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PERISHABLE FOOD CARGO LOSSES AND DAMAGE IN COLD CHAINS – AN EMPIRICAL ANALYSIS

STRATY I SZKODY W ŁADUNKACH ŻYWNOŚCI SZYBKO PSUJĄCEJ SIĘ W ŁAŃCUCHACH CHŁODNICZYCH – ANALIZA EMPIRYCZNA

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Summary: The purpose of the paper is to investigate the main causes and factors of losses of or damage to perishable food cargo in the cold chain. The empirical analysis is based on a study of 1816 claims and survey cases conducted by a leading surveyor company in the period 2015-2018. The prevailing causes were divided into five categories: 1) breaking cold chain integrity; 2) unsuitability of packaging, stacking and preparation of cargo for transit (especially the lack of or insufficient pre-freezing or pre-cooling to the required carrying temperature); 3) delays in delivery; 4) errors and omissions in transport documents or shipment instructions; 5) administrative decisions. A closer examination of the results showed that human error was the root cause of many incidents, being responsible for approximately 50% of all examined claims. This points to the need to raise awareness among all cold chain stakeholders with regard to the specific requirements of perishable food cargo, pointing out in particular that even their minor breach may result in total loss or damage.

Keywords: cold chain, perishable cargo, cargo losses and damage, breaking cold chain integrity, food losses.

Streszczenie: Celem artykułu była analiza przyczyn strat i szkód w ładunkach żywności szybko psującej się w łańcuchach chłodniczych. Analiza empiryczna 1816 roszczeń i ekspertyz szkodowych przeprowadzonych przez wiodącą firmę rzeczoznawczo-kontrolną w latach 2015-2018 pozwoliła zidentyfikować główne przyczyny strat i szkód w badanej grupie ładunków, które przypisano do jednej z pięciu kategorii: 1) przerwanie integralności łańcucha chłodniczego; 2) niewłaściwe opakowanie, sztauowanie i przygotowanie ładunku do przewozu (szczególnie brak lub niewystraczające wstępne mrożenie lub schłodzenie do wymaganej temperatury); 3) opóźnienia w dostawie; 4) błędy i opuszczenia w dokumentach transportowych i instrukcjach wysyłkowych; 5) decyzje administracyjne. Wnikliwa analiza tych wyników wykazała, że to błąd ludzki leżał u podłoża wielu szkód, przyczyniając się do powstania około 50% z nich. Wskazuje

to na potrzebę zwiększania świadomości wśród wszystkich uczestników łańcucha chłodniczego odnośnie do szczególnych wymagań żywności szybko psującej się, gdyż nawet niewielkie odstępstwa od nich mogą prowadzić do poważnej szkody lub straty całkowitej ładunku.

Słowa kluczowe: łańcuch chłodniczy, ładunek szybko psujący się, straty i szkody ładunkowe, przerwanie ciągłości łańcucha chłodniczego, straty żywności.

1. Introduction

There is a wide range of perishable products in global trade, many of which are transported in refrigerated conditions (frozen or chilled). This group of commodities is comprised predominately of horticultural and agricultural goods such as fruit, vegetables, and animal products. Some high-value goods, including flowers, medicines, live organs, and certain chemicals, also belong to the category of perishables but their share in the total volume of traded perishable products is insignificant. Perishable food commodities are those which may rapidly deteriorate and lose quality in ambient temperature and atmosphere, and therefore become unsafe for human consumption. They have a limited shelf life and their prices are time-sensitive.

The global trade of perishable food products[1] increased by 119.2 million tons between 2000 and 2017, when it reached 259.4 million tons, which represents a CAGR of 3.9% (Figure 1). The majority of these products require refrigeration during storage and transit.

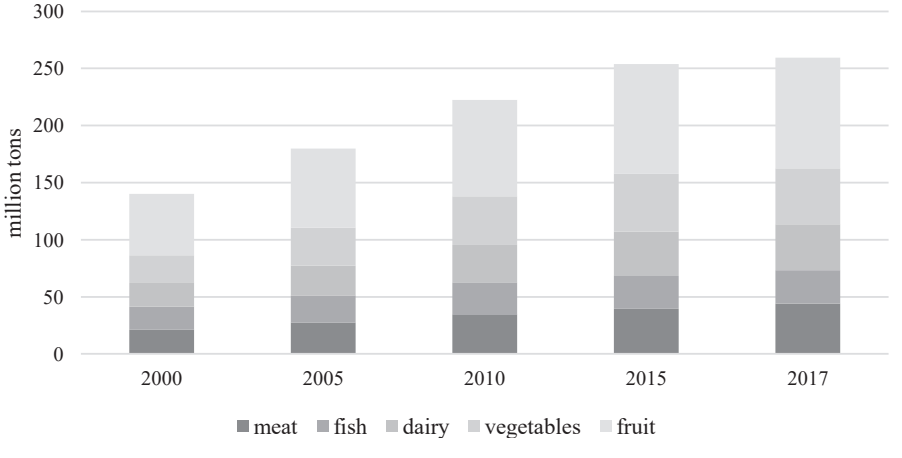

Fig. 1. Global trade of perishable food in 2000-2017

Source: own elaboration based on the United Nations Commodity Trade Statistics Database.

[1] In this paper for analysis purposes, attention was focused on five main categories of perishable food products: dairy, eggs and honey (HS-04); fish and crustaceans (HS-03); edible fruit and nuts (HS-08), meat and edible meat offal (HS-02); edible vegetables and certain roots and tubers (HS-07).

There are several factors that stimulate or facilitate growth in the international trade of perishable refrigerated products. These include:

- an increase in the world's population and demand for food, including perishables;
- an increase in disposable income (e.g. Coyle, Hall, and Ballenger, 2001; Rodrigue, Comtois, and Slack, 2017), especially in developing economies such as China and India (where the expansion of middle-class population has been observed) (Orbis Research, 2018);
- dietary changes and growing consumer interest in fresh and diverse food products, regardless of the season and geographic location;
- free trade agreements between countries (Serrano and Pinilla, 2014);
- expansion of food retail chains providing the year-round supply of fresh food from all over the world;
- continuous improvements and advances in reefer technology;
- development of maritime reefer container transport.

The growing trend of purchasing chilled and frozen food products, especially in the emerging countries of Asia Pacific, South America, and the Middle East, underpins the rising interest in the development of dedicated refrigerated infrastructure and services. The numbers reflect this tendency:

- The global cold-chain market is projected to reach a value of USD 293 billion by 2023 with a CAGR of 7.6% (from 203 billion USD in 2018) (Markets and Markets, 2018a).
- The refrigerated transport market was valued at USD 13.93 billion in 2017 and is projected to reach USD 19.29 billion by 2023, growing at a CAGR of 5.67% during the forecast period (Markets and Markets, 2018b).
- The refrigerated warehousing market was valued at USD 16.67 billion in 2016 and is projected to grow at a CAGR of 10.2% from 2017, to reach USD 29.17 billion by 2022 (Markets and Markets, 2017).

Nevertheless this rapid growth of the cold chain market and services is overshadowed by food losses and waste arising at every stage of global cold chains – a phenomenon that has been given increasing attention in recent years. According to the FAO data, as much as one-third of food produced around the world for human consumption is either lost or wasted, which amounts to about 1.3 billion tons annually (FAO, 2018). The World Resources Institute also indicates that each year food worth $750 billion is either lost or wasted across the cold chain (Lipinski, 2013).

Therefore the purpose of this paper is to investigate the main causes and factors that contribute to the losses of or damage to perishable food cargo in cold chains, as their thorough understanding is a prerequisite for reducing food losses and successful risk management across food cold chains.

2. Perishable food cargo losses and damage

The vast majority of perishables require continuous and uninterrupted cooling for preservation, as well as an environment controlled in terms of humidity and air composition, during the storage and transport processes. Owing to refrigeration, microbiological, physiological, and physical changes to food in post-harvest processes may be completely prevented or significantly reduced (Haas, Dittmer, Veigt, and Lutjen, 2015). As perishable food easily decays and deteriorates, any deviation from precisely defined conditions (e.g. temperature, barometric pressure, air composition, humidity) may potentially lead to losses of and damage to food cargo (Aung and Chang, 2014; Rong, Akkerman, and Grunow, 2011).

These losses and damage refer to a decrease (total or partial) in food quantity or quality, which makes the product unfit for human consumption (Grolleaud, 2002). Food quality is also directly related to other food attributes such as integrity, safety, and shelf life (Rong et al., 2011).

Food cargo losses and damage may be linked to a variety of risks occurring during transit, handling and storage as well as value-added operations, and they are usually considered random and unintended events, often beyond human control (Klopott, 2018). Having said that, human negligence or error may trigger food losses, too. This category may be extended to include losses resulting from post-harvest handling and preparation of cargo, or the use of an incorrect transport unit (e.g. one lacking pre-cooling).

Whenever a loss occurs, it inevitably entails economic losses to the contracting parties (exporter/importer), to the liable carrier, to the logistics services provider, and to the operator (of a terminal, warehouse, etc.), as well as to the insurance company (provided that the cargo or carrier liability have been insured). In a broader sense, perishable food losses and damage may disrupt the food supply, causing food shortages (especially in developing countries) or leading to food wastage, as already suggested in the introduction.

Changes to the condition and quality of perishable cargo, as well as delays in transport, may also prompt shipment rejections whose number has risen recently. The underlying reason for this may have to do with the ever more rigorous and rapidly changing food safety standards as well as the growing enforcement ability (Jaffee and Henson, 2005), although it may also spring from the mainstream retailers' policies of accepting only products with a high (usually over 70%) share of remaining shelf life (Mena, Adenzo-Diaz, and Yurt, 2011).

It is worth noting that food losses and waste significantly affect the environment as well. They can be linked to the waste of natural resources used for its production and to global warming because of the emissions generated by both the decomposition of wasted food in a landfill and, even more importantly, the embedded emissions associated with its production, processing, transport, retailing and accompanying energy production for refrigeration (Klopott, 2018; Venkat, 2012; Winkworth-Smith, Foster, and Morgan, 2015). The carbon footprint of food waste is estimated to be 3.3 Gigaton of carbon dioxide, i.e. approximately 7% of all global emissions (FAO, 2018).

The specific requirements of perishables directly translate to the technological and organizational complexity of cold chains (Aung and Chang, 2014) and impose demanding criteria on the parties involved in the cold chain logistics. Moreover, the global nature of the perishable goods trade, i.e. long distances and transit times, a lot of transhipment points, and many parties involved in arranging and handling transit, also increases the likelihood of breaking what is known as cold chain integrity. Regardless of the degree of cold chain complexity, compliance with the specific requirements of perishable cargo needs to be ensured at all stages of the cold chain.

Furthermore, new developments in food trade and transport markets, which have been observed in recent years, may pose an additional threat to perishable cargo.

First and foremost, the world's specialized reefer fleet has been in decline and is currently facing fierce competition from reefer container shipping. In recent years a steady shift to reefer container shipping has been observed (Klopott, 2015), and in 2016 as much as 79% of total perishable cargo was carried on board of container vessels (Drewry Maritime Research, 2018). This further increases the complexity of cold chains, resulting in a considerably longer transit time, which often takes more than promised by the shipping line (the cargo may sometimes miss a connection with another vessel at a certain port along the route and has to wait for the arrival of the next vessel), requires many transhipments and more parties involved. Nevertheless, in what concerns breakdown or malfunction of refrigeration machinery, the quantity of damaged cargo is significantly lower in favour of container shipping, as, contrary to conventional reefer vessels carrying cargo in holds, every reefer container is equipped with a separate refrigeration unit.

Another threat to the global cold chains of perishable food may be the current efforts to limit CO_2 emissions from shipping as pursued by the International Maritime Organization, in an attempt to introduce mandatory speed reductions as a short-term measure. Independently of how this measure may benefit the environment, it constitutes an additional risk to fruit and vegetable cold chains, where any increase in transit time can negatively affect the quality of cargo and shorten its shelf life (e.g. a shipment of cherries from Peru to China would take 33 days at the speed of 20 knots, and 44 days at the reduced speed of 15 knots).

3. Research and findings

There is no available data concerning perishable cargo losses in cold chains. Therefore, in order to achieve the goal formulated in the introduction, claims data derived from a leading cargo surveyor offering expertise in the field of perishables losses/damages, and acting on behalf of different parties (exporters, importers, insurance companies, carriers etc.), was examined.

The study sample consisted of 1,816 survey cases conducted over the period between 2015 and 2018, and of reports drafted at the conclusion of the survey, indicating the factors behind the occurrence of loss of or damage to cargo. All the incidents involved losses in the international transport of four commodity groups: fish

and seafood, meat (both usually transported frozen), as well as fruit and vegetables (transported chilled).

In the literature, no results were found confirming the use of a similar claim approach to investigate the cause of loss of/damage to cargo. Moreover, the existing studies present findings related predominantly to food losses and waste that arise in food retail chains or final consumption (e.g. Mena et al., 2011). A few articles (e.g. Lipińska, Tomaszewska, and Kołożyn-Krajewska, 2019) deal with losses during the transportation process, but in each such case the problem was explored using a survey questionnaire among the carriers or producers of one particular product. The claim approach provides a closer insight into the research problem at hand, as it concerns diverse types of cargo and different involved parties.

All 1,816 survey cases and reports were thoroughly reviewed, enabling an indication of the prevailing types of damage and the main causes that contributed to the loss or damage to perishable food cargo in the cold chain.

Thermal damage was the most frequently encountered type of loss of/damage to perishable food cargo and was responsible for the majority of all losses. Thermal damage mainly means a chilling or frost injury, but excessive temperature may also lead to losses, causing premature ripening or total spoilage (defrosting). These losses were often connected with microbiological (e.g. uncontrolled multiplication of micro-organisms like mould or fungus), physical (e.g. moisture loss, shrivelling), physiological or biochemical damages (e.g. browning reactions, lipid oxidation, and pigment degradation). Consequently, phenomena such as the loss of the ripening ability (tomatoes or bananas), the emergence of storage scald in apples or plums, brown heart in apples or woolliness in peaches, are common quality losses among perishable fruit. In addition, mechanical damages seemed to cause losses as well, especially during handling, stacking or transit (e.g. a damaged skin or tissue which can lead to mould or rot, and damage to the transport unit or to product packaging).

In terms of the number of claims and their volume, fruit and vegetables were predominant (57% and 52%, respectively), followed by meat and fish products. However, with regard to the value of claims, it was fish that generated the most costly losses of all (the highest single loss in the investigated period was approximately PLN 300,000). In the four years of research, the 1,816 cases led to a total financial loss of PLN 343,488,000 and to 43,822 tons of food cargo lost.

Figure 2 shows the share of each group of perishables in the total number of cases, their value and volume.

The main causes that contributed to the loss of or damage to perishable food cargo in the cold chain were divided into five categories:

1. Breaking cold chain integrity.
2. Unsuitability of packaging, stacking and preparation of cargo for transit.
3. Delays in delivery.
4. Errors and omissions in transport documents or shipment instructions.
5. Administrative decisions.

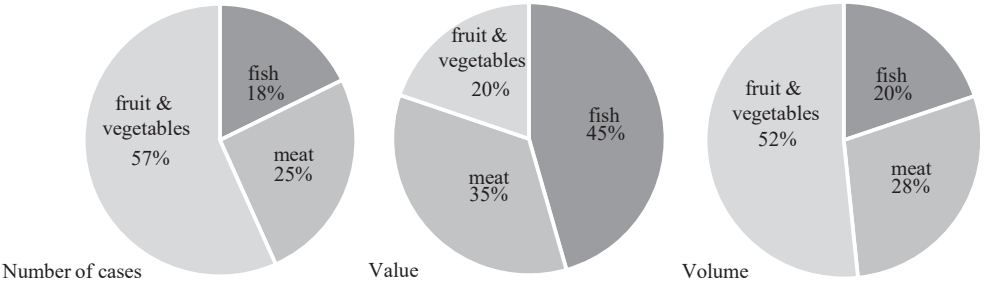

Fig. 2. Share of each group of perishables in the total number of cases, their value and volume

Source: own elaboration.

The share of each category in the total number of cases is shown in Figure 3.

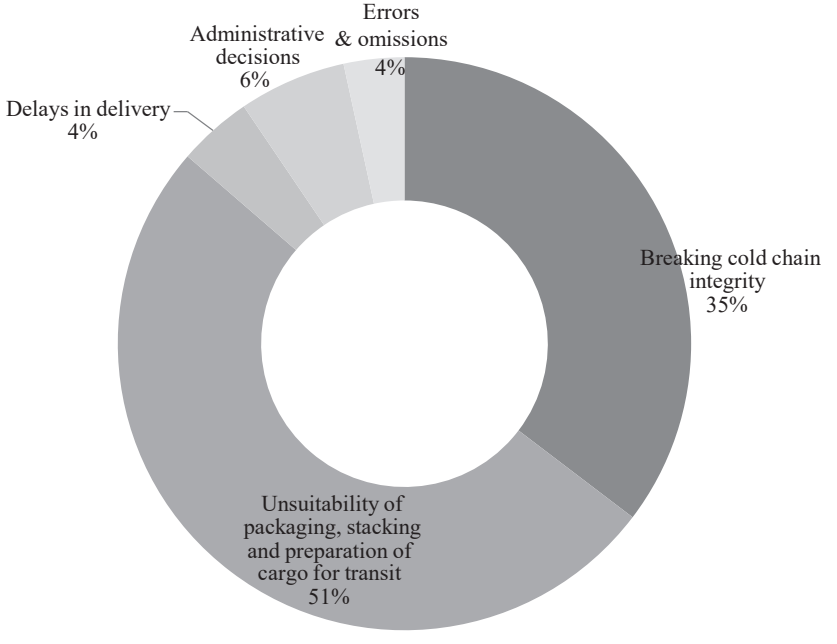

Fig. 3. Main causes of loss of or damage to perishable food cargo in the cold chain

Source: own elaboration.

Breaking cold chain integrity (35% of cases) means that a continuity in satisfying the expected cargo requirements such as temperature, air composition, humidity etc., has not been ensured across the entire cold chain. It needs to be emphasized that the margin of error is often very small for some commodities, and even a minor deviation from the required temperature may result in the total deterioration of cargo, leading

to high value claims of total loss and sometimes also to large disposal costs. Failure to maintain cold chain integrity gave rise to losses of/damage to 38% of fish, and similarly to 33% of fruit/vegetables and meat shipments.

A more in-depth review of the cases enabled the identification of the direct factors leading to cold chain breakage. They include:

- refrigerating equipment breakdown;
- refrigerating equipment malfunction (cooling equipment is working, but not correctly);
- lack of power supply (on board of the ship, during transit or in the place of storage);
- excessive time laps between changing transport modes or between storage and loading on the ship or conveyance;
- failure to connect the transport unit to the power source throughout the transit (or the cooling equipment has been switched off or forgotten to be switched on);
- not conforming with the special cargo requirements laid down in the shipment instructions regarding temperature, ventilation, humidity etc.;
- incorrect setting of temperature and other parameters;
- mistaking units of measurement (Celsius vs. Fahrenheit, where a common mistake is setting the temperature at 0°C – normally used for chilled cargoes vs. 0°F – for frozen cargo);
- mistaking positive and negative values when setting the temperature;
- failure to adapt the temperature of a cargo transport unit or a ship's hold adhering to the needs of a particular cargo shipment (before stacking, the transport unit or ship's hold must always be chilled to the required temperature);
- low availability of power plugs at terminals.

An unexpected finding in the research was that the **unsuitability of packaging, stacking and preparation of cargo for transit** accounts for more than half of all cases (50.99%) and is responsible for the losses of/damage to 56% of fruit and vegetables, 53% to meat, and to 39% of fish shipments.

The prevailing factor prompting loss in the first place was the unsuitable preparation of cargo for transit, meaning the lack or insufficient pre-freezing or pre-cooling to the required carrying temperature. It should be emphasized that this is a very serious negligence, as even with the correct setting of all parameters, the reefer transport unit (e.g. container or trailer) will not improve the cargo, being designed specifically to maintain the cargo's temperature, but not to lower it. However, such negligence is not always the fault of the producer or shipper but may arise from the lack of modern equipment such as blast freezers or cooling chambers in the producers' and harvesters' warehouses or the insufficient capacity of the refrigerating storage facilities.

Other damage-initiating factors include:

- substandard packaging made of stacking or which cannot withstand low temperatures or high humidity;
- improper stacking/stowage in a transport unit that does not comply with good practices, having a detrimental effect on the efficiency of the air flow;

- stacking cargo in a transport unit that was not properly prepared for transit (e.g. not clean, not free from odour etc.);
- careless handling during the stacking/unstacking of cargo in a transport unit or during loading/unloading.

Errors and omissions in transport documents or shipment instructions generated 3.41% of cases, and equally affected all groups of cargo (4%). It is the shipper's obligation and responsibility (which may be transferred to the logistics operator) to provide clear and accurate instructions on temperature and other parameters of the cooling equipment at which the cargo needs to be maintained throughout the entire transit. Any mistake in this regard will have a detrimental effect on the quality of the perishable cargo. Another mistake that can be considered relatively common was mistaking units of measurement or positive/negative values when setting the temperature.

Delays in delivery (4.11% of cases) may cause visible and non-visible damage to the cargo, but in either case they shorten perishables' shelf-life, lower their market value, and may even lead to cargo rejection. Particularly susceptible to delays in delivery are fruit and vegetables (69 cases, 7% of all the losses), which are carried in chilling conditions, unlike fish or meat which are usually transported frozen (only seven cases altogether).

Administrative decisions made by official veterinarians, which prohibit a release cargo for consumption, accounted for 110 cases (6.06%) and affected only cargoes of meat and fish. However, if value is to be considered, their share was much higher

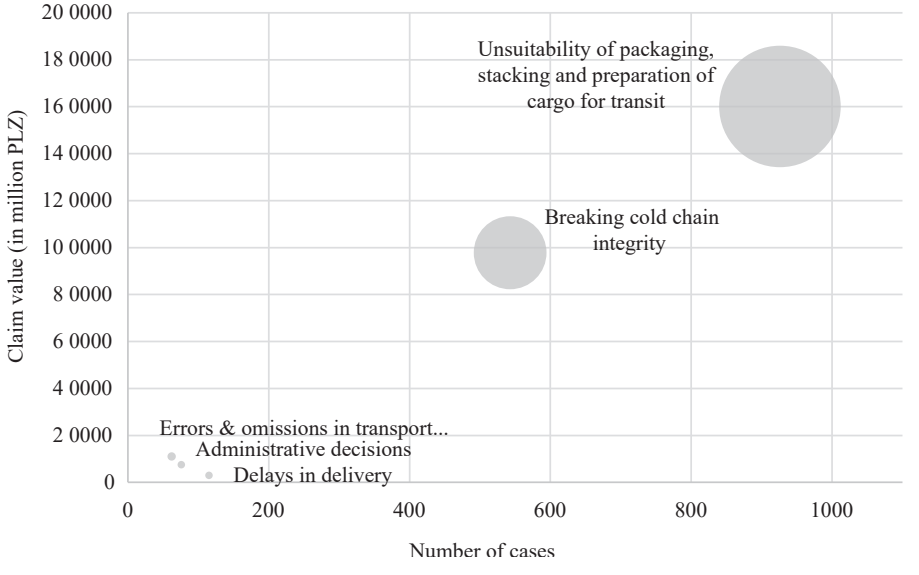

Fig. 4. Total loss to perishable cargo and its cause

Source: own elaboration.

(11.9%) and totalled approximately PLN 40 million. In many cases this was due to rigorous food safety rules, where even a slight deviation in temperature may provoke cargo rejection and lead to high disposal costs. Unfortunately, it is not uncommon for such decisions to be incorrect and arise from ignorance, or quite often the abuse of power by officials, when there were in fact no grounds for the cargo to be withdrawn. Figure 4. shows the total reported loss in value by each identified category of losses of/damage to perishable cargo.

A closer examination of the results shows that human error was the root cause of many incidents leading to losses and damage. It was observed in all cases in the category "errors and omissions in transport documents or shipment instructions" (3.41%) – office staff failure, in 6.28% of "breaking cold chain integrity" cases – proven failure of drivers and seafarers, and in the majority of losses resulting from the "unsuitability of packaging, stacking and preparation of cargo for transit" – failure on the part of the producer, shipper, logistics operator, etc. Roughly speaking, human error may have given rise to as much as 50% of all examined losses/damage. Ignorance, lack of expertise, insufficient training of employees working in the cold chain, the negligence by persons involved in arranging and handling transit and other processes along the cold chain, overwork, lack of incentives, time pressure, and improper work organization, are just a few of the reasons that may underpin human error.

4. Conclusions

The increasing demand for food has intensified the global food industry, bringing about rising volumes of perishable food products being transported globally. Perishable food cargo is often a valuable freight, which may also give rise to higher exposures that should ensure extra care is taken by all stakeholders. Unfortunately, the study found that the number, volume and value of food losses across the cold chain is considerably high. Breaking cold chain integrity and failure related to the pre-cooling of cargo or a transport unit for transit, as well as human error, are the most critical factors leading to losses.

However, this study is not without its limitations. Primarily only the losses requiring examination by a surveyor to determine the cause of a loss were taken into account. Incidents such as cargo being washed overboard due to bad weather, fire, ship foundering etc. were not considered, which nonetheless did not impede the proceedings. Moreover, the sample was not large enough to draw far-reaching conclusions, and the study did not involve samples of claims from insurance companies or carriers (that research is currently underway). Yet in spite of those limitations, the nature of the problem was successfully highlighted and the factors posing a significant threat to perishable food cargo were identified, revealing the potential areas that need to be improved.

The most urgent of these is to raise awareness among all cold chain stakeholders with regard to the demanding and specific requirements of perishable food cargo,

pointing out in particular that even their minor breach may result in total loss or damage. Adequate training schemes, incentives for employees, proper work organization, investment in modern refrigerating facilities and equipment, better planning and management of cold supply chains – these are just some of the ideas that may prove very useful in reducing cargo losses and damage in cold chains.

Exposure to risk in cold chains should be properly addressed and managed, given that "globally, billions of USD are spent on improving agricultural processes to create higher food yields, but the fact that nearly half of all food never makes it to a consumer's plate is largely ignored" (Miller, 2016).

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