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A comparison of shipping containers from technical, economic and environmental perspectives

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ABSTRACT

This paper compares standard, reefer, and thermal liner containers for the long-range transportation of temperature-sensitive products. The thermal liner container is an alternative solution for maritime, rail and truck transportation between the dry and reefer containers. This study introduces a multi-criteria methodology to assess and compare alternative container solutions that involves technical, economical, and environmental perspectives. The proposed methodology is applied to four significant instances of maritime shipments, which highlight the performances of alternative container solutions in reducing the transport temperature fluctuations. Economic aspects and transport environmental impacts are also analyzed.

1. Introduction

In the food sector, the increasing public awareness of the benefits of healthier food has pushed the demand for agriculture products for year-around availability. Thus, global food supply chains are expanding to match seasonal food production and demand. The quality of such products is certified at the vendor dock (the production facility) but can be significantly affected by its transportation and other logistics activities. The consumer is seldom informed about the efficiency, safety, and sustainability of the process that brings the product from the vendors to the place of consumption (Manzini and Accorsi, 2013).

Despite their origins, food products travel globally, and may experience diverse climates, weather conditions, handling activities and logistics processes, including packaging, storage and distribution. The quality of these products depends on the manufacturing activities as well as the packaging, handling and transportation. Specifically, the role of packaging systems in logistics is central in the efficient management of any supply chains, and especially in the protection of product quality and shelf life, the compliance with standards and general rules, as well as concerns about environmental sustainability.

This study assesses the performances of freight container systems for long-range shipments. The increasing trend in global food distribution creates new challenges for shippers, importers, and logistics providers. Logistic managers and practitioners focus on choosing the proper distribution system, the transportation means, and the use of freight containers. This study highlights the effects of transportation processes on temperature-sensitive products that are not recognized as perishables by law. These products are usually shipped with reefer or controlled atmosphere containers, but sometimes in dry container equipped with a wide variety of insulating materials. The choice of the system depends on the limitations of the legal classification of products, which in turn depend largely on the water content of the product and its resulting interaction with the environment humidity and temperature. For example, regarding high-water content products, the

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cooling process is designed to inhibit the growth of decay-producing microorganisms and restrict enzymatic and respiratory activities during the postharvest period[1].

Given a particular product category, numerous alternative container solutions can be used to transport products, and these can have widely different energy and related greenhouse gas (GHG) emissions profiles. We use a multi-criteria perspective to choose the container system for long-range shipments that merges the concerns of the consumer (i.e., the quality of products), the importer (i.e., the profit), and society (i.e., the impacts on environment).

2. Container systems

Global transportation is based on the assumption that an undamaged, tightly closed container protects its contents from external influences, such as ice, snow, rain, salt spray, dust, thermal radiation, ultraviolet light and other conceivable environmental influences (Wild, 2012). However, many climatic and environmental stresses influence transportation, such as extreme temperatures or moisture, which can affect products and their packages. We consider the implications on the environment of three container systems.

- The standard container (SC), also referred to as a general-purpose container or dry container is suitable for the loading of general cargo, with the majority of cargo being shipped with 20-foot (TEU) and 40-foot equivalent units (FEU) containers. Standard containers protect goods from mechanical stresses and rainfall, reduce the influences of moisture, and enable handling by cranes.
- There are two main categories of reefer containers: porthole, which are not equipped with their own reefer systems but supplied with cold air, and integrated systems, which are equipped with a refrigeration system powered by an external source. TEU porthole containers consume an average of 1–2 kW, while integrated containers consume 3–6 kW. Over the last decades, integrated containers (RC), which we focus on here, have become increasingly popular (Wild, 2012), being widely adopted for the transportation of bananas, meat, citrus fruit, fish, and seasonal fruit.
- Thermal liner containers (TLC) are basic dry containers equipped with a thermal liner that can partially or completely insulate cargo from climate stresses. We focus on thermal liners based on multi-sheet heterogeneous films that consist of two aluminum foils selected for their lightness, ductility, strength, resistance to environmental stresses, and ability to protect from thermal shocks. The inner side of the liner consists of two polyethylene (PE) foils that, because PE is inert at environmental temperatures, does not encourage the growth of algae or bacteria. PE also has low thermal conductivity and high flexibility enabling it to absorb mechanical stresses during handling and transportation activities. A woven fabric core makes the liner sweat and avoids condensation enabling air circulation between the inner and outer sides of the liner.

3. Methodology

The indoor temperature profiles in maritime long-range shipments were tracked to measure the technical performance of the system. The tracking is based on *ad hoc* thermometers embedded on the product's carton, which trace the shipment from the vendor facility to the importer docks. The sensor is a self-sufficient system that measures temperature and records the result in a protected memory section. A mix of on-field data and prior information is used to capture the economic performance associated with the shipping operations. The environmental performance results by a life cycle assessment (LCA) methodology that estimates the carbon footprint of the alternative container systems during one shipment from a vendor to the importer dock (Fig. 1).

The tracked shipments were selected based on the ports of origin and destination, the season of the year, and expected temperature stresses (e.g., shipments across the equatorial belt). Two sensors[2] per container recorded the temperature each hour between -40 °C and 85 °C and were placed at the middle and the top of the pallet. Tracked profiles are the average of the data from the two sensors. The sensors were collected at the destination port. The tracking specifically involved dry and insulated containers, taking the reefer container as the benchmark; it is assumed that the reefer container (RC) maintains a set temperature for duration of the shipment. Both containers were stowed on the upper deck and stacked in the middle to reduce the influence of direct radiation and to ensure well-ventilated conditions. The temperature profiles are for the assessment of alternative container systems from technical, economic, and environmental perspectives.

4. Tracking

The tracking involved four shipments of bottled olive oil and wine, which departed from Italian ports for North America and the Far East. Table 1 shows the travel characteristics.

[1] For some examples of the link between the choice of containers, their handling and transportation and the quality and shelf life of food products, for edible oils see Tsimis and Karakasides (2002) and Valli et al. (2013), for wines see Robinson et al. (2010), and for fish Margeirsson et al. (2012).

[2] Each sensor integrates a 1-wire transmitter/receiver, a globally unique address, a thermometer, a clock/calendar, a thermal history log, and 512 bytes of additional memory to store user data, such as a shipping certificate.