Quality of cold chain equipment, a guarantee of carbon footprint reductionfrom food waste to a sustainable environment.

Abstract

The objective of this work was to evaluate the current status of commercial cold chain equipment primarily, and secondarily to determine elements associated with the management of cold chain equipment.

To achieve this, a cross-sectional descriptive study began on August 7 to September 23 of 2023, covering 84 commercial establishments including supermarkets, delicatessens and butchers, food, and butchers in the city of Lubumbashi. The data were collected by interview and direct cross-sectional observation on the evaluation of the conservation of frozen products (fish, meat, and cold meats) on the market in the city of Lubumbashi.

The results show us that the structures using cold chains are food stores, butchers, delicatessens, and supermarkets and sometimes in a certain combination. All these structures mainly use freezing and sometimes refrigeration and freezing to guarantee this Cold chainfreezers, quick freezers, refrigerated cabinets and refrigerators and finally insulated boxes are all the equipment used for this purpose and using the supply of electric current throughout and often using generators and rarely solar panels in the event of an outage electric current. Thus, these structures operate in an environment rich in temperature fluctuations leading to rapid deterioration of food, waste, responsible for 4% of global greenhouse gas emissions GHG,the equivalent of the contribution of the entire African continent to climate change.

This work demonstrated the importance of the quality of cold chain equipment on food quality and its impact on the carbon footprint, a situation observable from the production, transport, storage, and elimination of food. the use of solar energy would be a solution in this process because it produces less greenhouse gases.

Introduction

The world faces many problems that require urgent attention to ensure the continued existence of humanity. Key among these issues are food security, the impact of greenhouse gas emissions, the depletion of fossil fuel reserves, and the production and management of food waste.[1]The cold chain is vital for reducing food waste and ensuring food safety [2,3]. Globally, it is estimated that around a third of all food produced for human consumption in the world is lost or wasted according to the FAO, or around 1.3 Gt.[4]. More precisely, the carbon footprint of food produced and not consumed is estimated at 3.3 Gt of CO_2 equivalent; Food waste has thus become the third largest emitter of CO_2 after the United States and China[4]

Recent decades have seen an increase in the world's population, which has put pressure on food availability, its management and disposal. The global increase in greenhouse gas emissions has deteriorated the climate, which is not only a burning but also a central issue

worldwide. The world is exploring new ways to solve some of its global problems. Solutions to these global problems are widely explored.[5]

The cold chain is responsible for preserving and transporting perishable foods within the appropriate temperature range to slow down biological degradation processes and provide consumers with safe, high-quality food. Studies show that cold chain efficiency is often far from ideal, as temperature exceedances above or below the product-specific optimal temperature range frequently occur, a situation that significantly increases food waste and endangers food security[1]

Cold allows foods to be preserved depending on the temperature for a few days to several months, while retaining their taste and nutritional properties. Conservation techniques by lowering the temperature of products and foods make it possible to extend their shelf life, and depending on the temperatures, cellular activity and the proliferation of microorganisms are either slowed down or stopped. [6]

Food waste is one of the crucial factors contributing to Critical loss point and thereby increasing global temperature. It is therefore relevant to reduce food waste and consequently Critical loss point. Treating food waste through different sustainable methods is essential to create a positive impact on the Critical loss point and the global environment[7]

Food produced but not consumed occupies nearly 1.4 billion hectares of land, which comprises approximately 30% of the world's agricultural land; it is estimated that to meet population demand by 2050, food production will need to be increased by 60%, but reducing food waste will mitigate this situation [8]. Thus, reducing this food waste is essential to reduce emissions and improve environmental protection. Furthermore, reducing food waste will save a substantial amount of natural and societal resources, while ensuring appropriate food safety.

The installation, monitoring and maintenance of cold chain equipment would play a vital role in solving this problem. Because an efficient cold chain will guarantee healthy food quality and reduce losses and pollution.

In this field work on cold chain equipment, the objective is to evaluate the current state of commercial cold chain equipment primarily, and secondarily to determine elements associated with the management of cold chain equipment. .

Methods

This is a cross-sectional descriptive study started from August 7 to September 23 of 2023, covering 84 commercial establishments including supermarkets, delicatessens and butchers, food, and butchers in the city of Lubumbashi. Data were collected by interview and direct observation.

Only commercial establishments selling fresh food and whose managers agreed to participate in these studies were included.

The data was encoded using a questionnaire on Google Form and converted into Microsoft Office Excel 2016 for import to EPI info 7.2.1 for analysis.The anonymity of establishments and personnel was guaranteed for reasons of confidentiality, in fact no personal data was

encoded. The variables studied are those related to the identification of cold preservation materials, the energy source, the shelf life, and waste management.

Results

The results of the survey relating to the characterization of product consultations in commercial frozen product establishments are presented in relation to the objectives

Table I: Structure and means of conservation

Structure	Means of preservation refrigeration	freezing	Rapid Freezing	TOTAL
Food	**9**	**45**	**24**	**45**
Food and butchery	**8**	**12**	**10**	**12**
Butchery and charcuterie	**15**	**16**	**16**	**16**
supermarket	**11**	**11**	**11**	**11**
Total	**43**	**84**	**61**	**84**

It appears from this table that freezing was the most used method, all structures have it; followed by freezing and finally refrigeration

Keeping food cold is a fundamental aspect of food safety, which is why fresh food trade structures also use refrigerated food storage. This could include commercial freezers and refrigerators and, also cold rooms.[9] . Low temperatures inhibit the growth of bacteria and disease-causing microorganisms, keeping food safe until you are ready to prepare it. The cold, controlled environment also prevents the entry of parasites and slows the processes that cause food spoilage, including enzymatic reactions, oxidation, and exposure to light.[10]

Maintaining the correct food temperature levels also affects your bottom line. Cold storage helps prevent perishable foods from going bad, saving you money on food spoilage.

Table II: structure and conservation material

Structures	Conservation equipment						
	Fridge N (%)	Quick Freezer N (%)	Refrigerator cabinet N (%)	Refrigerated display N (%)	Isothermal box N (%)	Freezer N (%)	Total
Food	6 (13.3%)	22 (48.9%)	2 (4.44%)	1 (2.22%)	11 (24.4%)	45 (100%)	45
Food and butchery	8 (66.7%)	11 (91.7%)	11 (91.7%)	0 (0%)	0 (0%)	12 (100%)	12
Butchery and charcuterie	11 (68.75)	12 (75%)	16 (100%)	2 (16.7%)	0 (0%)	16 (100%)	16
Supermarket	11 (100%)	11 (100%)	11 (100%)	3 (27.3%)	0 0%	11 (100%)	11
Total	36	56	36	6	11	84	

From this table, we observe that the cold chain equipment used in commercial structures is thus classified in descending order: freezers (100%); freezers, refrigerated cabinets and refrigerators and finally insulated boxes. It should be noted that this equipment was found more in supermarkets, food-butchers, and butchers-delicatessens and less in food stores. The list of refrigeration equipment cited in this table corresponds to those mentioned by NSF International in its NSF7 standard relating to commercial refrigerators and freezers, in addition to the requirements relating to refrigerators and freezers used to store and/or present cold foods. It defines the types of refrigerators and freezers covered by this standard include:storage refrigerators , storage freezers, rapid extraction refrigerators and freezers; refrigerated food transport cabinets; refrigerated buffets; refrigerated culinary preparation units; refrigerated display cases; beverage coolers; and glaciers.[11]

Table III: energy source and structures

structure	Energy source			
	Electric power	Solar panel	Electronic group	total
Food	45 (100%)	12 (26.7%)	19 (42.2%)	45
Food and - butchery	12 (100%)	3 (25%)	8(66.7%)	12
Butchery - charcuterie	16 (100%)	2 (12.5%)	10(62.5%)	16
Supermarket	11 (100%)	2 (18.18%)	10(90.9%)	11

It appears from this table that 100% of the structure uses electric current followed by the Energy produced by the generators and the panel is used less. Many structures have these two sources of Energy

Modern refrigeration systems keep food at safe temperatures. This helps reduce the growth of bacteria on your food, which can lead to food poisoning. In the event of a power outage, you should take additional steps to reduce the risk of food-related illness. For example, the CDC's Food Safety Fact Sheet in the event of a power outage recommends using containers of water and gel packs to help keep your food at 40°F or lower or at Buy dry ice or ice packs to keep your food cold in the refrigerator if the power is out for a long period of time.[12]

The use of vehicle fuel-consuming generators is a response to the growing demand for electricity and the production of electricity from fuels contributes significantly to greenhouse gas emissions and global climate change.[13 ,14]. This answer, which seems to be easy to access, poses a critical problem for optimizing the energy of electrical systems as well as the climate benefits under various constraints of equality and inequality[15] Because the largest part of the world's energy needs is met by carbon and hydrogen fuels, which are in limited supply [16] which are sources of pollution causing global warming, extreme weather conditions and the rupture of the ozone hole [17].

The use of solar panels is rare. Indeed, solar energy is affected by changing weather conditions. Renewable energy sources are also impacted by climate change, and changing climate influences can lead to various consequences on several types of renewable energy.Increasing temperature has been shown to reduce the efficiency of the photovoltaic energy system.[18]

Table IV: means of prevention

Prevention		Frequency	Percentage
Closing the tool		**84**	**100**
cleaning		**42**	**50**
Temperature monitoring		**0**	**0**
Physical observation	**color**	**22**	**26.19**
	smell	**42**	**50**
	Architecture	**5**	**8.3**
	Color and smell	**4**	**4.8**
Decision taken by the increase in temperature	**Food transfer**	**33**	**39.3**
	Unplug the device	**36**	**42.9**
	Nothing to report	**15**	**17.9**

The proper functioning of the cold chain is guaranteed for all structures by the proper closing of the equipment openings and half of the structure also carries out scheduled cleaning and no structure has a daily temperature monitoring system. Indeed, the CDC also recommends keeping refrigerator and freezer doors closed so food will stay safe for up to: 4 hours in the refrigerator. 48 hours in a full freezer; 24 hours in a half-full freezer.[12]

Spoiled foods caused by the metabolic process may appear undesirable and unacceptable to consumers due to the alteration of sensory characteristics, i.e., texture, odor, taste, and appearance[19]. Conventionally, the observation of food deterioration is carried out through sensory evaluation and chemical experiments[20] this method is also used in Lubumbashi in certain commercial structures; However, this method which can lead to human errors due to its inefficiency and low accuracy.[21] The rise in temperature is a result of poor temperature management throughout the cold chain leading to deterioration and loss of food quality [22] and temperature fluctuations have also accelerated the change in color and softening of foods.[23] Thus, the difficulty in maintaining a constant and optimal temperature throughout the cold chain is a major cause of deterioration in appearance and nutritional value[24,25]

According to FoodSafety.gov, fresh foods are generally considered safe in the refrigerator for only about four hours after a power outage. Any longer, and the USDA advises throwing out perishable foods like raw meat, defrosting meat, eggs, opened sauces, and leafy greens.[26,27]

Some structures advocate the transfer of food, while one of the reasons for this is that products are generally exposed to hot temperature when transferred from one operational unit to another.[28]

It should also be noted that no structure has a system for monitoring the daily temperatures of cold equipment and yet cold chain monitoring refers to the process of close monitoring and management of temperature and environmental conditions. temperature-sensitive products throughout the supply chain. The main objective of cold chain monitoring is to avoid temperature deviations, which can lead to product degradation, spoilage and even health risks[29].

Table V: Products sold in structures

Products	N	%
Fish	**84**	**100%**
Poultry meat	**68**	**80.95%**
Pork meat	**43**	**51.19%**
Beef	**43**	**51.19%**
Cervelats	**29**	**34.52%**
Cervelats and salami	**14**	**16.7%**
Cervelats, salami, minced meat	**11**	**13.1%**
Cervelats, pork meat	**5**	**5.95%**
Cervelats, salami, kidney, liver, mipanzi	**1**	**1.2%**
Brains, salami, kidneys, liver, mipanzi, minced meat	**1**	**1.2%**
Cervelats, salami, minced meat	**11**	**13.1%**
Total product	**84**	

In the 84 structures visited we observed that the most sold frozen products on the market in the city of Lubumbashi were fish, then poultry, then beef and pork, and finally cold cuts came as a last resort. All these products require cold chain organization. They are highly perishable and can deteriorate quickly if not refrigerated or frozen. Cold chain organization helps maintain the freshness, quality and safety of meat and seafood by preventing microbial growth, oxidation and enzymatic reactions that can cause spoilage, discoloration, and odor unpleasant. It also helps protect meat and seafood from physical damage, cross-contamination and temperature fluctuations during transportation and storage.

Indeed, the food supply chain, the production of meat and dairy products generates a significant amount of greenhouse gas (GHG) emissions[30] this production is evaluatedto

13.7 billion tonnes of carbon dioxide equivalents (COeq.). This represents 26% of total anthropogenic greenhouse gas (GHG) emissions[31]. Furthermore, a significant increase in emissions linked to the food chain is expected with increasing population and income level[32]. This highlights the essential role of food chains in the GHG reduction process[32,33].

The massive increase in food waste generation has led to an increased burden on landfills, thereby leading to increased greenhouse gas emissions.[34] And any waste of food products, mainly based on fish and meat, known to regenerate more GHGs[31]accounts for about half of all emissions from the global food system[35]

Table VI: structure and shelf life

Structure	**The duration of the conversation**			
	1-7 days	**7-14 days**	**>14 days**	**Total**
Food	**35**	**27**	**0**	**45**
Food and Butcher's shop	**12**	**0**	**0**	**12**
Butchery and charcuterie	**14**	**2**	**0**	**16**
supermarket	**10**	**0**	**1**	**11**

The storage time of food products in structures varies from 1-7 days for the majority.

Although low temperature is essential for maintaining the quality of fresh produce, it is well known that bacterial growth, and therefore spoilage rate, is strongly influenced by storage temperature and shelf life [36]:Fish is highly perishable due to its biological composition, and the shelf life of refrigerated fish is limited primarily due to microbial activities, therefore fish products require low temperature conditions to keep spoilage to a minimum. low rate. And aShelf life of 12 days requires continuous storage temperature of 0°C. [37]

Meat is a perishable product with a short shelf life and therefore short sales times. Therefore, cold chain management in meat supply and preservation is of utmost importance for maintaining the quality and safety of meat/meat products[38]. Raw meat/meat products are likely to support the growth of pathogenic microorganisms and/or spoilage bacteria and should be stored at temperatures that do not pose a health risk. The cold chain must not be interrupted at any time throughout the meat distribution chain.[39]

Table VII: Structures and products from deteriorate

Structure	From damaged products		Total
	Free distribution N (%)	Elimination N (%)	
Food	12 (26.7%)	33 (73.3%)	45
Food and butchery	3 (25%)	9 (75%)	12
Charcuterie and butchery	2 (12.5%)	14 (87.5%)	16
Supermarket	5 (45.5%)	6 (54.6%)	11
Total	22 (25.20%)	62 (74.80%)	84

In the event of deterioration of food products, disposal as waste constitutes the most used method in 73.80% of cases compared to 25.20% of cases which claim to distribute damaged products free of charge in the community.

Thus, 25.20% wrongly consumed by the population who believe they are receiving a donation, could be responsible for illnesses and 74.80% of damaged products will constitute food releases into the environment. Unfortunately, food loss and waste are one of the biggest problems in the modern world. The scale of this phenomenon is so great that it should be treated as a global problem.[40]The Food Waste Index report prepared by the United Nations (UNEP) shows that 931 million tonnes of edible food are wasted worldwide each year, representing 17% of the food available to consumers.[41]Meat and meat production meat products are characterized by an unfavorable impact on the environment, which requires rational management of these products throughout the chain: production, processing, transport and consumption. Reducing food loss and waste across the meat sector is important for economic and environmental reasons.[42]

I n developing regions (North Africa, West and Central Asia, Latin America, South and Southeast Asia, Sub-Saharan Africa), most losses and waste occur at the production and production levels. storage[43] because of insufficient infrastructure and lack of investment in storage technologies[44,45]

Conclusion

Maintaining adequate temperature control is essential to ensure food safety and minimize the risk of foodborne illness. Cold chains help prevent the proliferation of harmful bacteria and pathogens in perishable food, thereby protecting the health of consumers. Currently, the food cold chain is responsible for 4% of global GHG emissions, including emissions related to cold chain technologies and food loss and waste due to lack of refrigeration. This may seem small, but it is not. This is the equivalent of the contribution of the entire African continent to climate change.

Foods supplied throughout the cold chain are vulnerable to ambient temperature. There is always a risk of deterioration due to accidents or improper handling. Spoiled food cannot be sold or served, resulting in wastage of all materials. Thus, guaranteeing a reliable food cold chain is crucial to making our food system sustainable and allows the minimization of its environmental footprint.

Maintaining a consistent cold chain requires specialized equipment, monitoring systems. Temperature fluctuations: Extreme weather conditions in remote locations can cause rapid temperature fluctuations, making it difficult to maintain the temperature range. temperature required for sensitive products. Monitoring and maintaining a cold chain require advanced technologies such as temperature sensors, data loggers and real-time tracking systems. Remote areas often do not have access to these technologies, making it difficult to ensure the integrity of the cold chain. So the use of solar-powered refrigeration units can provide a sustainable solution for areas with unreliable electricity. These units can operate independently, ensuring that the cold chain remains intact even in areas with inconsistent power supply.

Indeed, the production of meat and meat products is characterized by an unfavorable impact on the environment, which requires rational management of these products throughout the chain. Food loss and waste is indeed global, and in the meat sector this problem appears to be of particular importance in terms of economic and environmental aspects which constitute a key factor influencing food waste management decisions taken by retailers. These impacts can include GHG emissions, water consumption and pollution of water, air, and soil systems.

Reducing food waste is now a challenge facing governments, charities, businesses, and individuals, with the United Nations aiming to halve global per capita food waste at the retail and consumer level. by 2030 [46].

Also, the use and disposal of animal by-products (AAP; foods no longer intended for human consumption consisting of or containing products of animal origin) from food retailers must be strictly regulated.

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