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Recent advances in the cold chain system

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Abstract
Compliance with the cold chain is essential in order to ensure optimal preservation of perishable foods and provide consumers with safe, wholesome products. In this article, new developments in the cold chain at production, processing, storage, transport and retail levels, as well as an insight into certain concepts related to specific refrigeration issues in warm developing countries are presented. Several aspects are dealt with: national structures required in order to develop cold chains; higher costs hindering cold-chain development in developing countries; the prime importance of tailored training and research; the role of exports in promoting refrigeration technologies; and finally, the role of local engineering and design consultants.

Keywords: cold chain, refrigeration, food storage, warm climates, storage.

Introduction
Refrigeration is a food preservation process that preserves the original property of a foodstuff. Its main field of application is the preservation of foodstuffs of animal origin: meat, dairy and seafood products. However, the process is also used to freeze foodstuffs of plant origin, or to chill them, in which case the purpose is to extend their storage life and to maintain their freshness. The protective action of refrigeration lasts only as long as it is applied. It is therefore necessary to keep products refrigerated, from production to consumption. Some products, such as ice cream, owe their very existence to refrigeration. The three basic rules of refrigeration are as follows: wholesome food, early refrigeration, permanent refrigeration (Commére et. al., 1999). The third rule, which refers to the continuity of refrigeration, is commonly known as the "cold chain", which is defined as the means successively employed to ensure the refrigerated preservation of perishable foodstuffs from the production to the consumption stage. If a break in the cold chain occurs, the consequences may take various forms, from early wilting of foodstuffs of plant origin, particularly vegetables, to the development of spoilage flora, or, even worse, of pathogenic flora or toxins, which may cause food borne diseases.

I. New Developments in the Cold Chain
Production and processing
Trends in the production and processing stages are to

- Reduce the time interval between harvesting, picking, slaughtering, capturing or milking, and cooling: this is called early refrigeration. This makes it possible to reduce water loss and to prevent multiplication of micro-organisms. Under optimal conditions, bacteria divide every 20 minutes: therefore, within 8 hours under optimal temperature conditions and where the medium is of optimal composition, one bacterium will have generated over 16 million descendants (more than the number of inhabitants in Paris and its suburbs!).This confirms that temperature is a fundamental factor enabling the control of microbial risks (Stainer, 1997).

- Separate cooling and storage functions. Milk is cooled in milk chillers, meat in carcass chilling rooms, vegetables in packing and precooling premises, fish on ice while still at sea and frozen foodstuffs in freezing tunnels. Even fruits, which were traditionally cooled in storerooms, are now starting to be cooled in special premises prior to storage. Storage premises can thus be cooled more rapidly and there is no oversizing.
- Increase capacities to ensure rapid chilling in precooling units.
- Design more flexible systems: direct-access storage instead of mass storage in cold stores; smaller rooms in fruit stations so that each room can be filled and emptied more rapidly; use of air as cooling medium as it is polyvalent and cheap, even if it has poor exchange properties; multi-compartment and multi-temperature vehicles; indirect refrigerating systems in supermarkets in order to facilitate display redesign.
- Design intelligent cooling and storage systems: forced air through foodstuffs, plant monitoring based on product parameters (temperature, rate of water loss etc.).
- Reduce water loss by improving relative humidity control: humid-air cooling for vegetables, spray-cooling for meat.
- Make equipment cleaning ability a priority: milk coolers or freezers with a cleaning cycle; washable air conditioners in cheese factories or meat processing plants; removable, washable textile blowing ducts; insulation materials with smooth washable coatings; extra-fine joints, cold rooms with rounded angles.
- Control ambient conditions: modified atmosphere in fruit stations or during long-term marine transport; modified atmosphere in individual packs; microbiologically-modified rooms where temperature, relative humidity, excess pressure, air flow and direction in turbulent or laminar flow, and particle concentration are controlled.
- Gradually move away from batch processes towards continuous processes.
- Ensure more widespread use and standardisation of pallets.

Storage

Trends in the storage stage are to

- Reduce energy consumption: fast-opening and closing doors or sliding shutters instead of doors; variable-speed ventilators; floating condensation to lower the condensation temperature whenever possible; external coatings to protect from impinging solar radiation. Energy consumption of 30-50 kWh/m^3 year or even less can now be achieved (ECSLA, 2000).
- Move away from mass storage towards direct-access storage, thus making it possible to handle the increasingly large number of products and high turnover levels.
- Increase the number of distribution hubs, these hubs being particularly suitable for supermarkets.
- Store quick-frozen foodstuffs at lower temperatures than those authorised (–25 instead of –18°C, for example).
- Guarantee product and temperature traceability using temperature recorders and follow-up documents.
- Implement self-inspection systems.
- Improve interface management: closed-off air-conditioned docks fitted with insulated doors; fast-loading devices in trucks.

Transport

Trends in the transport stage are

- To benefit from increased flexibility.
- Class C-vehicles (ATP, 1996) used to transport either chilled or quick-frozen foodstuffs.
- Multi-temperature and multi-compartment vehicles with fixed or mobile walls.
- To improve temperature homogeneity.
- Pallet layout and stacking (spacers on the sides to allow free air flow).
- Air distribution ducts for long vehicles.
- High air renewal rates (60 renewals/hour).
- To ensure product and temperature traceability (Billiard, 1998).
- Temperature recorders.
- Electronic records.
- To equip delivery vehicles with flaps and plastic-strip curtains, in order to restrict temperature rises during door openings.
- To ensure protection from shocks (pneumatic suspension) for products.
- To envisage multi-modal transport (road and rail) by using swap bodies more extensively.

Retail display

Trends in this field are

- Increased sales in supermarkets and conversely, decreased sales in small retail outlets.
- To comply with regulatory temperatures (or those indicated by the manufacturer on the packaging) using thermometers in all display cabinets (probe at air inlet, not air outlet).
- To pay attention to hygiene (regular cleaning of display cabinets) and to the layout of packs.
- To ensure that display cabinets are located away from direct sunlight and air terminals.
- To restrict energy consumption, given that refrigeration represents 30-50% of total energy consumption of supermarkets (Billiard, 1999).
- To ensure environmental protection. For example, one trend in some countries is to shift from direct cooling systems to indirect systems in order to reduce the refrigerant charge.
- To maintain consumer confidence in food freshness (thanks to time-temperature indicators, thermometers, removal of products from shop shelves several days before the best-before date).

Mandatory and voluntary tools

Voluntary restrictions are going beyond regulations; inspections by state authorities are gradually being replaced by selfinspection. Governmental regulations cover human safety, hygiene, the environment and, generally speaking, essential requirements, standardisation and good practice codes governing technical issues.

II. Specific issues in warm and developing countries

In early 2003, the world population reached approximately 6.3 billion inhabitants; 5.1 billion inhabitants, i.e. 81% of global population, live in developing countries. Most of these countries have a warm (equatorial, tropical or Mediterranean) climate, which means that refrigeration is all the more important. Furthermore, it was estimated that 35% of the population of developing countries lives in cities, where food supply problems are becoming increasingly acute and where

the development of refrigeration is again essential (United Nations, 1998). A few thoughts on specific issues in warm developing countries, on opportunities and on unavoidable difficulties are provided below.

(i) Preservation methods - On the whole, developing countries focus more on increasing agricultural production than on preserving agricultural products. This explains why post-production losses are so high, whether in the field or during transport, storage and distribution. In developing countries, there is a debate over food preservation. Some think that traditional methods (salting, curing, storage in the ground, etc.) are most appropriate as they are inexpensive. Others think that populations in developing countries have the right to the food preservation technology that has been tried and tested in developed countries, particularly refrigeration technology (United Nations, 1998 and Cleland, 1998). This is also the IIR's position. Every household rightfully aspires to a roof over its head, a means of transport (bike, motorbike or car), a television set and a refrigerator. From the moment that households have refrigerators, cold chains must be developed upstream.

(ii) Structures - The main professions involved in the setting up and the implementation of cold chains are producers, designers, trainers, equipment manufacturers, storage specialists, transporters and retailers. It is essential to set up an organisation that combines government departments and members of the industry in order to put forward action plans, priorities, schedules and funding programs. National refrigeration associations are also essential: they are needed in order to bring together the country's refrigeration experts, to promote developmental efforts and to circulate information. Supranational organisations are also very useful; they enable countries with similar climatic and economic conditions to share successful experience.

(iii) Costs - Refrigeration is more expensive in developing countries because equipment tends to be imported and the labour required to build the plants is sometimes from abroad, and thus more expensive. Literature indicates that investment costs are 1.4 to 1.6 times higher than in developed countries (Djiako, 1999). Despite the cost of labour being lower in developing countries, it is not certain that overall running costs are lower, since energy tends to be more expensive. Some regions are not connected to a power network, and power cuts and voltage variations must also be taken into consideration.

(iv) Training - Refrigeration technicians and fitters are crucial to the design and maintenance of refrigerating plants. Insufficient maintenance of refrigerating plants can lead to equipment breakdown and can therefore harm the image of the refrigeration sector. It is important to make sure that training matches needs. Beyond the initial training, continuing education courses must also be set up for those who were not able to benefit from sufficient initial training or to receive training on new technology and new refrigerants.

(v) Research - Research is often restricted to the creation of mathematical models, which are not always corroborated, and are of little value in the development of cold chains. It would be more useful to develop applied research programs in collaboration with industrial stakeholders and equipment manufacturers in order to adapt plants and processes to the local situation.

(vi) Exports - There are many export opportunities for food products that are of a better quality thanks to the sunny conditions in warm countries, and which are in great demand in developed countries. This concerns tropical or Mediterranean fruit and vegetables, but also fruit and vegetables from temperate climates (green beans, strawberries, tomatoes, peppers, etc.). The requirements for exported products are: compliance with standards and regulations, traceability, hygiene, etc. The setting up of cold chains for exported foodstuffs promotes the adoption of similar systems for local trade.

(vii) Imports - Reductions in trade barriers and major progress in transport and logistics have led to cost reductions. In order to obtain the proteins that are essential to good nutrition, many developing countries import frozen foodstuffs (meat, fish), which require a specific infrastructure and local logistics for their marketing.

(viii) Stockpiling - Countries consider that stockpiling cereals, groceries and quick-frozen foodstuffs is essential since it enables countries to withstand any food shortages that may occur (due to conflicts, unfavourable climatic conditions, etc.). Warehouses are built for the purpose of stockpiling.

(ix) Engineering and design units - Local expertise that is tailored to the geographical location, to the country's specific features and to its culture, is required: it is thus important to promote the setting up of local engineering and design units. Imported concepts and technology are often unsuitable (for example, oversized cold rooms that cannot be filled up completely lead to water loss in products).

(x) Difficulties - The stages that encounter the most difficulties are storage on production sites, refrigerated transport and refrigeration in retail shops. These difficulties comprise power-supply problems on production sites, a lack of private investment in these activities, the cost and the technical aspects of refrigerated transport, cultural aspects and the influence of traditions and customs. Implementing a cold chain is a very slow process which can take up to 30 or 40 years. Starting the process and remaining committed to succeeding are what matter most.

Conclusion

In developed countries, progress in the cold-chain field is undeniable and is consumer-driven: consumers demand that the safety of food on table be faultless. Progress is more transparency, information and traceability driven than arising from the development of new technologies. In warm developing countries some sectors are expanding, particularly in response to export-related needs; domestic refrigeration is also expanding fast.

References

1. ATP. Accord relatif aux transports internationaux de denrées périssables et aux engins spéciaux à utiliser pour ces transports, CEE, Genéve. Agreement on the international carriage of perishable foodstuffs and on the special equipment to be used for such carriage. EEC, Geneva, 1996.

2. Billiard F. La traçabilité du froid. Compte rendu Conférence de l'IIF. Traceability of refrigeration. Proceedings Nantes Conf., IIR, Nantes, 1998, 52-60.
3. Billiard F. Nouveaux développements dans la chaîne du froid au niveau mondial. Compte rendu, 20e Congr. Int. Froid. New developments in the food cold chain worldwide. Proceedings 20th IIR Int. Cong. of Refrigeration, Sydney, Australia. CDROM, 1999.
4. Cleland A. Le transport frigorifique face aux exigences du marché. Market-pull factors for refrigerated transport services. Bulletin de l'IIF. Bulletin of the IIR, 1998; 6:2-12.
5. Commére B, Billiard F. La chaîne du froid dans l'agroalimentaire. Techniques de l'Ingénieur, 1999.
6. Djiako T. Le froid pour les pays en développement ñ la suppression des CFC et le froid alimentaire en Afrique. Refrigeration in developing countries. CFC phase-out and refrigeration of food in Africa. Bulletin de l'IIF, Bulletin of the IIR, 1999; 2:2-15.
7. ECSLA. Energy Guide, Brussels, Belgium, 2000.
8. Stainer F. Conséquences et risques pour la chaîne du froid et la sécurité des aliments, Compte rendu du Colloque USNEF,Paris, France, 1997.
9. United Nations. World Population Prospects ñ the 1996 Revision, United Nations, New York, 1998.