Cold chain management during transport operations of perishable food in Mexico

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This paper aims to identify how cold chain management is provided throughout the transportation of perishable food, as well as the role of the experience and working conditions of drivers in perishable food transportation. It draws on survey data collected from Mexican perishable food carriers with headquarters in six major cities. The results show the characteristics of the vehicles used to transport perishable food by Mexican carriers and the cooling technologies utilized by vehicles carrying different types of meat. Further, the results elucidate the work experience and training of drivers handling perishable products and problems related to cold chain transportation as a major strength, while weaknesses were those reported with loading delays and lack of widespread wireless system implementation for temperature registration. It also provides one of the first pieces of information on Mexico's foodstuff transportation system, with the aim of designing strategies for better cold chain tracking during transportation, as a key factor in food waste reduction. It is necessary to incorporate a greater number of participants from other geographical areas of the country in order to get a more detailed overview and to determine similarities and differences between regions. This study provides baseline information for the development of appropriate logistics strategies in cold chain management.

Keywords: transportation logistics, food quality and safety, Mexican cold chain management, developing countries

THE COLD CHAIN IS A PHYSICAL process that dominates the supply chain logistics of processed foods, and its integrity must be preserved from the point of production or processing, all the way through each of the transport phases: loading, unloading,

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handling, storage, and, depending on the situation, even retail. It is reported that within developing countries, the cold chain must extend into locations with greater challenges in terms of economies of scale (Salin and Nayga, 2003). The food supply chain (FSC) includes activities such as storage, domestic and/or international transport, local distribution, and retail of final products (Likar and Jevšnik, 2006). Cold chain management (CCM) in the FSC shows several problems at different stages throughout the chain, including quality and safety of perishable food through transportation. Technologies such as IoT (internet of things) and software have been reported as powerful tools for e-tracing information exchange between FSC actors. The EPCglobal (electronic product code), based on IoT, RFID (radio-frequency identification), and WSN (wireless sensor network), is used to support FSC, in order to reduce tracing time and overlapping of tracing systems (Chen, 2015). A product traceability system requires the identification of all the physical entities and locations of the food product, including every agent in the supply chain (Regattieri et al., 2007).

Enterprises sustain economic losses due to spoiled food during transportation and storage, as well as withdrawals of food products of short shelf life (Rossaint and Kreyenschmidt, 2014). Accordingly, temperature is recorded as an important parameter in food safety and quality and any changes during the logistics process may cause spoilage and loss of flavour (Ovca and Jevšnik, 2009; Montanari, 2008). The food industry, in order to achieve performance improvements across many business levels, has built global partnerships and directly supports its suppliers through collaborative practices with them. Hence, collaboration has increased, among and across the entire agri-food supply chain. Some barriers are also recorded as limits to collaboration capacity; most of them are related to the agri-food industry's complexity and heterogeneous structure (Matopoulos et al., 2007). Therefore, transportation of food products, especially those related to meat, becomes the significant link through the supply chain. It is also registered that the most effective preventative controls to increase the safety of perishable food transportation are related to incorrect handling of perishable meat products (Rossaint and Kreyenschmidt, 2014). Current activities related to transport operations have been given minor importance in the current focus on managing uncertainty within the food supply chain (Stank and Goldsby, 2000). Moreover, there is a significant demand for more flexible transport services in order to meet market requirements. Thus, logistical participation that involves carriers, processors, and wholesale and retail enterprises of food products is required (Naim et al., 2006). Among these considerations, the keystone is the hiring of safety-conscious drivers by the safest food enterprises (Savage, 2013).

Literature reviews/research

Due to the presence of strict traceability requirements from customers, the specific requirements of each food product, and the demand for temperature control in the supply chain, it is both challenging and crucial to practise cold chain management (CCM) (Raab et al., 2008; Tsironi et al., 2008). Additionally, demands for value-added food imports have grown rapidly in Mexico with the

introduction of the food supermarket distribution systems. Therefore, CCM is required in order to maintain quality and safety and extend the shelf life of most value-added food products. The Mexican supermarkets, typified as a large, diverse, and accessible market, have the duty of completing the critical link in the cold chain that enables value-added food products from Canada and the United States to be exported to this market. However, efficient logistics and transportation are critical to the competitiveness of food for both domestic and exporting suppliers (Prentice and McLachlin, 2008).

According to a survey conducted in 2006 (Morales and De la Torre, 2006), refrigerated food carriers in Mexico were distributed as follows: 62 per cent were trucks owned by one person; 29 per cent owned by small companies (2–4 trucks); 6 per cent owned by medium-sized companies (5–10 trucks); and 3 per cent owned by large companies (over 10 trucks). There was a clear preference for two semi-trailer axle trucks, adapted to the transportation needs of different kinds of perishable foods in Mexico. Food distribution services were at local or regional level in Mexico City, Monterrey, and Guadalajara. The 38 per cent of the refrigerated fleet is registered in the northern part of the country. Morales and De la Torre (2006) also indicated that Mexican refrigerated carriers transport different types of perishable food: meat, seafood and fish, and fruits and vegetables. Besides these foodstuffs, they also transported medicines and raw materials for some chemicals that require specified temperature ranges. These companies had implemented training programmes in order to reduce the risks of handling the products. The cost and quality aspects of the services provided can be enhanced by proper management and logistics training of the local staff. This finding on the need for management and logistics training is consistent with previous studies (Vanden Bloomen and Purvanov Petrov, 1994).

In addition cold chain management failures were also described in Mexico. Technical issues and a frequent and continual operating risk of a refrigerated delivery truck having more than 10 deliveries on its route, where the door is opened and closed with environmental temperatures of more than 25ºC, resulted in frequent breaks in the cold chain (Prentice and McLachlin, 2008). Most refrigerated transport operations started on the northern border, specifically in Nuevo Laredo, Tamaulipas, Mexico and from this point, to the rest of the country. The exporting and importing activities took place mainly on the border towns of Nuevo Laredo and Reynosa, Tamaulipas, Mexico that made the north-east of Mexico the major port of entry and departures. These refrigerated units are traced by global positioning system (GPS) and enterprises had ongoing training programmes for drivers in proper management of these refrigerated units (Morales and De la Torre, 2006). Besides it is also mentioned by Ta et al. (2000), that logistics and transportation are closely related to a country's economic development. An early study by Fawcett et al. (1995) indicated that most Mexican facilities were often equipped with older, less technologically advanced machinery, while only a few enterprises had used modern equipment in their facilities and operations. In reference to transportation operations, the demands of professional drivers are largely predetermined. However, the importance of a culture of organization as well as job duties is clearly indicated for safe driving and traffic safety (Öz et al., 2010). Thus, the paper aims to identify how CCM is provided throughout transportation of

perishable food, as well as the role of drivers, as pertaining to their experience and working conditions.

Research methodology

During 2012–13 there were a total of 102 Mexican, registered, perishable food carriers with headquarters in six major Mexican cities shipping or receiving food products. The study was made in five northern border cities: Nuevo Laredo, Juarez, Colombia, Tijuana, and Mexicalli; and in Mexico City. The survey had four main segments: 1) related to drivers: work experience, training courses, duration of transport routes, and associated work problems, 2) vehicle characteristics and cooling-freezing technologies; 3) goods being carried, shipment frequency and length; and 4) characteristics of enterprises and carriers (Raab et al., 2008).

Of the 102 Mexican carriers, 71 (69 per cent) returned the questionnaires. Eighty per cent of the sample was located in the north of the country, and the cities with a response rate of 50 per cent or more were Nuevo Laredo and Mexico City. A direct method of standardization was used to reclassify categorical variables according to the number of completed answers in order to obtain a rough comparison of proportions. In addition to a general proportion distribution of specific answers, analysis of the categorical answers per question, a crossover study between carrier characteristics and cold chain transportation conditions is supplied. The exploratory analysis was made using Rattle version 3.3 as the main statistical tool (Williams, 2011).

Findings and discussion

The first analysis was performed on education level and driver work experience. Forty-nine per cent of drivers finished secondary schooling, no more than 13 per cent had a college degree, and around 38 per cent finished elementary school. Distribution of drivers based on time as refrigerated truck drivers indicated that 29 per cent had between 5 and 10 years' experience, and 27 per cent had less than a year. However, 6 per cent had more than 15 years' experience (Table 1). It should be noted that of the 96 per cent of drivers reported to have training in operating transport trucks, 90 per cent answered that they were trained for performance with

Table 1 Work experience of Mexican drivers transporting perishable food

Years	*Proportion of respondents (%)*
<1	27
1–3	15
3–5	12
5–10	29
10–15	11
>15	6

Table 2 Some identified problems during cold transportation of perishable food

Problem	*Proportion of respondents (%)*[1]
Delays in loading and unloading activities	80
Robberies and assaults	66
Long waiting times for processing of papers	59
Extortions	51
No cash money for road breakdowns	48
Numerous checkpoints	45
Inadequate capacity of the unit	41
Lack of assistance from enterprises	37
Poor condition of roads	35
Lack of toilets and resting places	27
Deficiencies in cooling system	23

Note: [1] More than one option was available

cooling equipment, and 11 per cent reported having appropriate training in safe handling of frozen and refrigerated foods.

The statistical analysis has substantiated the associated problems expressed by drivers of cold food transportation. The 11 principal problems are indicated in Table 2. Of the four main problems registered by more than 51 per cent of respondents, two of them were associated with administrative and operational management, and the others were correlated with social and security problems. The flow of food within the CCM shows that the highest problem dealt with delays of loading and unloading foodstuff (80 per cent), followed by personal security and robbery issues (66 per cent), and finally delays by pending documentation and corruption issues, 59 per cent and 51 per cent, respectively. The rest of the problem variables were associated with lack of enterprise support, excess of checkpoint inspections, road deficiencies, and lack of restrooms and rest areas. It is important to notice that deficiencies in cooling systems represented the least mentioned problem among the presented options. Accordingly, Sanchez-Rodrigues et al. (2008) indicated that it is crucial to determine the root problems in transport operations, and precisely codify and analyse their causes according to level of risk, in order to improve the management efficiency of the supply chain. On the other hand, exogenous events can also cause disruptions in the supply chain, and they can lead to disturbances in the stability of the cold chain of perishable food during transportation. Thus risks in food safety may increase (Peck et al., 2003), as the same diverse exogenous problems showed in this study.

The results indicated that 72 per cent of the interviewed persons reported transportation times normally longer than 8 hours. Additionally, 21 per cent of the carriers reported a trip length within 5 to 8 hours. The most employed temperature measurement systems were thermocouples (53 per cent). For smaller distances (less than 5 hours) the use of mechanical temperature recorders is not common;

however, resistance temperature sensors and thermocouples are jointly employed. Ninety-two per cent indicated having daily shipments, 7 per cent weekly, and only 1 per cent several times a month. The findings also showed that 37 per cent of these trips were carried out by two drivers (separate shifts); however, 31 per cent of respondents only reported trips by one driver; 21 per cent reported that occasionally two drivers were assigned; and 11 per cent reported that two drivers were rare. The number of drivers per trip shows differences in distribution depending on the cooling technology the vehicles use. One driver is twice as frequent for cooling system vehicles (45 per cent) as for those with cooling technique (22 per cent). The opposite relationship is observed in the answers reporting rarely or occasionally two drivers (19 per cent and 41 per cent, respectively) for vehicles employing cooling technique. There are no considerable differences in the proportions of cases where two drivers (shift) are always used, independently of the cooling technology used by the vehicles.

Sanchez-Rodrigues et al. (2008) proposed a model that comprises five uncertainty sources that can have a negative effect on transport operations: 1) point of loading and unloading of goods; 2) delivery restrictions of the receiver; 3) reliability issues with carriers such as malfunction of the transport units or insufficient drivers; 4) lack of control systems and quality of information and communications (ICT) systems in logistics operations; and 5) all those external problems of uncertainty that are not under the control of the supply chain such as road congestion and fuel prices. These five uncertainty sources were also identified in the survey applied in our study: all of them clearly show negative impacts in transporting operations of the cold chain in supply chain management (SCM). Sanchez-Rodrigues et al. (2010) emphasize the importance of measuring the probability of occurrence and risk level of food supply chain uncertainties during food ground transportation. Uncertainty occurs when the outcome of an event or the probability of its occurrence is not estimated. However, uncertainty, as a consequence of external and internal uncertainties, increases the total risk within supply chains when individual risks are functions of outcome and probability (Van der Vorst and Beulens, 2002).

Another important factor to take into account is the length of transportation routes and type of transport units used. In this case it is pertinent to point out that Mexican cities important to trade are concentrated towards the middle of the country, thus it could explain the load-size and the distance covered on individual trips. In contrast, Raab et al. (2008) registered that most German pork and poultry products are transported 500 km or less. Most perishable foods are transported by road because of two main reasons: the first reason is related to the time factor involved and the possibility of foodstuff deterioration; and the second reason is associated with the flexibility of offering door-to-door deliveries (Blauwens et al., 2002).

Regarding food and foodstuff transportation in Mexico, 70 per cent is transported either in heavy or in medium vehicles. Of those, 49 per cent use heavy vehicles (>30 t), with 16–18 m cargo space for the cooling area, and 21 per cent use medium vehicles (6–30 t) with 10–15 m cargo space for the cooling area. Additionally, 20 per cent of respondents indicated that both medium and heavy vehicles were utilized.

Table 3 Vehicle characteristics used to transport food by Mexican carriers

Vehicle/Size/Cooling Area	*Proportion of respondents (%)*
Heavy (>30 t) (16–18 m cargo space)	48.6
Medium (5.5–30 t) (10–15 m cargo space)	21.4
Medium and heavy	20.0
All kind of vehicles	7.1
Light (<5.5 t) (<10 m cargo space)	2.9

Table 4 Cooling technologies used by Mexican vehicles carrying chilled/frozen meat

Technology	*Proportion of respondents (%)*
Cooling technology (controlled atmosphere)	53
Vehicle cooling system or container cooling system	44
Cooled truck combined with separated passive cooling by insulated boxes	3

Lastly, less than 3 per cent of carriers used light vehicles (<6 t) with less than 10 m cargo space for the cooling area, and 7 per cent used all kinds of vehicles (Table 3).

The analysis of our study has revealed that controlled atmosphere and vehicle cooling systems were used as the cooling technology, while only 3 per cent reported cooled trucks combined with passive cooling (Table 4). Within enterprises that based their transportation on controlled atmosphere, 78 per cent relied on thermocouples to monitor temperature, while for transportation made with vehicle cooling systems, 71 per cent used resistance temperature sensors for temperature monitoring. Rodríguez et al. (2011) and Raab et al. (2011) reported that temperature abuses and related reductions of food quality and safety are often caused by failures in the cooling system or during the loading and unloading of trucks A parallel study indicates that perishable products continue to be particularly sensitive with regard to on-time reliability (Patterson et al., 2008). Furthermore, Rossaint and Kreyenschmidt (2014) proposed the application of intelligent packaging with time-temperature indicators, in order to decrease the amount of food waste because of improper storage or missing information. Thus, to perform a quality evaluation, there is a need for cold chain data to be registered efficiently (Giannini et al., 2001).

Mai et al. (2010) reported that time-temperature records from using radio frequency identification (RFID) tags coupled with a temperature sensor could be used as evidence about the compliance or non-compliance of product handling conditions. However, one of the disadvantages of using the RFID-technology is the rather high cost of investment in suitable equipment, and only high added value of product can compensate for that significant investment cost (Storøy et al., 2008). Therefore the real-time logistics information for transportation tracking and management and food quality traceability can be provided, by incorporating mobile technology along the supply chain (Kuo et al., 2010). Small interruptions

in the cold chain can also lead to a significant reduction of shelf life (Bruckner et al., 2012), and food quality reduction represents an irreversible and cumulative factor, as a factor in the time–temperature history of the product (Wang et al., 2010). Consequently, the importance of maintaining rigorous control of product storage conditions, in order to have a product in optimum condition, is emphasized (Kreyenschmidt et al., 2010; Ovca and Jevšnik, 2009). Therefore, controlled CCM is taking on a key role, and, as a result, inter-organizational CCM systems are becoming more and more important and complex as the food supply chain turns to a more heterogeneous structure. Thus, increased cooperation among participants is one of the main challenges to be met (Eden et al., 2011; Montanari, 2008).

Seventy per cent of the carriers were not specialized in meat only, they transported a large range of products (vegetables, fruits, canned goods, confectionery, non-alcoholic drinks, drug products, fertilizers, and minerals); 30 per cent carried only meat. In the case of this study, when the analysis was restricted to only meat transport, cooling and freezing areas were employed jointly (62 per cent) more frequently than separately. Chilled meat (91 per cent) was reported as transported weekly, beef being the type of meat with the highest frequency (32 per cent), followed by poultry (30 per cent) and then pork (Table 5). The food transporting criterion most employed was daily batches (31 per cent) and some combination with it. Within the longest average transportation time cases, daily batches were the most frequently observed criterion for transportation (55 per cent). This criterion was never used for transportation times lower than 5 hours. When the analysis is restricted to medium transportation times, daily batches without sorting classification are equally employed criteria. Together, they represent more than 80 per cent of cases.

In the framework represented by Raab et al. (2011) there are a variety of aspects that could affect all cold chain participants. For an accurate approach to CCM, incorporating additional information about the characteristics of perishable products is relevant. It is also known that the use of temperature measuring aspects is beneficial since temperature acts as a product quality control parameter, and the capacity to measure the impact can justify the change of a certain procedure or parameter (Rodríguez et al., 2011). The system integrated RFID with GPS, and mobile communication with time temperature tolerance (TTT) theory was developed by Zhang et al. (2009) with a temperature-managed traceability system for frozen and chilled food during storage and transportation. This system might increase the flow of information in real time among all parties involved (managers, drivers, stakeholders), sharing any

Table 5 Type of meat and percentage of chilled and frozen meat transported in the unit on a weekly basis

	Proportion of respondents (%)		
	Chilled	*Frozen*	*Total*
Pork	30	4	33
Beef	32	3	34
Poultry	30	1	33

unexpected delays. An equally important piece of information is the knowledge of temperature monitoring systems within all stages of the supply chain, in order to solve temperature-related problems. Monitoring the cold chain with radio frequency-based technologies can support continuous monitoring and control of the temperature throughout the entire supply chain (Kreyenschmidt, 2008).

Additionally, Rodríguez et al. (2011) emphasized that transit route times and equipment maintenance are difficult issues in Mexico, thus cold food transportation and the temperature control of the equipment has to be constantly checked on the route (Prentice and McLachlin, 2008). Therefore, training programmes developed by enterprises play an important role as prerequisites to be set up in the daily business routine (Olsson, 2004). Nevertheless, training courses for a global CCM system should include aspects such as measurement equipment use and measurement procedures, as well as knowledge of food characteristics (Raab et al., 2011). For this purpose, quality assessment methods are recommended by Aung and Chang (2014), regarding the management of product quality in a cold chain that is based on the presence of product metabolism changes and distance costs over temperature fluctuations.

This study also provided information on the type of registered transport logistics services that carry perishable food; respondents were asked to indicate the type of agency to which they belonged. They indicated three different types of transport logistics agencies: 56 per cent reported being contracted transportation agencies, with an individual fleet to cover all transport segments; 23 per cent of respondents had partial transportation for receiving enterprises' foodstuffs, but they also required the services of a contracted transportation agency; finally, 21 per cent were importing agency services. The latter were mostly used for meat carriers only (71 per cent), but never used when meat and other types of food products were transported. However, contracted transportation logistics service agencies were used less for meat-only transportations (10 per cent) in comparison to meat and other types of foodstuffs (29 per cent). Resistance temperature sensors and other methods not including thermocouples were the preferred instruments to measure temperature (62 per cent) for transportation agencies. Importing agencies were relatively small (7 per cent). All drivers belonging to importing logistics agency services (100 per cent) were restricted to meat transports only; otherwise, about 89 per cent of carriers were related to meat and other types of products.

It is stated that carrier performance evaluation systems used by logistics services also need further examination (Brooks, 2000). Security implementation differences and corresponding performance implications are different between firms with globally oriented supply chains and those with domestic supply chains. In general, those with global supply chains may be more likely to ensure the security procedures of supply chain partners. That means that the food industry could be more attuned to the importance of food safety than other industries due to recent contamination incidents and the effect on consumers' purchasing habits. In order to determine a relation between the supply chain and the sustainability of transport operations, McKinnon (2007) established a framework with six sustainability ratios linked to

supply chain processes that can be influenced by uncertainty in freight transport at the operational level. These ratios are correlated with the number of links in the supply chain, average length of the route, modal split, average load on laden trips and empty running, and fuel efficiency. Although it was reported that this variation was attributable to differences in the nature of the distribution operation as well, it is also recommended in this study that enterprises could achieve significant improvements in transport efficiency by emulating current best practices within the specific subsector. Bogataj et al. (2005) indicated that food safety regulations include product temperature control along the supply chain, tracking of air and product temperature in refrigerated vehicles, loading–reloading points, and verified standardized equipment. As indicated in this study, external factors contribute to delays and failures in the cold chain of perishable food. Sanchez-Rodrigues et al. (2010) also indicated that length of routes, handling factors, average load when laden per trip, and empty running were reported as the predominant causes for delays and delivery constraints next to traffic flow, which represents the biggest single issue leading to uncertainty in food transport operations. Besides, as Winter and Knemeyer (2013) pointed out, SCM continues to expand, and research must continue to find ways to support enterprises' efforts to proactively achieve sustainability in the food supply chain.

Conclusions

To achieve sustainable food chains in Mexico, this research addressed the types of transport services and detailed the categories of logistics service transport agencies that operate within the national territory, as well as distances and duration of travel used for food cooling transportation. Additionally, driver educational background and work experience, as well as the various problems drivers experience, are described. An inter-organizational CCM system is becoming more important and complex as the food supply chain develops a more heterogeneous structure. Logistics problems must be approached within the local context of major technical and social problems. Staff training becomes one of the most important factors, in order to improve their performance throughout the food supply chain. Another relevant issue found in our study is the fact that the economic value of perishable food significantly depends on an appropriate and accurate CCM throughout transportation operations; therefore, it is also necessary to consider that transfer points are the weak links to preserve the safety and quality of food products. The above considerations are related to the long duration of Mexican food transport routes coupled with multiple deliveries, which may lead to a decrease in the economic value of food.

To the extent that Mexican enterprises responsible for perishable food transportation may resolve their internal and external problems related to CCM, they have the possibility of operating harmoniously in all transport situations with modern technological systems for cooling and temperature measurement. Furthermore they will also be able to integrate the assessment management and data on changes in temperature, in order to provide precise and reliable information on the remaining

shelf life. It is necessary that transporting enterprises are able to register and transfer this relevant information on time, in order to accurately estimate the probability of the occurrence of internal and external events that significantly affect the stability of the cold chain for perishable foods during transport. With regards to research, it provides updated and accurate information for designing strategies to be applied for a better cold chain tracking during food transportation. However, it is clear that more research is needed that includes more participants from other geographical areas of the country, thereby expanding the sample size, and developing a comprehensive database of how perishable food is transported in Mexico. This will help improve the performance of logistics operations, and consequently the quality, safety, and value of food in Mexico.

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