

Research on quality control system for cold-chain road transport

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Abstract. The prime aims of the cold-chain transportation quality control are to guarantee that the temperature control is uninterrupted, the quality of the goods is intact, and to prevent "chain breaking" which constitute the greatest threat to cold-chain transportation. As per the requirements of Hazard Analysis and Critical Control Point (HACCP) management system, this paper analyzes the quality hazards in all aspects of the cold-chain transportation operation covering personnel, equipment, environment, method, material, and test; and clarifies the quality control objects, the key control points and control measures of cold-chain transportation, to build a road cold-chain transportation quality control system.

Introduction

Cold-chain transportation features an important mode of transport to ensure product quality and reduce circulation loss, therefore its quality implicates food safety, agro-product circulation and other important areas. At present, the management and operation of cold chain transportation in China are not yet standardized, featuring low quality of transportation and the serious phenomenon of "chain breaking", resulting in huge waste. Therefore constructing a quality control system for cold-chain road transportation with specified key quality control points and control measures is of great significance for optimizing the operation and improving the quality of cold-chain transportation, and ensuring the quality of the goods.

Methodology related to cold chain quality management

In terms of cold chain quality management, based on the analysis of the connotation and realization conditions of the cold chain, scholars at home and abroad have applied the relatively mature theory and methods, such as the HACCP system, Six Sigma (6σ), supply chain management, and comprehensive system intervention in cold-chain logistics, to direct its quality management.

Among them, a mature system is HACCP, which is an internationally accepted system of food safety assurance that ensures the safety of food in the process of production and distribution, and has mature and systematic methods in hazard identification, evaluation and control. HACCP includes seven basic elements: (1) hazard analysis; (2) identification of critical control points; (3) establishment of critical limits for each critical control point; (4) monitoring of critical control points; (5) corrective actions; (6) record keeping procedures; (7) self-verification process. The essence of HACCP system is to eliminate possible hazards in the process of production and circulation. Some scholars apply HACCP's preventive thinking to cold chain quality management to analyze the hazards that may pose a threat to the safety of perishable food in the logistics process, with a view to controlling the critical points and taking preemptive measures to prevent the occurrence of the hazards. For instance, Zhao Yanyan et al. classified cold-chain logistics as per its basic functions into procurement, acceptance inspection, loading & unloading and handling, transportation, distribution, storage, sorting and other links, which are subject to hazards analysis and critical control point determination from the biological, chemical, and physical standpoints to ensure the quality and safety of fresh agro-products.

In view of the scarcity of current research on the quality control of cold-chain transportation, the HACCP system thus has certain reference value. However, the HACCP system focuses on the control of the operation process and takes less consideration of management and other factors. The construction of the quality control system for cold-chain transportation should also be comprehensively analyzed at various levels.

Objectives for road cold-chain transport quality control

In recent years, under the dual stimulation of policies and markets, cold-chain logistics saw rapid development in China, the gradual improvement of its infrastructure, the step by step expansion of its market scale, and the continuous innovation of its business models have played an important role in meeting residents' multi-level consumer demand and ensuring food safety. At the same time, the development of cold-chain transportation in China started relatively late, compared with the market demand and the level of developed countries, it still has many shortfalls encompassing low market share of cold-chain transportation; inadequate R&D and innovation of technology; insufficient input for facility and equipment (plus non-standard use); delayed development of third-party professional cold-chain logistics; and imperfect regulatory standards and supporting policies. One of the most prominent problems in the cold-chain transportation is the non-standard transport operations resulting in serious "chain breaking". At present, many enterprises are still using ordinary vehicles with quilts, refitted vans, and phased-out shipping refrigerated containers for cold-chain transportation, which cannot meet the temperature requirements of goods. Other problems include loading and unloading in the open space; rough estimation of the quality of goods based merely on smell or the degree of melting without strict acceptance criteria; the absence of temperature monitoring equipment and the lack of appropriate monitoring measures; and even worse, the artificial shut-down of refrigeration equipment for the mere purpose of saving oil. These problems have seriously affected the quality of cold-chain transportation, and can by no means guarantee the quality of goods.

A good cold-chain transportation must ensure the quality and safety of goods, therefore, the most important objective of quality control of cold-chain transportation is that controlling the temperature, sanitation and working time in the whole process of transport so as to ensure that the cold chain is not "broken" and that the goods are delivered to their destination in good quality.

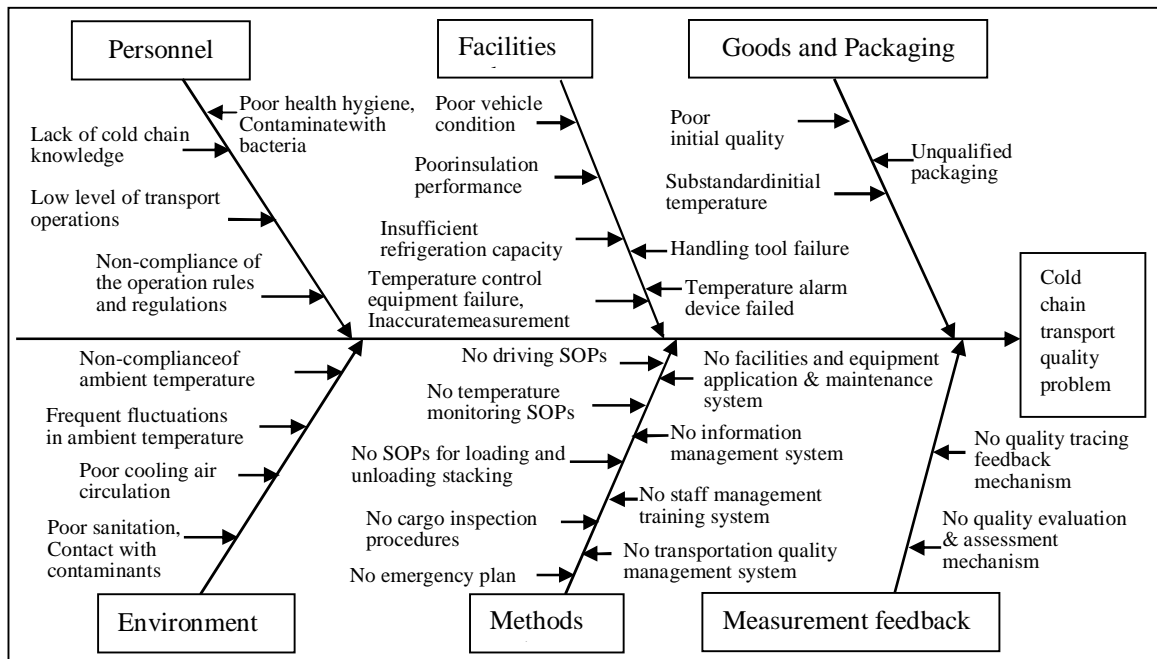


Fig. 1 The 5M1E Analysis for quality factors of cold-chain transportation

Analysis of Quality Hazard in Road Cold-chain Transport

The influence of the above factors over the quality of the cold-chain infiltrates in all links of the transport, therefore the analysis of the potential quality hazards and their causes in each link helps to develop measures to optimize the operation process, to effectively reduce the direct impact of unfavorable factors in the facilities and equipment, goods and packaging, environment and other aspects, and improve the methods and systems. Quality control in each link of transport operations is an important part of the quality control of cold-chain transportation process, which generally includes

the following major links: business acceptance, preparation before loading, loading, transport, delivery and unloading, and in addition, temperature monitoring and record keeping also features an important part of transport operations and runs through the whole process. As per the requirements of HACCP management system, all links in the whole process of cold-chain transportation are subject to hazard analysis to sort out potential quality hazards in each link (see table 1).

Table 1 Major links and potential quality hazards in the cold-chain road transport

Transport links	Potential quality hazards and their causes
Business acceptance	Wrong information and arrangements in this link may lead to a series of deviations in subsequent work.
Preparation before loading	Improper selection of means of transport can not meet the temperature requirements of the goods, resulting in deterioration.
	Where equipment inspections are not in place, un-qualified equipment may be used for transportation, resulting in quality problems such as vehicle failure and accident due to poor vehicle conditions; incapability of maintaining low temperature environment due to failure of the refrigeration unit; incapability of timely temperature control due to temperature control equipment failure; and cross-contamination of the goods due to poor sanitation within the carriage (container), and the temperature control equipment in direct contact with the goods.
	Where cargo & packaging inspection is not in place, goods with unqualified initial temperature and spoilage may be put into the transport, contaminate other intact goods, and expand the scope of spoilage. Weak packaging with leakage and breakage entails impurities and other damage to the goods.
	If the carriage is not precooled, the cooling effect may not be able to meet the requirement, and the carriage cannot maintain appropriate low temperature, resulting in the spoilage of goods.
Loading operation	Excessively high temperature of loading environment and overlong working time can cause fluctuations and rise in cargo temperature, leading to the deterioration of goods.
	Instable cargo stacking will result in dumping, damage and other hazards. Mixed stacking of smelly goods, polluted goods, and goods with different temperature control requirements without zoning cannot guarantee the sanitation and temperature of the goods, leading to spoilage. Not enough clearance between cargo piles may lead to poor circulation of air-conditioning, resulting in local hot zone and temperature rise in some cargo.
transport	Vehicle failure, traffic accidents, congestion, and extreme weather may cause prolonged transit time, resulting in deterioration of the goods; refrigeration system failure, man-made closing cooling equipment cannot maintain low temperature then lead to deterioration of the goods. In the event of a major accident, the goods maybe dumped and damaged, and the packaging maybe damaged by external pollution.
Unloading delivery	Improper discharge time and environmental control, resulting in temperature fluctuations affect the quality of goods; unloading improper operation, packaging damage may cause the introduction of impurities contaminated goods; cargo inspection is not in place, may lead to quality disputes.
Temperature monitoring	Temperature control equipment failure may result in temperature inaccuracy, the inability to realize whole-process monitoring and early warning, handling to minimize losses. Unreasonable selection of temperature measurement points may cause the incapability of accurate measurement of local temperature and the loss of monitoring.
Record keeping	Where record keeping is incomplete, quality supervision, evaluation and traceability are short of evidence, problems are difficult to find and disputes would arise.

Quality control system for cold-chain road transport

According to the analysis of the quality influencing factors of cold-chain road transportation and the hazard analysis of each link of transportation, this paper puts forward a quality control system for cold-chain road transportation, as shown in Table 2. The control system mainly includes four aspects: the control layers, the control objects, the critical control points and the control measures. The control layers include: facility and equipment control; operation process control, mainly for control of direct factors such as facilities, equipment, goods, packaging and environment; transportation management control, mainly for control of personnel, system and operation rules, quality evaluation and other factors. Each layer clarifies the objects to be controlled and their critical control point, for which control measures are set.

Three layers are controlled simultaneously with mutual influence and combined effect over the quality of cold-chain transportation. Operation process control involves every transport mission and

is thus a direct control over the quality of the transport. Each operation is a repeated practice controlled by the operation process layer, which is the optimized management of the details of each operation, ensuring the standard operation of each step and effectively preventing the hazards of facilities, equipment, environment, goods and packaging due to human negligence. The effective operation process control depends on the daily improved facility and equipment control and management control, which runs through the day-to-day operation of the entire transport enterprises. The effective routine inspection and maintenance of well-conditioned facilities and equipment form the basic conditions for high-quality, high-efficiency transport operations. Layer of transport management control, as a basic guarantee, effective supervision & implementation mechanism for the infrastructure and equipment control and operation process control, is an indirect transport quality control that provides reliable staff, method, system and management tools for all transport-related activities.

Table 2 Quality control system for cold-chain road transport

Control layers	control objects	Critical control points	Control measures	
Facilities and equipment	Transport vehicles	Vehicle condition	Regular inspection and maintenance.	
		Refrigerating unit	Regular inspection and maintenance.	
		Insulation structure	Regular inspection and maintenance.	
		Air circulation system	Regular inspection and maintenance.	
		Sanitation situation	Regular cleaning and disinfection.	
	Loading and unloading places	Sanitary condition	Regular cleaning and disinfection.	
		Low temperature environment	Set a closed loading and unloading platform or use connecting devices for door-to-door connection.	
	Loading and unloading tools	Technical condition	Regular inspection and maintenance.	
		Sanitation situation	Regular cleaning and disinfection.	
	Temperature control equipment	Performance parameters	Ensure that all functional parameters meet transportation requirements.	
		Technical condition	Regular inspection, calibration and maintenance.	
		Sanitation situation	Regular cleaning and disinfection.	
		Over-temperature warning device	Regular inspection and maintenance.	
	Operating process	Business acceptance	Clarify information	Verify cargo information and transport requirements.
			Develop transport plans	Set plans according to the number of goods, characteristics, delivery and reception place and time, temperature requirements etc.
			Selection of means of transport	The selection of means of transport is based on the temperature requirements and <i>GB/T 22918</i> .
Preparation before transportation		Vehicle inspection	Check the vehicle condition, sanitation, and refrigerating units, to ensure that the cooling and defrosting systems are normal; there is no frost inside the carriage; and the heat insulation wall and door are intact.	
		Temperature control equipment inspection	Check the temperature control equipment for technical condition cleanliness and adequate power.	
		Pre-cooling	Pre-cooling of the carriage shall ensure that the door is secured.	
		Packaging inspection	Check the packaging for damage, spillage, leakage, and contamination; and the compliance with the requirements for packaging size, materials, sanitation and labeling etc.	
		Cargo inspection	Check the cargo center temperature with reference to <i>GB/T</i>	

Control layers	control objects	Critical control points	Control measures
			28843 and <i>SB/T 10928</i> ; consult with the consignor for solutions of problems found, and make detailed records.
	Loading	Loading environment	It is advisable to keep the environment closed at a low temperature; shut down the refrigerating units when loading; monitor the temperature in real time; close the car door after loading; check the airtight condition, and then restart the refrigeration unit.
		Loading time	Use loading tools as fast as possible, and strictly control the loading time.
		Stacking method	Gently handle and stack the goods in designated zones to avoid cross-contamination. The stacking shall not block the air outlet and return air inlet, and shall not exceed the maximum load limit line, to maintain adequate circulation space for air-conditioning. For stacking rules, see <i>GB/T 22918</i> . Use fixing device to prevent the goods from displacement.
	Transport	Transport time	Do not stay on the road for a long time; repair the vehicle as soon as possible at an accident or failure, or take measures according to emergency plans.
		Transport environment	Temperature real-time monitoring.
		Transport safety	Drive smoothly to reduce turbulence and vibration.
	Unloading delivery	Unloading environment	It is advisable to maintain a closed environment at low temperatures, turn off refrigerating units during unloading, and perform real-time temperature monitoring.
		Unloading time	Use unloading tools as fast as possible, strictly control the operation time limit.
		Cargo inspection	Deliver temperature records, randomly check product packaging and temperature, handle problems found in inspection as per the contract via the signature and confirmation of both parties.
		Post-delivery processing	Cleaning and disinfection of means of transport
	Temperature monitoring	Real time monitoring	Confirm the temperature control requirements, deploy temperature control equipment for real-time monitoring of the ambient temperature, whose sensors shall not be in direct contact with other objects. Cargo temperature can be subject to real-time monitoring upon agreement, if any.
		Layout of temperature measurement points	Refer to <i>GB/T 28843</i> .
		Over-temperature warning treatment	Immediate check shall be performed upon over-temperature warning, to take measures to adjust the temperature within the allowable range.
		Data record	Record temperature data, the ambient temperature should be automatically recorded and the recording interval shall not surpass 10min.
	Record keeping	Record contents	Record the spot checks, ambient temperature, temperature measurement equipment, early warning treatment and other status.
		Requirements for records	The Records shall be true, complete, unalterable, and shall be submitted to interested parties upon termination of operation.
		Requirements for record-keeping	The records shall be kept for at least 2 years.
Transport management	Personnel	Staffing	Staffed with practitioners accommodative to transport management and operating scale.
		Health status	People who come into direct contact with foods and drugs

Control layers	control objects	Critical control points	Control measures
			shall undergo an annual medical examination and obtain a health certificate.
		Licenses& certificates	Special equipment operators shall obtain the appropriate qualifications.
		Quality and skills	Drivers, loading and unloading staff, transportation management personnel, etc. shall be subject to pre-job training and regular training to master the required knowledge and skills.
Management system and operating procedures		Management System	Formulate and implement transport quality management system, facilities & equipment utilization management system, personnel management & training system, information management system, emergency response plans, etc.
		Operating procedures	Develop and implement refrigerated vanoperating procedures, temperature monitoring procedures, loading/unloading and stacking operating procedures, cargo inspection procedures, etc.
Informatization		System construction	Improve the cold-chain transport information system.
		Management information	Track and manage records of orders, customers, goods, lines, vehicles, temperature, operator and other information.
		Actualized functions	Actualize cold-chain vehicle positioning, cargo tracking, temperature monitoring and other functions. Actualize online query of customer order status, temperature data, early warning processing and other information.
Quality evaluation and traceability		Quality evaluation	Develop evaluation indicators and regularly evaluate the quality of transportation.
		Quality tracing	Preservation of cold-chain transportation traceability information, to provide information and traceability; timely implement quality tracing for detected problems, and the trace records shall be archived in a timely manner.

Conclusions

In the quality control system established in this paper, the three layers of facility & equipment, operation process and transportation management cover six aspects of man, machine, material, method, environment and measurement. The critical control points at all layers are basically listed with all the factors that may cause cold-chain transportation quality problem. Through the control measures for each of the critical control points, the latter can be effectively utilized to minimize the potential quality hazards in advance.

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