Analysis of New Energy-saving Technology for Cold Chain Logistics

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Abstract. Cold chain logistics with cold storage as the core is an important part of logistics development. Energy saving and consumption reduction of cold chain logistics has become a common concern. Based on the basic connotation of cold chain logistics, this paper puts forward the energy saving ways of each link of cold chain logistics, and finally summarizes the new energy saving technology of cold chain logistics, hoping to provide some reference for cold chain logistics technology improvement.

1. Introduction
Cold chain logistics is a supply chain system with low temperature environment as the core. Compared with normal temperature logistics, cold chain logistics has higher requirements, more complex requirements, greater investment and higher energy consumption. 40% of the world's food needs refrigeration, and 11% of the world's electricity consumption is used in the cold chain of food, the energy consumption of cold chain logistics has been widely concerned. It is of great practical significance to study the energy saving and consumption reduction of cold chain logistics.

2. Current situation and problems of cold chain logistics
The data in table 1 are mainly from the statistics bureau of China. It can be seen that China's cold-chain logistics market has great potential. At the same time, a large number of cold chain logistics facilities are required. But cold chain logistics costs a lot of energy. In terms of refrigeration and transportation, China's unit energy consumption is 2-3 times that of developed countries, and the cost of cold chain logistics accounts for 70% of the total cost, more than 2 times that of developed countries.

| Year | vegetables | fruit | meat | milk | egg | Aquatic products |
|------|------------|-------|------|------|-----|------------------|
| 2017 | -          | -     | 8588.11 | 3545.26 | 3069.95 | 6953.01          |
| 2016 | 79779.71   | 28351.09 | 8537.76 | 3602.20 | 3094.86 | 6901.25          |
| 2015 | 78526.10   | 27375.00 | 8625.04 | 3754.67 | 2999.22 | 6699.65          |
| 2014 | 76005.48   | 26142.24 | 8706.74 | 3724.64 | 2893.89 | 6461.50          |
| 2013 | 73511.99   | 25093.04 | 8535.02 | 3531.42 | 2876.06 | 6172.00          |
| 2012 | 70883.06   | 24056.84 | 8387.24 | 3743.60 | 2861.17 | 5907.68          |
| 2011 | 67929.67   | 22768.18 | 7965.14 | 3657.85 | 2811.42 | 5603.20          |
| 2010 | 65099.41   | 21401.41 | 7925.80 | 3575.60 | 2762.70 | 5373.00          |
| 2009 | 61823.81   | 20395.51 | 7649.70 | 3518.80 | 2742.50 | 5116.40          |
| 2008 | 59240.35   | 19220.19 | 7278.70 | 3555.80 | 2702.20 | 4895.60          |

Table 1. In recent 10 years, China's main raw and fresh product output (unit:10kt/y)
China's cold storage refrigeration equipment is old, refrigeration technology is backward and sealing generally poor, resulting in high energy consumption of refrigeration, according to statistics, the average power consumption of China's cold storage enterprises as high as 106 kWh/m$^3$, and Japan only about 50 kWh/m$^3$. Many cold storage rooms ignore the temperature record, the temperature adjustment in the storage room only rely on intuition and experience, randomness is larger, the professional training of personnel is not enough, there are unreasonable operation, cleaning is not in place, maintenance errors. In addition, the loading time control, stacking mode and the interval time of refrigeration system opening are not effectively managed, resulting in energy waste. Therefore, China's cold chain logistics energy saving and consumption reduction still has a long way to go. As one of the important links of cold chain logistics, cold storage, the future development trend will be large, high-end, and the level of automation is getting higher and higher[1].

3. Energy saving and consumption reduction in each link of cold chain logistics

The energy conservation of cold chain logistics should consider the problems involved in reducing heat load, using high-efficiency and low-energy equipment, reasonable operation and management of refrigeration equipment, and constantly researching new energy-saving and environment-friendly refrigeration technology and refrigeration and fresh preservation technology, and coordinate the treatment of each link[2]. In the whole cold chain logistics, the energy consumption of cold processing, storage, transportation and sales accounts for about 23%, 5%, 19% and 53% respectively. The energy consumption and energy saving potential of each link are shown in the following table[3]. The energy saving measures in each specific link of cold chain logistics are expounded, and the emphasis is on the energy saving and consumption reduction of refrigeration system.

| link            | Emissions(1000t) | Energy consumption GWh/y | Saving ratio % | Energy saving GWh/y |
|-----------------|------------------|--------------------------|----------------|--------------------|
| sales           | 3100~6800        | 5800~12700               | 30~50          | 6300               |
| kitchen refrigeration | 2100   | 4000                     | 30~50          | 2000               |
| transport       | 1200             | 4820                     | 20~25          | 1200               |
| storage         | 500              | 900                      | 20~40          | 360                |
| precooling      | 20~330           | 310~610                  | 20~30          | 180                |
| frozen          | 120~220          | 220~420                  | 20~30          | 130                |

3.1. Cold treatment and characteristics

Cold treatment is to point to use refrigeration low temperature method to reduce food temperature quickly to the temperature suitable for storage or transportation, inhibit its respiratory function, reduce the growth of microorganism and harmful bacteria and the loss of food nutrients, prolong the storage life, to maintain the quality of food to the maximum extent, including pre-cooling and quick-freezing. As the first step of cold chain logistics, cold processing has a non-negligible impact on the quality of cold chain products and plays a decisive role in subsequent processing[4].

Refrigeration system is the core of cold chain logistics. The energy saving and consumption reduction of refrigeration system is directly related to the efficiency, product quality and cost of the whole logistics chain. At present, the refrigeration system used in cold chain logistics is mainly based on gas compression refrigeration cycle, and its energy saving can be considered from the following aspects:

1) Compressor. In the process of pretreatment, the thermal load of food varies greatly from large to small, and the efficiency of compressor is lower when partial load is running than when full load is running. Therefore, multiple low-power compressors can be used to replace one high-power compressor. With the decrease of thermal load, the number of running compressors is gradually reduced. Another solution is to use frequency conversion technology, variable speed compressor than fixed speed compressor energy saving 20%~30%. In the pretreatment system of large refrigeration system, two-stage
compression intermediate cooling or economizer is generally used to improve the efficiency of the whole system.

(2) Heat exchanger (including evaporator, condenser and fan coil). The main energy-saving measures are the choice of materials, the increase of heat transfer area and the improvement of heat transfer performance. Material selection takes into account heat transfer performance and cost. The methods to increase the heat transfer area are to increase the face heat transfer area, increase the number of pipe rows, increase the fin density and increase the supercooling degree of the condenser. The methods of improving heat transfer performance include improving fin design, pipeline design and special treatment of fin surface.

(3) Fan and pump as the power source of coolant load, fan and pump power consumption can account for about 35% of the total power consumption, the main methods of energy saving include selecting efficient equipment, frequency conversion and variable speed technology.

(4) Operation and maintenance. Related studies have shown that, evaporator, oil film within 0.1 mm, will bring down the evaporation temperature 2.5 ℃, power consumption increased by 11%. Such as evaporation temperature drops 1 ℃, the refrigerating capacity decreased by 5%, power consumption increased by 4.4%; Condenser furring within 1.5 mm, will make the condensing temperature increased 2.8 ℃, power consumption increased by 9.7%; Condenser if the remaining oil film in 0.1 mm, will make the condensing temperature 1 ℃, refrigerating capacity decreased by 1.4%, power consumption increased by 2.9%; When the non-condensing gas is mixed in the refrigeration system, the power consumption will increase by 18% and the cooling capacity will decrease by 8%. After frosting on the outer surface of evaporator, the heat transfer effect deteriorates due to the large thermal resistance of frosting layer, which leads to the decrease of evaporation temperature and the increase of power consumption. Therefore, we must pay attention to the daily operation and maintenance of the refrigeration system, timely adjust the valve, frost discharge oil, descaling, air. These energy-saving methods are also applicable to the storage, transportation and sales of the three links of the refrigeration system.

3.2. Storage methods and characteristics of cold chain logistics
Besides the above mentioned refrigeration system itself, the energy saving of cold storage should also be considered from the following aspects:

(1) The choice of heat insulation materials. Cold storage through insulation layer of heat transfer accounts for 20%~35% of the total heat load, the choice of appropriate heat insulation material can effectively reduce the external heat into the cold storage, heat insulation material insulation, moisture insulation characteristics, insulation layer optimal economic thickness, new insulation material is a research hotspot.

(2) Air curtain. In order to prevent the outside hot and humid gas from infiltrating into the cold storage, and reduce the cold load inside the storage, air curtain is usually set up at the cold storage door.

(3) Peak cutting and grain filling technology. In China, there is a great difference between the electricity price of industrial power in peak period and low period. Cold storage uses grain power to store cold and reduce the refrigeration load in peak period, which not only saves cost, but also reduces the power supply pressure of power grid system, so as to achieve the purpose of energy saving.

(4) Application of liquefied natural gas (LNG) cold energy. Before LNG is supplied for use, a large amount of cold energy is released in the gasification process in the gasification station, and the cold energy can be utilized into the cold storage, which can not only obtain good benefits, but also achieve energy saving and consumption reduction.

3.3. The transport mode and characteristics of cold chain logistics
The energy consumption of refrigeration transportation includes the energy consumption of refrigeration system and the energy consumption of transportation vehicle itself. The energy saving of refrigeration system in refrigerated transportation can be referred to that in refrigerated treatment. Energy saving and consumption reduction of various means of transportation include:
(1) Energy-saving technologies of automobiles mainly include the improvement of internal combustion engine and new energy technologies (electric vehicles, hybrid vehicles and clean fuel vehicles, etc.);
(2) The main direction of energy saving of trains is electrification and high speed;
(3) The energy saving of ships mainly includes improving the thermal efficiency of ship engines and reducing the energy consumption of electrical components;
(4) Energy saving of air transport mainly includes biofuels and new energy, efficient operation, effective infrastructure and positive economic means.
(5) Improving the management level, reasonably optimizing the traffic routes and multimodal transport, and improving the delivery rate are all conducive to the realization of energy saving and consumption reduction of vehicles.

3.4. Cold chain logistics sales methods and characteristics
Sales is the last link of the cold chain, refers to the food after short or long distance transportation, in the sales place of the supermarket or convenience store in the low temperature refrigerator sales process, its main equipment is the refrigerator and frozen display cabinet. Supermarket refrigeration freezing showcase energy-saving measures include: the optimal design of the air curtain, evaporator optimization design, the intelligent control, night dew heater cover, parallel units, the use of liquid refrigerant too cold, the right means of defrosting and defrosting control, coupled with hvac system can greatly reduce the energy consumption of the supermarket[5]. And the energy-saving of domestic freezer and dining-room freezer basically is to raise the refrigeration efficiency of refrigeration system.

In short, cold chain logistics is a complex system engineering, which requires close cooperation between all links. Energy saving of the whole cold chain logistics in addition to ensure that every link to work effectively, also need the advanced management technology, such as information technology (electronic data interchange (edi) and global positioning system (GPS), logistics technology (automatic and intelligent) and organization (third party logistics and the supply and marketing cooperative cooperation), to ensure the smooth operation of the cold chain logistics.

4. New energy-saving technology for cold chain logistics
Cold chain logistics and refrigeration technology are complementary and mutually promoting. The development of cold chain promotes the development of refrigeration technology, and the application of new refrigeration technology ensures the energy saving and consumption reduction of cold chain logistics and the safety of cold chain food. Therefore, the energy saving of cold chain logistics is largely dependent on the development of new technologies, especially refrigeration.

At present, most refrigeration systems use gas compression cycle, but this refrigeration cycle consumes a large amount of high-grade electric energy, but also brings many environmental problems (greenhouse effect, ozone layer damage, etc.), some alternative refrigeration cycle and new refrigeration technology has been widely concerned. In addition, the use of new food technology also has a positive impact on the energy saving and consumption reduction of the whole cold chain logistics. Domestic and foreign experts and scholars have done a lot of research work on cold chain logistics and some new technologies and achieved a series of results. Table 3summarizes some new technologies of cold chain logistics and their applications in cold chain logistics.
Table 3. New energy-saving technology for cold chain logistics

| The new technology                  | Cold treatment | storage | transport | sales | terminal |
|-------------------------------------|----------------|---------|-----------|-------|----------|
| Absorption refrigeration            | √              |         | √         |       |          |
| Jet refrigeration                   | √              |         |           |       |          |
| Air circulation                     | √              |         |           |       |          |
| The thermoelectric refrigeration    | √              |         |           |       | √        |
| Thermoacoustic refrigeration        |                |         |           |       | √        |
| Magnetic refrigeration              | √              |         |           |       | √        |
| HFOS                                | √              |         |           |       | √        |
| Cold storage technology             | √              |         |           |       | √        |
| Cascade system                      | √              |         |           |       | √        |
| Antifreeze proteins                 |                |         |           |       |          |
| Fluidized ice technology            |                |         |           |       |          |
| Perfusion precooling                |                |         |           |       |          |

For newly-built cold storage, energy-saving design is adopted from the source. For existing cold storage, improving equipment utilization rate and service life through energy-saving transformation and energy-saving management is of great significance to saving energy and reducing production cost [6].

5. Conclusion

Energy saving and consumption reduction of cold chain logistics is a long-term and arduous task. Cold chain logistics in China started late, and there is a big gap between the advanced level and foreign countries, energy saving potential. Only by adhering to the basic principle of energy saving and consumption reduction and using advanced logistics management technology to ensure the smooth flow of cold chain logistics can the best energy saving effect be achieved by discussing the energy saving potential of each link in cold chain logistics. The application of new technologies can greatly reduce the energy consumption of cold chain logistics, and has many benefits for cold chain products themselves, so it is imperative to increase the application of new energy-saving technologies in cold chain logistics.

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