INTERGOVERNMENTAL ORGANIZATION FOR THE DEVELOPMENT OF REFRIGERATION June 2009

INTERNATIONAL INSTITUTE OF REFRIGERATION
177, Bd Malesherbes - 75017 PARIS (France)
Tel.: 33 (0)1.42.27.32.35
Fax: 33 (0)1.47.63.17.98
E-mail: iif-iir@iifiir.org
Web site: www.iifiir.org

The Role of Refrigeration in Worldwide Nutrition

5th Informatory Note on Refrigeration and Food

Introduction

The world faces a high level of malnutrition and population growth.[1-2] Ensuring both adequate food supply and food quality to almost 7 billion inhabitants today and over 9 billion by 2050[1] is a major global challenge. Most solutions to meet growing food demand are based on the increase of agricultural output, which is vital, but probably insufficient without reaching a level that would irreversibly harm the environment. Therefore, a major focus should be the reduction of post-harvest losses, which average about 25% of the food production worldwide.

Increased use of refrigeration would make it possible to substantially reduce post-harvest losses. Refrigeration already plays a key role in many food supply chains by preserving the initial quality of foodstuffs, thus providing consumers with foodstuffs that are both wholesome and safe. Refrigeration is still insufficiently and unequally used to ensure food safety and security, as illustrated by the lack of suitable refrigeration infrastructure in many countries, above all in the least-developed countries where undernourishment is of the greatest concern and the population is growing the fastest.

The aim of this note is to show how more effective cold chains, from production to consumers, can substantially reduce post-harvest losses, thus significantly improving food safety and food security.

Global status of food security

Even though the latest United Nations forecasts[1] show that global population growth is likely to slow in the future, the annual increase remains high at 77 million people per year. This growth is projected to decrease to 43 million people per year over the period spanning 2045 to 2050. From 2030 onwards, 85% of this population growth will be concentrated in developing countries.[1]

Year	Unit	2000	2015	2030	2050
Global population	Billion inhabitants	6.12	7.30	8.31	9.15
Population of developed countries*	Billion inhabitants	1.19	1.25	1.28	1.28
Population of developing countries**	Billion inhabitants	4.92	6.05	7.03	7.87
% of global population	%	80.5	82.9	84.6	86.0
Undernourishment[2]	Billion inhabitants	0.86	0.61	0.44	

* More-developed regions[1] ** Less-developed regions[1]

The global food energy intake per person is increasing, from 9555 kJ/inhabitant/day in the period 1961-1963 to 11 730 kJ/inhabitant/day in the period 2001-2003.[3,4] However, such progress is taking place slowly and in an unequal manner.

Undernourishment therefore remains a crucial issue that has not yet been satisfactorily addressed. The target set at the World Food Summit in 1996 of reducing by half the number of chronically undernourished people on Earth by the year 2015, thus reducing this figure to 410 million people, will not be attained. Further, this goal may not be achieved by 2030[3] given that in 2008, there were 963 million undernourished people worldwide. Ninety seven percent of these people were living in developing countries[2]. Undernourishment is at its most alarming level in the least-developed countries, particularly in Sub-Saharan Africa where half of all births worldwide will occur in 2050.[3]

To achieve worldwide equitable food security, the global food supply must increase. The most commonly cited solutions in order to raise production are: i) expansion of the quantity of arable land; ii) higher crop frequency (often through irrigation); and iii) increased crop yields thanks to improved agricultural production technology. The lack of arable land along with limited water resources in many parts of the world are likely to hamper the first two solutions. Nitrogenous fertilizers used to increase yields are under scrutiny due to their environmental impact on water eutrophication and gas emissions. Biotechnology is undoubtedly promising, but there are ethical, safety and environmental concerns about some of its applications, such as the use of genetically modified plants and animals for food.

Therefore, increasing agricultural production alone may prove insufficient to address food security and safety. Greater emphasis on a holistic solution, that encompasses the reduction of post-harvest losses, is an additional sustainable way of increasing food availability.

The role of refrigeration in food safety and security

Refrigeration has a vital role to play in reducing post-harvest losses. There are currently many preserving technologies applied to perishable foods (e.g. irradiation, drying, salting, high pressure processing, canning, pulsed electric fields). However, no other processing technology combines the ability to extend product shelf life and in parallel maintain the initial physical, chemical, nutritional and sensory properties desired by consumers to the same extent as refrigeration. Greater use of refrigeration technologies would ensure better worldwide nutrition, in terms of both **quantity** and **quality**.

- From a **quality** point of view, it should be emphasized that refrigeration plays a vital role in food safety and spoilage reduction. Foodstuffs of animal and plant origin are highly perishable and can host pathogens. Significant causes of foodborne diseases and spoilage are bacterial contamination, survival and growth. The use of refrigeration substantially reduces bacterial growth in foods. Refrigeration is even more vital in hot countries, where bacterial growth takes place faster because of high temperatures. Refrigeration also reduces the rate of many undesirable chemical and physiological reactions that reduce quality.
  A study[5] indicates that annually, an estimated 1777 people die every year from known pathogens, out of a total of 5000 deaths from all foodborne diseases in the USA. Analysis of data[6] on causes of foodborne illnesses suggests that over 90% of these illnesses are at least partly associated with poor temperature control.[7] According to a 2008 WHO report[8] in the United States, refrigeration and improved hygiene have reduced stomach cancer by 89% in men and 92% in women since 1930.

- From a **quantity** point of view, current agricultural production is theoretically more than sufficient to meet the needs of the entire global population.[9] Yet 14% of the global population suffers from undernourishment. Reducing post-harvest losses would help improve this situation to a large extent.[9] These losses are mostly due to the following:
  – Increasing distances between production areas and consumers. Production regions are located geographically far from consumers and this trend is increasing as cities expand. For example, in 1950, the urban population on a global scale was 17%, while in 2008 50% of the global population lived in urban areas. This figure is expected to rise to 70% by 2050, mainly because of increased urbanization in developing countries.[10]
    One way to reduce the impact of transport between production sites and markets is through the introduction of novel supply chain networks, for example, increasing local trade by developing regional storage and transport infrastructure for perishable foods handling. Developing countries are the most in need of higher levels of trade and are also the most underequipped in terms of refrigeration equipment. They also need international trade. For example, the quantity of cereals imported by developing countries is likely to triple over the next 30 years and meat imports are likely to rise five-fold in the same period.[3]
  – Due to its seasonal characteristics, agricultural production fluctuates considerably over time. Reserves and stocks are therefore of great importance in food security. Again, refrigerated storage, currently under-utilized in this area, should be considered as a key factor enabling food security to be achieved.

The need for extensive, high-performance cold chains

Global food production comprises roughly one third of perishable products requiring preservation. In 2003, out of a total global food production (agricultural products, fish, meat products and dairy products) of 5500 million tonnes, it was estimated that only 400 million tonnes were preserved thanks to refrigeration (chilled or frozen), whilst at least 1800 million tonnes required refrigeration.[4,9] This results in huge losses.

The figures shown in the following table are derived from different sources and various estimations.

	World population	Developed countries*	Developing countries**
Population in 2009 (billion inhabitants)[1]	6.83	1.23	5.60
Refrigerated storage capacity (m^3/1000 inhabitants)[11,12]	52	200	19
Number of domestic refrigerators (/1000 inhabitants)[11,13,14]	172	627	70
Food losses*** (all products) (%)[9,15,16]	25%	10%	28%
Losses of fruit & vegetables*** (%)[9,15-20]	35%	15%	40%
Loss of perishable foods through a lack of refrigeration (%)[15,16]	20%	9%	23%

* More-developed regions[1] ** Less-developed regions[1]

******* The loss rate comprises post-harvest losses, i.e. during processing, storage, transport and retail sale. It does not include final losses at consumer level for several reasons:
– these final losses are particularly difficult to evaluate, although a US study[18] has demonstrated that such losses are about 14% in the USA;
– the value of final losses depends far less than post-harvest losses on the refrigerated equipment available in industrialized countries that are well-equipped: waste accounts for a major amount of losses; Kader[17] considers that final losses are slightly higher in developed than in developing countries.

These figures clearly demonstrate that greater amounts of refrigeration equipment and a high-performance cold chain in a country equate with lower post-harvest losses. For instance, for fruit and vegetables, the loss rate varies by a factor of up to 3 or 4: e.g. the USA has losses of about 12%[17] and a refrigerated storage volume of 300 m^3 per 1000 inhabitants,[12,21] whereas India has losses of about 40%[20] and in spite of a two-fold increase in volume over the last decade, still has a refrigerated storage volume of only 75 m^3 per 1000 inhabitants.[12,22]
These figures suggest that around 360 million tonnes[15,16] of perishable foods are lost each year through insufficient use of refrigeration. Thus, in theory, if developing countries could acquire the same level of refrigerated equipment as that in industrialized countries, over 200 million tonnes of perishable foods would be preserved, this being roughly 14% of the current consumption in these countries.
The strengthening of the cold chain is thus vital within the framework of food safety and prevention of undernourishment. The cost of refrigeration, including both the acquisition and the operation of equipment, can often be offset, especially for the most expensive foods, by the revenue from sales of foodstuffs that, without refrigerating equipment, would otherwise have been lost.[9]
This strengthening of the cold chain must take into account country-specific factors. The first condition to be ensured, particularly in warm countries, is the implementation of rapid cooling of products of animal or plant origin, as soon as possible following production, in refrigeration plants geographically close to production sites and designed to handle cooling loads. Another essential component is an unbroken cold chain, particularly at the interfaces between various modes of transport and/or storage sites. Raised awareness of the risks inherent in non-compliance with the cold chain, and training in good practice, are vital.
The various types of refrigeration processes should be used correctly. For example, chilling of perishable foods — provided that the recommended storage temperatures are applied (ranging from –2°C to +13°C according to the products in question) — significantly lengthens their shelf life (by 10 to 120 days depending on the perishable nature of the products); whereas freezing and frozen storage

(generally at –18°C and below) enables products to be preserved over much longer periods and is less sensitive to minor temperature fluctuations, but entails greater energy costs. It is suggested that developing countries with undernourished populations should initially concentrate on frozen rather than chilled foods wherever possible.[7]

IIR recommendations

Refrigeration can make a significant contribution to addressing the issue of undernourishment especially in the least-developed countries. The setting up of cold chains for perishable foodstuffs that are as extensive and reliable as those in industrialized countries would enable developing countries to raise food supply by about 15%. The vital links in an effective cold chain are cooling and storage at production sites, refrigerated transport and implementation of refrigeration in retail outlets. The following conditions govern the setting up of cold chains where they are currently lacking:

- awareness on the part of decision-makers of the benefits of high-performance cold chains;
- setting up of local structures involving all the ministries, refrigeration stakeholders and experts concerned in order to define action plans and priorities;
- transfer of high-performance, environmentally friendly and cost-effective technology to developing countries in which such equipment is not yet available;
- training of local engineers, technicians and users in order to set up, operate and efficiently maintain refrigeration plants forming effective links in cold chains.

The IIR is a neutral, independent intergovernmental organization, with an expertise network encompassing 61 member countries on all continents. It is committed to enabling refrigeration to play a key role in food security for all. Everyone who shares this goal is welcome to join the IIR (***www.iifiir.org***).

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