there are currently no problems to meet these fluctuations as far as the southbound transportations of fish are concerned. This is due to the fact that there is a possibility to collect units for refrigeration in Narvik before an expected increase of demand around Christmas, for instance. Generally speaking, it's claimed that there is no, or seldom, shortage of refrigeration units or freight carriers for southbound transports.

In 2009 the weekly number of trains running between Narvik-Oslo decreased from 12 to 11. Sometimes two locomotives are used in order to attend the demand. While one locomotive drags 48 wagons, two locomotives drag 64 wagons. The capacity of the train depends on the volume transported to the northern part of Norway, which means that the backload volume can be smaller and, consequently, the train will run partially empty on its way back. As said before, it is a shuttle train, since it is loaded in the point of origin and unloaded at its destination. Stops for loading/unloading are seen as quality loss for CargoNet. The next table shows the train schedule during a week.

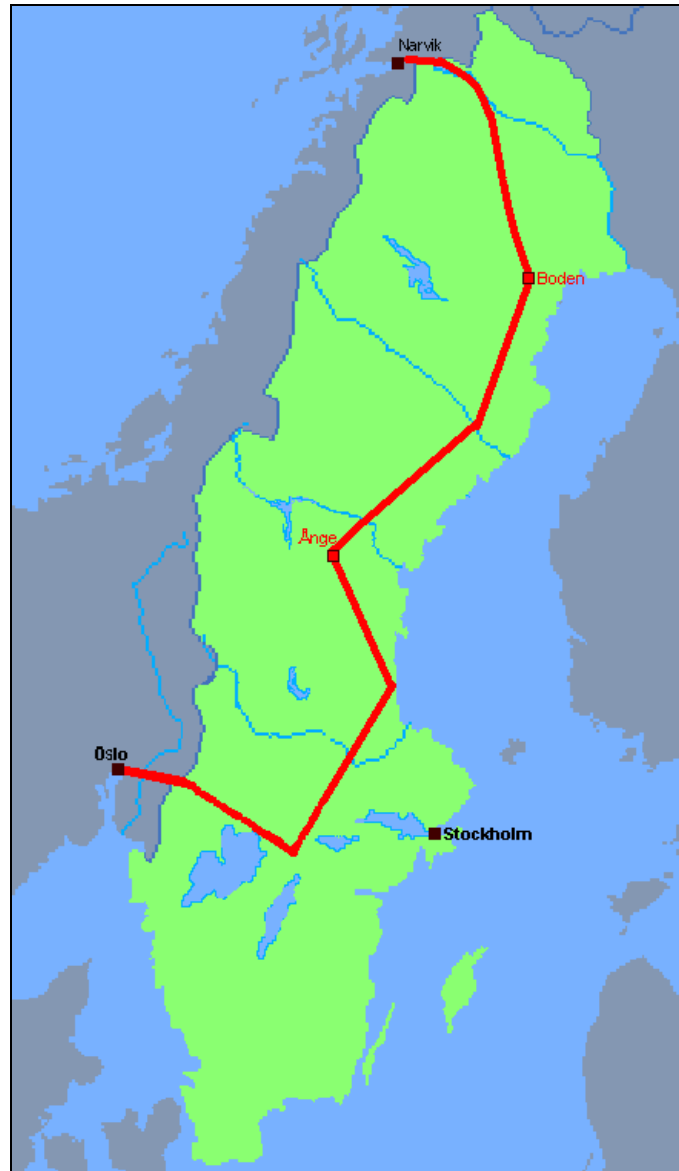
**Table 8.2:** ARE-train schedule

| From   | to     | Train no. | Loading days       | Loading deadline                               | Unloading days     | Unloading time |
|--|--------|-----------|--------------------|--|--------------------|----------------|
| Oslo   | Narvik | 4001      | Monday – Friday    | 21:10  | Wednesday - Sunday | 00:50          |
| Oslo   | Narvik | 4001      | Saturday           | 19:00  | Monday             | 00:50          |
| Oslo   | Narvik | 4013      | Monday – Friday    | 18:20  | Tuesday - Saturday | 23:10          |
| Narvik   | Oslo   | 4005      | Monday - Saturday  | 23:30 1)                                       | Tuesday - Sunday   | 04:30 5)       |
| Narvik   | Oslo   | 4019      | Wednesday - Sunday | 23:30 2)3)                                     | Thursday - Monday  | 07:30 6)       |
| Narvik   | Oslo   | 4017      | Tuesday - Saturday | 22:30 4)                                       | Thursday - Monday  | 07:30 6)       |
| 1) loading deadline for fish 12:00 pm            |        |           |                    | 4) from 01.06.2009                             |                    |                |
| 2) loading deadline for fish (Saturday) 02:00 am |        |           |                    | 5) Sunday unloading from 06:30 am              |                    |                |
| 3) Route time from 31.05.2009                    |        |           |                    | 6) Saturday and Sunday unloading from 07:00 am |                    |                |

Source: CargoNet

The temperature inside the containers is checked in Boden or Ånge (Figure 7.3). During warmer periods an additional verification is necessary, for safety reasons, though modern containers have good isolation and ability to keep the desired temperature for a long period of time. Since CargoNet's customers have their own track and tracing system (mostly real time), the company's temperature control is seen as a support function. ARE-train can also offer extreme cooling if needed: at 80 km/h, temperature can drop from -40°C, in a cooling unit, to -70°C or -80°C, when using refrigerants.

The average travelling time is 27 hours, covering 2 100 km, but delays may occur, in spite of the train's high priority. In fact, from all trains ran by CargoNet, ARE-train is the one with lowest punctuality (85 %). Among the causes of those delays are: the terminals opening hours, loading/unloading process, railway maintenance work and the bottleneck between Kiruna and Narvik (with a number of more slow-moving heavy iron transports).



**Figure 8.3:** Are-train - length and check points for refrigeration system

CargoNet points out price and speed as good incentives to use intermodal transport. It is also mentioned that the lack of flexibility, loading and unloading process, infrastructure quality in Sweden (Are-trains extent) are some barriers for using intermodality. From Boden and the northern part of the country, for example, goods are limited.

CargoNet is willing to develop its intermodal transport to the continent and is therefore working with two of the biggest European intermodal transport companies. The train used nowadays for goods transport is a system train – customers fill the train with their products. CargoNet wants to develop an “open access” intermodal unit to disengage the train from the ferry services.

In Norway, it's easy to create optimal transports on railway, since urban structures are suitable for railway transports and they are used in most cases. In general the distance between major urban areas is approximately 500 km, which is an optimal distance for railway transports.

Road transport is used just for high priority products (extremely time-sensitive products, for instance).

Time is a critical factor, no matter if the product is temperature sensitive or not, according to CargoNet, and high valued products demands as much priority as a TSS.

## 7.2. *Bring Frigoscandia*

Bring Frigoscandia already has an intermodal transport solution for foodstuffs between Scandinavia and Italy. An express train (which is also shuttle) covers the distance Verona (Italy) – Padborg (Denmark) transporting frozen, chilled and fresh goods three times a week.



**Figure 8.4:** Distance Verona Padborg.  
Source: Bring Frigoscandia

From Italy to Denmark the company carries a small quantity of non-temperated goods, fruits and vegetables and frozen meat. From Denmark to Italy, fresh and frozen commodities are carried.

The table below shows the quantities (in tons) carried by Bring Frigoscandia within a year.

**Table 8.3:** Quantities transported by Bring Frigoscandia

| From Denmark to Italy |  | TONS   |
|-----------------------|--|--------|
| Fresh                 |  | 27 000 |
| Vegetables            |  | 12 000 |
| From Italy to Denmark |  | TONS   |
| Fresh                 |  | 22 000 |
| Frozen                |  | 32 000 |

Bring Frigoscandia is responsible for loading the trailers in Padborg, but not in Verona. The transport time is 24 hours but it takes an additional two hours to load or unload a complete train (30 trailers) and check the trailers.

Season variations occur for fruits and vegetables. See table 8.4 below.

**Table 8.4:** Season variation for fruits and vegetables

| Goods                        | Season                               | Region in Italy |
|------------------------------|--------------------------------------|-----------------|
| Onions, carrots and potatoes | April – June                         |                 |
| Peaches and nectarines       | June – September                     | Emiglia Romana  |
| Grapes                       | August – October/November            |                 |
| Apples                       | November – April                     | Bolzano         |
| Cauli flower                 | October – December                   |                 |
| Other vegetables             | mid October – 1 <sup>st</sup> of May |                 |

The parameters used to combine different goods in the same unit are: the value of the good and carriage temperature. Since it is an express train and it is a very short period of time, commodities that have low aggregated value and similar carrying temperature can be transported together, like onions, carrots and potatoes. Meat and fish are high valued goods and, therefore, cannot be mixed with anything else. While meat is transported fresh (hanged, unwrapped) and frozen, fish is mainly carried frozen. After reaching its destination and being unloaded, the trailers are disinfected, in order to be loaded again with other goods. Table 8.5 shows some information about volumes of meat transported within a year from Italy, Denmark and Sweden.

**Table 8.5:** Shipments transported within a year

| Country | Shipments |
|---------|-----------|
| Denmark | 1000 +    |
| Italy   | 100       |
| Sweden  | 900       |

Real time temperature monitoring is used as well as a temperature recording system that shows to which temperatures the products were exposed during transportation. GPS and professional temperature monitoring ensures an unbroken cold chain through the entire logistical flow and the company is positive about the solution.

Temperature sensitive products demand special treatment. For the company, there are four main requirements: time, temperature, hygiene and capacity. Time and temperature are, furthermore, a critical factor, as well as logistics, but time and temperature influence the product's quality when it reaches the final customer. Depending on the destination, delivery may take one or two days. From Italy to Sweden, it takes two days. Nowadays, just express trains run and their schedule must be synchronised with ferries schedule also. Table 8.6 shows the requirements mentioned above and the transport solutions found by Bring Frigoscandia.



**Table 8.6:** Foodstuffs – Conditions

| Requirements | Solutions   |
|--------------|---|
| Time         | Products like fish are taken care of asp. after arrival at terminal - often within 15 minutes           |
|              | Fruits and vegetables are delivered 04.00 am at the terminal  |
| Temperature  | Tracking and tracing system + skilled staff   |
| Hygiene      | Rules for loading different products in the same loading unit, as well as equipment’s cleaning routines |
| Capacity     | Large contact network, flexible fleet   |

Source: Bring Frigoscandia

According to Bring Frigoscandia, road costs are increasing more than rail costs in late years. Railway transport is more attractive to suppliers and customers, due to road fees, heavy road traffic, fuel costs and weight limitations in roads and highways. Table 8.7 shows negative and positive aspects of using intermodal solutions.

**Table 8.7:** Positive and negative aspects of intermodal transport

| Positive aspects                     | Negative aspects   |
|--------------------------------------|--|
| Possibility to lower transport costs | Less flexibility for shipments (customers must adjust themselves to departures)    |
| Environmental friendliness           | Less flexibility for deliveries (customers must collect products when they arrive) |
| Avoid infrastructure’s restrictions  | Need to keep a constant volume every week  |
| Avoid delays caused by traffic jams  | Need of special investments in equipments  |

Source: Bring Frigoscandia

The company accredits the intermodal solution’s success to the following factors:

- Satisfactory partnership with operators;
- Priority in Germany’s railway;
- Transboundary locomotives;
- Effective terminals;
- Mixed trains (possibility to carry different kinds of trailers);
- Access to evaluation service (statistics, etc); and
- Real time monitoring.



**Figure 8.5:** Intermodal transport.  
Source: Bring Frigoscandia

The trailers are sealed by the client in Denmark, or in the terminal in Padborg, as well as in Verona. And as soon as the trailers arrive to the terminals in Padborg or Verona, the rear bumpers are closed behind the back doors, and it is not possible to open the trailers during the trip.

Bring Frigoscandia's key market is Scandinavia, where they have twenty two Food Logistics Centres with a total of over 1 200 000 m<sup>3</sup> of storage space for frozen, chilled and room temperature goods. The storage for frozen products has 270 000 m<sup>3</sup> and can store 100 000 standard pallets. The fleet of vehicles for chilled food transport consists of more than 800 vehicles that reach all Europe and their solutions for Supply Chain Management cover both incoming as well as outgoing flows from Japan, China, Southeast Asia, Australia, North America and Russia (Altenstedt, 2009).

## 8. Main Outcomes and Conclusions

Foodstuffs can be basically separated in three groups: fresh, chilled and frozen. Each group requires its own carriage temperature range. Frozen and deep-frozen products, respectively, require  $-12^{\circ}\text{C}$  and  $-18^{\circ}\text{C}$ . Ice-cream should be transported at  $-20^{\circ}\text{C}$ . Chilled products must be carried at temperatures between  $-1,5^{\circ}\text{C}$  and  $+5^{\circ}\text{C}$ , depending on the product. Fresh fruits and vegetables have the higher temperature range: between  $-0,5^{\circ}\text{C}$  and  $+14^{\circ}\text{C}$ . Mixing different products in the same loading unit may cause serious problems if some parameters are not set to determine their compatibility. Based on the literature, the factors that establish the compatibility are: relative humidity, temperature, ethylene production and sensitivity (fruits and vegetables), odour production and sensitivity and need of ventilation. In this sense, packaging is a very important factor for foodstuffs quality, not only as a protection tool, but also as a handling and distribution tool, as well as marketing tool.

The interviews with Swedish retailers were important to locate the first break points in the country. Most of them are situated in the south, due to the country's demographic density. The interviews have also given information about import flows. The Netherlands is the country that exports the higher volumes to Swedish retailers. Denmark and Italy are, respectively, second and third largest exporters. At the same time, the preliminary analysis has shown that dry/colonial goods are most imported, followed by fresh products. Together, they represent 76 % of all imported commodities.

The volume imported is a critical factor for the implementation of an intermodal solution between Italy and Scandinavia that attends Swedish retailers. If the amount of Temperature Sensitive Shipments (TSS) imported is not enough to provide daily train departures but, nevertheless, is close to the necessary volume, maybe a mixed load solution should be considered. Further investigation is though required.

The two case studies presented in this study are successful examples of an intermodal solution. In both trains express that covers a long distance are used. And the main incentives given for the use of intermodal transport were:

- Speed;
- Costs;
- Time reliability (better than road transport);
- Environmental issues; and
- Infrastructure.

Road and rail transport are, in many cases, competitors, depending on the volumes to be carried and the distance between origin and destination. In many situations, intermodality is more economic and efficient. Though quality and price are important, and near markets (like Denmark) decrease transport and storage costs, "on time" deliveries (speed, reliability) are appealing enough to promote a modal shift and encourage imports.

Finally, the next steps of the research will be:

- Delimitation in the flow analyses. Flows from Italy to Scandinavia will be studied;
- Identification of possible backloads. Adequate backloads are necessary to achieve an economic efficient intermodal transport;
- Study of equipments for TSS carriage; and
- Determination of possible solutions for TSS intermodal transport.



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# Appendix 1

## Product Classification and Temperature Sensitivity.

| Groups of products                                      | Sub-groups of products  | Kinds of products   | Temperature sensitivity |
|---|---|---|-------------------------|
| <b>0. Agriculture, forestry and fishery products</b>    | <i>Products of agriculture, horticulture and market gardening</i> | Cereals   | **                      |
|   |   | Vegetables  | ****                    |
|   |   | Fruits  | ****                    |
|   |   | Nuts  | **                      |
|   |   | Oil seeds and oleaginous fruit  | **                      |
|   |   | Living plants   | ****                    |
|   |   | Cut flowers   | ****                    |
|   |   | Flower buds   | ****                    |
|   |   | Flower seeds  | **                      |
|   |   | Fruit seeds   | **                      |
|   |   | Vegetable seeds   | **                      |
|   |   | Beverages   | ***                     |
|   |   | Spice crops   | **                      |
|   |   | Unmanufactured tobacco  | **                      |
|   |   | Plants used for sugar manufacturing   | ****                    |
|   | Raw vegetable materials   | ****  |                         |
|   | <i>Live animals and animal products</i>                           | Live animals  | ****                    |
|   |   | Other animal products   | ****                    |
|   | <i>Forestry and logging products</i>                              | Wood in the rough   | *                       |
|   |   | Natural gums  | **                      |
|   |   | Other forestry products   | **                      |
|   | <i>Fish and other fishing products</i>                            | Live fish   | ****                    |
|   |   | Fresh fish  | ****                    |
|   |   | Chilled fish  | ****                    |
|   |   | Crustaceans, not frozen   | ****                    |
|   |   | Oysters   | ****                    |
|   | Other aquatic invertebrates live                                  | ****  |                         |
|   | Other aquatic invertebrates fresh                                 | ****  |                         |
|   | Other aquatic invertebrates chilled                               | ****  |                         |
|   | Other aquatic animals   | ****  |                         |
| <b>1. Ores and minerals; electricity, gas and water</b> | <i>Coal and lignite; peat</i>                                     | Coal and lignite  | *                       |
|   |   | Peat  | *                       |
|   | <i>Crude petroleum and natural gas</i>                            | Crude petroleum   | *                       |
|   |   | Natural gas   | *                       |
|   | <i>Uranium and thorium ores</i>                                   | Uranium ores and concentrates   | *                       |
|   |   | Thorium ores and concentrates   | *                       |
|   | <i>Metal ores</i>   | Iron ores and concentrates (other than roasted iron pyrites)                                  | *                       |
|   |   | Non-ferrous metal ores and concentrates (other than uranium or thorium ores and concentrates) | *                       |
|   | <i>Stone, sand and clay</i>                                       | Monumental or building stone  | *                       |
|   |   | Gypsum  | *                       |
|   |   | Anhydrite   | *                       |
|   |   | limestone flux  | *                       |
|   |   | Limestone and other calcareous stone, of a kind used for the manufacture of lime or cement    | *                       |
|   | <i>Other minerals</i>   | Chemical minerals   | *                       |
|   |   | Fertilizer minerals   | *                       |
|   |   | Salt sodium chloride  | *                       |
|   |   | Pure sodium chloride  | *                       |

|  |   |   |  |      |
|--|---|---|--|------|
|  |   | Sea water   | *  |      |
|  |   | Precious stones   | *  |      |
|  |   | Semi-precious stones  | *  |      |
|  |   | Pumice stone  | *  |      |
|  |   | Emery   | *  |      |
|  |   | Natural abrasives   | *  |      |
|  |   | Other minerals  | *  |      |
|  | <i>Electricity, town gas, steam and hot water</i>                             | Electrical energy   | *  |      |
|  |   | Coal gas  | *  |      |
|  |   | Water gas   | **   |      |
|  |   | Producer gas  | *  |      |
|  |   | Similar gases, other than petroleum gases and other than gaseous hydrocarbons   | *  |      |
|  |   | Steam water   | **   |      |
|  |   | Hot water   | ***  |      |
| <i>Water</i>   | Natural water   | *   |  |      |
| <b>2. Food products, beverages and tobacco; textiles, apparel and leather products</b> | <i>Meat, fish, fruit, vegetables, oils and fats</i>                           | Meat and meat products  | ****   |      |
|  |   | Prepared and preserved fish   | ****   |      |
|  |   | Prepared and preserved vegetables   | ****   |      |
|  |   | Fruit juices  | ****   |      |
|  |   | Vegetable juices  | ****   |      |
|  |   | Prepared and preserved fruit  | ****   |      |
|  |   | Prepared and preserved nuts   | **   |      |
|  |   | Animal and vegetable oils and fats  | **   |      |
|  |   | Cotton linters  | *  |      |
|  |   | Oil-cake and other residues resulting from the extraction of vegetable fats or oils   | **   |      |
|  |   | Flours and meals of oil seeds or oleaginous fruits, except from the treatment of fatty substances or animal or vegetable waxes. | **   |      |
|  | <i>Dairy products</i>   | Processed liquid milk   | ****   |      |
|  |   | Processed liquid cream  | ****   |      |
|  |   | Other dairy products  | ****   |      |
|  |   | Grain mill products   | **   |      |
|  | <i>Grain mill products, starches and starch products: other food products</i> | Starches and starch products  | **   |      |
|  |   | Sugars and sugar syrups   | **   |      |
|  |   | preparations used in animal feeding   | ***  |      |
|  |   | bakery products   | ****   |      |
|  |   | sugar; cocoa and sugar confectionery  | **   |      |
|  |   | chocolate   | ****   |      |
|  |   | macaroni, noodles, couscous and similar farinaceous products  | ***  |      |
|  |   | Food products n.e.c.  | ****   |      |
|  |   | <i>Beverages</i>  | Ethyl alcohol                                    | **** |
|  |   |   | Spirits, liqueurs and other spirituous beverages | **** |
|  | Wines   |   | ****   |      |
|  | Malt liquors and malt   |   | ***  |      |
|  | Soft drinks   |   | **   |      |
|  | Bottled mineral waters  |   | *  |      |
|  | <i>Tobacco products</i>   | Tobacco products  | *  |      |
|  | <i>Yarn and thread; woven and tufted textile fabrics</i>                      | Natural textile fibres prepared for spinning  | *  |      |
|  |   | Man-made textile staple fibres processed for spinning   | *  |      |
|  |   | Textile yarn and thread of natural fibres   | *  |      |
|  |   | Textile yarn and thread of man-made filaments or staple fibres  | *  |      |
|  |   | Woven fabrics (except special fabrics) of natural fibres other than cotton  | *  |      |



|   |   |  |   |   |
|---|---|--|---|---|
|   |   | Woven fabrics (except special fabrics) of cotton                               | *   |   |
|   |   | Woven fabrics (except special fabrics) of man-made filaments and staple fibres | *   |   |
|   |   | Special fibres   | *   |   |
|   | <i>Textile articles other than apparel</i>  |  | Made-up textile articles  | * |
|   |   |  | Carpets and other textile floor coverings   | * |
|   |   |  | Twine, cordage, ropes, and cables and articles thereof (including netting)  | * |
|   |   |  | Textiles n.e.c.   | * |
|   | <i>Knitted or crocheted fabrics; wearing apparel</i>                                |  | Knitted or crocheted  | * |
|   |   |  | Wearing apparel, except fur apparel   | * |
|   |   |  | Fabrics tanned or dressed furskins and artificial fur   | * |
|   |   |  | Articles thereof  | * |
|   | <i>Leather and leather products; footwear</i>                                       |  | Tanned or dressed leather; composition leather  | * |
|   |   |  | Luggage, handbags and the like; saddlery and harness; other articles of leather   | * |
|   |   |  | Footwear, with outer soles and uppers of rubber or plastics, or with uppers of leather or textile materials, other than sports footwear, footwear incorporating a protective metal toe-cap and miscellaneous special footwear | * |
|   |   |  | Sports footwear, except skating boots   | * |
|   |   |  | Other footwear, except asbestos footwear, orthopaedic footwear and skating boots  | * |
|   |   |  | Parts of footwear; removable insoles, heel cushions and similar articles; gaiters, leggings and similar articles, and parts thereof   | * |
|   |   |  |   |   |
|   | <b>3. Other transportable goods, except metal products, machinery and equipment</b> | <i>Products of wood, cork, straw and plaiting materials</i>                    | Wood, sawn or chipped lengthwise, sliced or peeled, of a thickness exceeding 6mm; railway or tramway sleepers (cross-ties) of wood, not impregnated   | * |
|   |   |  | Wood continuously shaped along any of its edges or faces; wood wool; wood flour; wood in chips or particles   | * |
| Wood in the rough, treated with paint, stains, creosote or other preservatives; railway or tramway sleepers (cross-ties) of wood, impregnated |   |  | *   |   |
| Boards and panels   |   |  | *   |   |
| Veneer sheets; sheets for plywood; densified wood   |   |  | *   |   |
| Builders' joinery and carpentry of wood (including cellular wood panels, assembled parquet panels, shingles and shakes)                       |   |  | *   |   |
| Packing cases, boxes, crates, drums and similar packings, of wood; cable-drums of wood; pallets, box pallets and other load boards, of wood   |   |  | *   |   |
| Casks, barrels, vats, tubs and other cooper' products and parts thereof, of wood (including staves)   |   |  | *   |   |
| Other products of wood; articles of cork, plaiting materials and straw  |   |  | *   |   |
| <i>Pulp, paper and paper products; printed matter and related articles</i>  |   |  | Pulp, paper and paperboard  | * |
|   |   |  | Books, brochures and leaflets (except advertising material) printed, printed maps; music, printed or in manuscript  | * |
|   |   |  | Newspapers, journals and periodicals, appearing at least four times a week  | * |
|   |   |  | Newspapers, journals and periodicals, appearing less than four times a week   | * |
|   |   |  | Stamps, cheque forms, banknotes, stock certificates, postcards, greeting cards, advertising material, pictures and other printed matter   | * |
|   |   |  |   |   |

|   |  |      |
|---|--|------|
|   | Registers, account books, notebooks, letter pads, diaries and similar articles, blotting-pads, binders, file covers, forms and other articles of stationery, of paper or paperboard  | *    |
|   | Composed type, prepared printing plates or cylinders, impressed lithographic stones or other impressed media for use in printing   | *    |
| <i>Coke oven products; refined petroleum products; nuclear fuel</i> | Coke and semi-coke of coal, of lignite or of peat; retort carbon   | *    |
|   | Tar distilled from coal, from lignite or from peat, and other mineral tars   | *    |
|   | Petroleum oils and oils obtained from bituminous materials, other than crude; preparations n.e.c. containing by weight 70% or more of these oils, such oils being the basic constituents of the preparations   | *    |
|   | Petroleum gases and other gaseous hydrocarbons, except natural gas   | **   |
|   | Petroleum jelly; paraffin wax, micro-crystalline petroleum wax, slack wax, ozokerite, lignite wax, peat wax, other mineral waxes, and similar products; petroleum coke, petroleum bitumen and other residues of petroleum oils or of oils obtained from bituminous materials   | **   |
|   | Radioactive elements and isotopes and compounds; alloys, dispersions, ceramic products and mixtures containing these elements, isotopes or compounds; radioactive residues   | **   |
|   | Fuel elements (cartridges), for or of nuclear reactors   | *    |
| <i>Basic chemicals</i>  | Basic organic chemicals  | **   |
|   | Basic inorganic chemicals n.e.c.   | **   |
|   | Tanning or dyeing extracts; tannins and their derivatives; colouring matter n.e.c.   | **   |
|   | Activated natural mineral products; animal black; tall oil; terpenic oils produced by the treatment of coniferous woods; crude dipentene; crude para-cymene; pine oil; rosin and resin acids, and derivatives thereof; rosin spirit and rosin oils; rum gums; wood tar; wood tar oils; wood creosote; wood naphtha; vegetable pitch; brewes' pitch | **   |
|   | Miscellaneous basic chemical products  | **   |
|   | Fertilizers and pesticides   | **   |
|   | Plastics in primary form   | **   |
|   | Synthetic rubber and factice derived from oils, and mixtures thereof with natural rubber and similar natural gums, in primary forms or in plates, sheets or strip  | **   |
| <i>Other chemicals products; man-made fibres</i>                    | Paints and varnishes and related products; artists' colours; ink   | **   |
|   | Pharmaceutical products  | **** |
|   | Soap, cleaning preparations, perfumes and toilet preparations  | ***  |
|   | Chemical products n.e.c.   | ***  |
|   | Man-made fibres  | **   |
| <i>Rubber and plastic products</i>                                  | Rubber tyres and tubes   | **   |
|   | Other rubber products  | **   |
|   | Semi-manufactures of plastics  | **   |
|   | Packaging products of plastics   | **   |
|   | Other plastics products  | **   |
| <i>Glass and glass products and other</i>                           | Glass and glass products   | *    |
|   | Non-structural ceramic ware  | *    |

|   |  |  |     |
|---|--|--|-----|
|   | <i>non-metallic products<br/>n.e.c</i>                           | Refractory products and structural non-refractory clay products  | *   |
|   |  | Cement, lime and plaster   | *   |
|   |  | Articles of concrete, cement and plaster   | *   |
|   |  | Monumental or building stone and articles thereof  | *   |
|   |  | Other non-metallic mineral products n.e.c.   | *   |
|   | <i>Furniture; other transportable goods</i>                      | Furniture  | *   |
|   |  | Jewellery and related articles   | *   |
|   |  | Musical instruments  | **  |
|   |  | Sports goods   | *   |
|   |  | Games and toys   | *   |
|   |  | Roundabouts, swings, shooting galleries and other fairground amusements  | *   |
|   |  | Prefabricated buildings  | *   |
|   | <i>Wastes and scraps</i>   | Other manufactured articles n.e.c.   | *   |
|   |  | Wastes from food and tobacco industry  | *** |
|   |  | Non-metal wastes or scraps   | *   |
| Metal wastes or scraps                            |  | *  |     |
| <b>4. Metal products, machinery and equipment</b> | <i>Basic metals</i>  | Other wastes and scraps  | *   |
|   |  | Basic iron and steel   | *   |
|   |  | Rolled, drawn and folded products of iron and steel  | *   |
|   |  | Basic precious metals and metals clad with precious metals   | *   |
|   |  | Copper, nickel, aluminium, alumina, lead, zinc and tin, unwrought  | *   |
|   |  | Semi-finished products of copper, nickel, aluminium, lead, zinc and tin or their alloys  | *   |
|   | <i>Fabricated metal products, except machinery and equipment</i> | Other non-ferrous metals and articles thereof (including waste and scrap); cermets and articles thereof; ash and residue (except from the manufacture of iron or steel), containing metals or metallic compounds | *   |
|   |  | Structural metal products and parts thereof  | *   |
|   |  | Tanks, reservoir and containers of iron, steel or aluminium  | *   |
|   |  | Steam generators, (except central heating boilers) and parts thereof   | *   |
|   | <i>General-purpose machinery</i>                                 | Other fabricated metal products  | *   |
|   |  | Engines and turbines and parts thereof   | *   |
|   |  | Pumps, compressors, hydraulic and pneumatic power engines, and valves and parts thereof  | *   |
|   |  | Bearings, gears, gearing and driving elements, and parts thereof   | *   |
|   |  | Ovens and furnace burners and parts thereof  | *   |
|   |  | Lifting and handling equipment and parts thereof   | *   |
|   | <i>Special-purpose machinery</i>                                 | Other general-purpose machinery and parts thereof  | *   |
|   |  | Agricultural or forestry machinery and parts thereof   | *   |
|   |  | Machine-tools and parts and accessories thereof  | *   |
|   |  | Machinery for metallurgy and parts thereof   | *   |
|   |  | Machinery for mining, quarrying and construction, and parts thereof  | *   |
|   |  | Machinery for food, beverage and tobacco processing, and parts thereof   | *   |
|   |  | Machinery for textile, apparel and leather production, and parts thereof   | *   |
|   |  | Weapons and ammunition and parts thereof   | *   |
|   | Domestic appliances and parts thereof                            | *  |     |
|   | Other special-purpose machinery and parts thereof                | *  |     |

|  |  |  |                     |               |                     |
|--|--|--|---------------------|---------------|---------------------|
|  | <i>Office, accounting and computing machinery</i>                                | Office and accounting machinery, and parts and accessories thereof   | *                   |               |                     |
|  |  | Computing machinery and parts and accessories thereof  | *                   |               |                     |
|  | <i>Electrical machinery and apparatus</i>  | Electric motors, generators and transformers, and parts thereof  | *                   |               |                     |
|  |  | Electricity distribution and control apparatus and parts thereof   | *                   |               |                     |
|  |  | Insulated wire and cable; optical fibre cables   | *                   |               |                     |
|  |  | Accumulators, primary cells and primary batteries, and parts thereof   | *                   |               |                     |
|  |  | Electric filament or discharge lamps; arc lamps; lighting equipment; parts thereof   | *                   |               |                     |
|  |  | Other electrical equipment and parts thereof   | *                   |               |                     |
|  | <i>Radio, television and communication equipment and apparatus</i>               | Electronic valves and tubes; electronic components; parts thereof  | **                  |               |                     |
|  |  | Television and radio transmitters and apparatus for line telephony or telegraphy; parts and accessories thereof  | **                  |               |                     |
|  |  | Radio broadcast and television receivers; apparatus for sound and video recording and reproducing; microphones, loudspeakers, amplifiers, etc; reception apparatus for radio-telephony or radio-telegraphy | **                  |               |                     |
|  |  | Parts for the goods of classes 4721 to 4733 and 4822   | *                   |               |                     |
|  |  | Audio and video records and tapes  | ***                 |               |                     |
|  |  | Cards with magnetic strips or chip   | ***                 |               |                     |
|  | <i>Medical appliances, precision and optical instruments, watches and clocks</i> | Medical and surgical equipment and orthopaedic appliances  | ***                 |               |                     |
|  |  | Instruments and appliances for measuring, checking, testing, navigating and other purposes, except optical instruments; industrial process control equipment; parts and accessories thereof                | ***                 |               |                     |
|  |  | Optical instruments and photographic equipment, and parts and accessories thereof  | ***                 |               |                     |
|  |  | Watches and clocks, and parts thereof  | ***                 |               |                     |
|  | <i>Transport equipment</i>   | Motor vehicles, trailers and semi-trailers; parts and accessories thereof  | *                   |               |                     |
|  |  | Bodies (coachwork) for motor vehicles; trailers and semi-trailers; parts and accessories thereof   | *                   |               |                     |
|  |  | ships  | *                   |               |                     |
|  |  | Pleasure and sporting boats  | *                   |               |                     |
|  |  | Railway and tramway locomotives and rolling stock, and parts thereof   | *                   |               |                     |
|  |  | Aircraft and spacecraft, and parts thereof   | *                   |               |                     |
|  | Other transport equipment and parts thereof                                      | *  |                     |               |                     |
|  | * not particularly sensitive   |  | ** little sensitive | *** sensitive | **** very sensitive |

Source: based on United Nations Statistics Division (2002).















| COMPATIBILITY MATRIX                  | potato sweet | tamaind | taro | tree-tomato | tomato, mature green | tomato, ripe | turnip | parsley | watercress | watermelon | jam | chilled meat | chilled poultry | chilled fish | pasteurized milk | butter | cultured milk products | fresh cheese | camembert cheese | cheddar cheese | emmental cheese | eggs | deep frozen meat | deep frozen poultry | deep frozen fish | deep frozen fruits and concentrated | deep frozen vegetables | frozen beef | frozen poultry | frozen butter |  |
|---------------------------------------|--------------|---------|------|-------------|----------------------|--------------|--------|---------|------------|------------|-----|--------------|-----------------|--------------|------------------|--------|------------------------|--------------|------------------|----------------|-----------------|------|------------------|---------------------|------------------|-------------------------------------|------------------------|-------------|----------------|---------------|--|
| apple                                 |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| apricot                               |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| artichoke                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| asparagus                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| aubergine                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| avocado                               |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| baby corn                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| banana, ripening                      |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| banana, unripen                       |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| bean                                  |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| beet, topped                          |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| beet                                  |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| bitter gourd                          |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| blueberry                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| broccoli                              |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| brussels sprout                       |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cabbage                               |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cabbage red                           |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cabbage white                         |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| gooseberry                            |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| carambola                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| carrot                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cauliflower                           |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| celeriac                              |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| celery                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| chanterelle                           |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cherimoya                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cherry                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| chicory                               |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| chilli                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cabbage, chinese                      |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| clementine                            |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| coconuts                              |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| courgette/squash (hard shell)         |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| courgette/squash (soft shell)         |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cranberry                             |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cucumber                              |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| date                                  |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| endive/fescarole                      |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| feijoa                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| fennel                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| fig                                   |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| garlic                                |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| grape (fumigated with sulfur dioxide) |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| grape (without sulfur dioxide)        |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| grapefruit                            |              |         |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |

| COMPATIBILITY MATRIX      | potato sweet | tamarind | taro | tree-tomato | tomato, mature green | tomato, ripe | turnip | parsley | watercress | watermelon | jam | chilled meat | chilled poultry | chilled fish | pasteurized milk | butter | cultured milk products | fresh cheese | camembert cheese | cheddar cheese | emmental cheese | eggs | deep frozen meat | deep frozen poultry | deep frozen fish | deep frozen fruits and concentrated | deep frozen vegetables | frozen beef | frozen poultry | frozen butter |  |
|---------------------------|--------------|----------|------|-------------|----------------------|--------------|--------|---------|------------|------------|-----|--------------|-----------------|--------------|------------------|--------|------------------------|--------------|------------------|----------------|-----------------|------|------------------|---------------------|------------------|-------------------------------------|------------------------|-------------|----------------|---------------|--|
| guava                     |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| horse radish              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| jackfruit                 |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| artichoke, jerusalem      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| kaki                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| kiwi fruit, ripe          |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| kiwi fruit, unripe        |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| kumquat                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| leek                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| lemon                     |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| lettuce                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| lime                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| loquat                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| lychee                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| mango                     |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| mangosteen                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| manioc/ yucca root        |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| melon, cantaloupe         |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| melon, honeydew           |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| mushroom                  |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| nectarine                 |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| okra                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| onion, dry                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| onion, green              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| orange                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pak choi (celery cabbage) |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| papaya                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| parsnip                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| passion fruit             |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pea                       |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| peach                     |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pear                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pineapple                 |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| plum                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pomegranate               |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| potato                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| prickly pear              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pumpkin                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| radish                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| raspberry                 |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| whortleberry, red         |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| rhubarb                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| scorzonera                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| spinach                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| strawberry                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| sugar pea                 |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| swede (rutabaga)          |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |

| COMPATIBILITY MATRIX                      | potato sweet | tamarind | taro | tree-tomato | tomato, mature green | tomato, ripe | turnip | parsley | watercress | watermelon | yam | chilled meat | chilled poultry | chilled fish | pasteurized milk | butter | cultured milk products | fresh cheese | camembert cheese | cheddar cheese | emmental cheese | eggs | deep frozen meat | deep frozen poultry | deep frozen fish | deep frozen fruits and concentrated | deep frozen vegetables | frozen beef | frozen poultry | frozen butter |  |
|---|--------------|----------|------|-------------|----------------------|--------------|--------|---------|------------|------------|-----|--------------|-----------------|--------------|------------------|--------|------------------------|--------------|------------------|----------------|-----------------|------|------------------|---------------------|------------------|-------------------------------------|------------------------|-------------|----------------|---------------|--|
| sweet corn                                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pepper, green                             |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pepper                                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| potato sweet                              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| tamarind                                  |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| taro                                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| tree-tomato                               |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| tomato, mature green                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| tomato, ripe                              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| turnip                                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| parsley                                   |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| watercress                                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| watermelon                                |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| yam                                       |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| chilled meat *                            |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| chilled poultry                           |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| chilled fish                              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| pasteurized milk                          |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| butter                                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cultured milk products                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| fresh cheese                              |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| camembert cheese                          |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| cheddar cheese                            |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| emmental cheese                           |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| eggs                                      |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| deep frozen meat                          |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| deep frozen poultry                       |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| deep frozen fish                          |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| deep frozen fruits and concentrated juice |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| deep frozen vegetables                    |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| frozen beef                               |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| frozen poultry                            |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |
| frozen butter                             |              |          |      |             |                      |              |        |         |            |            |     |              |                 |              |                  |        |                        |              |                  |                |                 |      |                  |                     |                  |                                     |                        |             |                |               |  |





TFK– TransportForsK AB  
Warfvinges väg 29  
112 51 Stockholm  
Tel 08-652 41 30  
Fax: 08-652 54 98

TFK– Transportforskningsgruppen i Borlänge AB  
Borganäsvägen 43  
784 33 Borlänge  
Tel: 0243-685 00  
Fax: 0243-685 06