Breaking the barrier against the purchase of cold meat in Tanzanian consumers for reduction of postharvest losses and improved investment in cold chains: A review

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Abstract: Suppose the realization of Tanzania’s government’s commitment to industrialize the country is to be achieved. In that case, the certainty of value addition to agricultural produce and the resulting extensive supply chain, encompassing meat, becomes apparent. Without the development and utilization of cold chains, progress toward industrialization in the meat industry remains unattainable. Considering the current infrastructure of cold chains in Tanzanian abattoirs, meat processing plants, and specialized retail establishments, the estimated cold storage capacity stands at 6,700 tons of meat per day, equating to 39 kg per capita annually. Despite this capacity, approximately 100,000 metric tons of meat, equivalent to 15% of Tanzania’s yearly production, are lost due to postharvest losses and waste. This substantial loss could be significantly mitigated by appropriately implementing cold chains. However, over 90% of meat consumers in Tanzania and other African countries prefer to purchase warm meat and exhibit an aversion to cold meat. This consumer preference hinders comprehensive investment and the adoption of cold chains in the meat industry to reduce meat spoilage and postharvest losses. To overcome this barrier and bolster industrialization in Tanzania’s meat industry, a three-tier approach is necessary: coordinated consumer awareness campaigns to promote the suitability of cold meat, widespread training of stakeholders in the value chain regarding proper meat handling and storage practices, and the implementation of adequate legislation to guide the gradual transformation of the supply chain towards the provision of cold meat. In conclusion, the current cold storage capacity for meat in Tanzania primarily serves export and niche markets. Efforts are required to shift local consumers’ attitudes towards cold meat, enabling comprehensive investment and utilization of the cold chain in the meat industry to mitigate postharvest meat losses.

Keywords: cold chain, consumer behaviour, post-harvest losses, warm meat

1. Introduction

Tanzania’s substantial livestock resource comprises 35.3 million cattle, 25.6 million goats, 8.8 million sheep, and 92.8 million chickens (URT 2022). Despite the magnitude of this resource, the contribution of the livestock sector to the national gross domestic product stands at a mere 7.1%. Postharvest losses present one of the numerous challenges encountered by the livestock sector in the country (TLMP 2017). It is estimated that approximately 100,000 metric tons of meat, equivalent to 15% of Tanzania’s yearly production, are wasted due to postharvest losses and waste. This substantial loss carries severe environmental, social, and economic consequences (Stefan et al 2013; Ren et al 2022). Raising awareness regarding the occurrence of meat losses and waste, including their causes and locations, will facilitate the recovery of meat that would otherwise go to waste (Ranaei et al 2021). This awareness is expected to drive both private and public sector actions aimed at salvaging the meat produced but currently unavailable for human consumption.

Meat spoilage has been shown to contribute significantly to meat loss throughout the value chain (Ye et al 2019; Jofré et al 2019). However, this loss can be mitigated simply by effectively managing the meat value chain, including the implementation of cold chains (Bassey et al 2021; Ren et al 2022). Cold chains are employed to lower the temperature of meat at various stages of handling, inhibiting the growth of microorganisms, reducing enzyme activity, and slowing the rate of meat deterioration (Han et al 2021; Ren et al 2022). Nonetheless, in Tanzania, as in many other African countries, the majority of consumers (over 90%) prefer to purchase warm meat, as it is perceived to be “fresh.” This consumer behavior acts as a barrier to comprehensive investment and the utilization of cold chains in the meat industry for reducing postharvest meat losses. This perception may have stemmed from past consumer experiences with cold-purchased meat exhibiting signs of spoilage due to inadequate cold storage. It is understood that any disruption of temperature and/or humidity beyond tolerable ranges at any
stage of cold storage renders the entire cold chain ineffective (Ndraha et al 2018; Han et al 2021). Furthermore, cross-contamination of meat before storage also contributes to meat spoilage during cold storage (Ye et al 2019; Jofré et al 2019).

Warm meat refers to meat obtained from animals slaughtered on the same day and not cooled below ambient temperature. It is known that the nutrient-rich nature of meats makes it a suitable medium for the growth and proliferation of spoilage and pathogenic microorganisms if not adequately stored (Zhou et al 2010; Bassey et al 2021; Ren et al 2022). Hence, the utilization of cold chains in meat supply is essential for maintaining the quality and safety of meat by inhibiting microbial growth. Furthermore, adequately handled cold meat surpasses warm meat in terms of eating quality (Zhang et al 2022; Barragán-Hernández et al 2022). Cold storage of meat beyond the day of slaughter improves tenderness, flavor, and dry matter content. Thus, cold storage enhances meat quality, extends shelf life and distribution chains, reduces postharvest losses, lessens the demand on the environment to support livelihoods, and diminishes the impact of food production on climate change (Nastasijević et al 2017; Kayikci et al 2020; Bassey et al 2021).

Breaking the barrier against the majority of Tanzanian consumers’ preference for warm meat is crucial to realize the benefits associated with cold storage. To the best of my knowledge, there has been no systematic study conducted on the use of cold chains and postharvest meat loss and waste in Tanzania. Consequently, there is limited literature available on these two aspects of the meat value chain in the country. This paper aims to review postharvest meat loss and waste in Tanzania, the extent to which cold chains are employed in the meat industry, the limitations hindering their use, and the necessary interventions to scale up their implementation and foster further investment, enabling the country to fully reap the benefits associated with the use of cold chains.

2. Postharvest meat loss and waste

Meat loss is the reduction in quantity or quality at the pre-consumer stages in production, postharvest, and processing. In contrast, meat waste is the removal from the supply chain of meat appropriate for human consumption or spoiled or expired for various reasons, mainly due to consumer behaviour (Stefan et al 2013; Kayikci et al 2020; Ranaei et al 2021). Globally, 30% of food produced for human consumption is lost or wasted (Ranaei et al 2021). When converted into calories, about one out of every four calories is wasted and therefore unavailable for human consumption (Lipinski et al 2013). As shown in Figure 1, postharvest losses (PHL) in developing countries mainly occur at the postharvest level (close to the farm).

![Figure 1](https://www.malque.pub/ojs/index.php/mr)

**Figure 1** Part of the initial production lost or wasted for meat products at different stages in the FSC in different regions. **Source:** FAO 2011

Some causes of PHL are structural and related to a lack of infrastructure, such as cold chains and processing facilities (Han et al 2021). Other causes are systemic, related to improper systems functioning and non-supportive policies and regulations. In contrast, in developed countries, it occurs mainly at the retail and consumer level - close to the fork (Sawaya 2017).

In Tanzania, structural causes of meat loss relate to the quality of slaughter facilities and meat distribution infrastructure. The majority of the 1,502 slaughter facilities in the country fall under the slaughter slabs category, which is poorly designed and not fitted with the requisite infrastructure. In these facilities, proper handling of carcasses is quite a challenge. *Rigour mortis* is induced at inappropriate temperature and humidity, which can lead to excessive shrinkage and weight loss from drip loss (Hultgren et al 2022; Kumar et al 2023). In abnormal *rigour mortis*, meat is lost due to quality changes in the form of dark firm dry (DFD), pale soft exudative (PSE), cold shortening, thaw, and heat rigour (Ranaei et al 2021; Hultgren et al 2022). In addition, the lack of facilities to restrain animals and render them insensible before slaughter causes animals to be slaughtered while struggling for their last chance to survive. Under this stressful condition, animals mobilise energy reserves to combat the stressor leading to carcasses with low glycogen reserves (Hultgren et al 2022; Kumar et al 2023). Carcasses may not attain optimum ultimate pH with concomitant low water holding capacity (Shange et al 2018; Zhao et al 2022). Meat from such
carcasses is prone to high drip loss, purge loss, evaporative weight loss, and shorter shelf life (Ranaei et al 2021; Barragán-Hernández et al 2022).

Meat distribution infrastructure that includes meat transportation and retailing in meat shops are other likely hotspots for meat loss in Tanzania. Except for the refrigerated meat vans serving the export processing abattoirs, the rest mainly distribute meat for local consumption. They are not fitted with the necessary infrastructure. Similarly, most meat shops are not equipped with the requisite infrastructure to enable hygienic meat handling and proper storage. The most critical challenge is that the operators of both meat vans and meat shops are not well-versed with appropriate knowledge on meat handling despite the efforts invested by the Tanzania Meat Board (TMB 2022) in training them, mainly because of their high turnover rate. However, as most consumers in Tanzania prefer purchasing warm meat in quantities just enough for the same day’s meal, the time interval between animal slaughter and cooking of the meat obtained is very short. For this reason, the effects of poor infrastructure and meat handling have neither been pronounced nor a matter of public health concern.

Globally, 20% of meat for human consumption is lost or wasted in the meat value chain (Halloran et al 2014; Kayikci et al 2020; Ranaei et al 2021). In Sub-Saharan Africa (SSA), 15% of the meat produced is lost during postharvest handling, storage, processing, packaging, and distribution (Gustavsson et al 2013; Han et al 2021). To my knowledge, no systematic study has been carried out on the PHL of meat in Tanzania. However, going by the established percentage of PHL of meat in SSA, the quantity and value of PHL of meat in Tanzania can be estimated (Fig. 2). Despite the increase in meat production from 597,757 in the year 2014/2015 to 738,165 tons in 2020/2021 financial year; the country probably experienced an average loss of 100,000 tons of meat worth 300,000 USD every year due to PHL. Reducing this loss and waste is essential in reducing the economic and environmental costs of meat production in Tanzania.

Figure 2 Estimates of meat production and losses in Tanzania. Source: Derived from the Budget speeches for the Ministry of Livestock and Fisheries.

Reduction of PHL is tantamount to lessening the demand on the environment to support livelihood and therefore reducing the impact of food production on climate change (Saway 2017). Food loss and waste account for around 8% of global greenhouse gas emissions, arising from the land, livestock, and energy inputs needed in food systems and waste disposal (Lipinski et al 2013). Although the proportion of global meat production that is lost (20%) is not as high as that of cereals (30%) or root crops (40%–50%), the carbon footprint of meat production and the impact of meat waste on greenhouse gas emissions are higher than that of cereals and root crops (Saway 2017). Therefore, the prevention of PHL is an essential strategy for meeting the demand for meat without any extra production and unnecessary GHG emissions (Kayikci et al 2020). In this connection, the Sustainable Development Goals (SDGs) recognise food waste and loss as essential components of food insecurity under the Zero Hunger Challenge (Halloran et al 2014). Overall, meat loss and waste distort meat availability, exacerbate rising meat prices, and put excessive pressure on the environment (Kayikci et al 2020).

3. Meat spoilage

Meat spoilage is caused by the activities of spoilage bacteria, mould and/or endogenous enzymes, all of which trigger physicochemical changes in meat (Han et al 2021). Although endogenous enzymes are also responsible for the deterioration of meat through processes like proteolysis, lipolysis, and oxidation, microbial spoilage is by far the most critical factor in the shelf life of fresh meat (Nastasijević et al 2017; Bassey et al 2021). About 25% of postharvest food loss globally is caused by microbial spoilage (Bassey et al 2021). The candidate bacteria responsible for food spoilage are Pseudomonas spp., Enterobacteriaceae, Brochothrix thermosphacta, and lactic acid bacteria - LAB (Bassey et al 2021). Pseudomonads, Lactobacillus, and Enterococcus produce slime on meat, while Enterococcus have hydrogen peroxide greening spots, similar to greening caused by Clostridium.
These specific spoilage organisms typically damage food texture and cause malodours and off-flavours. The growth of these bacteria on the meat surface is determined by the storage temperature, pH, water activity, nutrient availability, storage atmosphere (aerobic or anaerobic), and competition with other microflora present in meat (Nastasijević et al 2017; Bassey et al 2021; Ren et al 2022). An efficient cold chain eliminates or reduces the rate of microbiological invasion in foods (Bassey et al 2021). To prevent microbial growth and extend the shelf life, the warmest point of the carcass (centre of the hind leg) has to attain a temperature of < 7°C for red meat or < 4°C for poultry meat (Nastasijević et al 2017). These temperatures can be attained in 16 - 24 hours in small carcasses (lamb, goat), less than 48 hours in large carcasses (beef, pork), and less than two hours in poultry carcasses. However, carcasses must not be cooled so fast and trigger the formation of cold-shortening and excessive meat toughness (Nastasijević et al 2017; Yan et al 2022). Based on this understanding, it is recommended that beef and lamb carcasses should not be cooled to < 10°C within the first 10 hours.

4. Use of cold chain as a solution to PHL

Time-temperature (t - T) profiles along the meat supply chain are essential predictors of meat shelf-life (Mercier et al 2017; Nastasijević et al 2017). Cold chains lower meat temperature to below ambient temperature during different stages of meat production, processing, storage, transportation, sales, and at the point of final consumption to inhibit the growth of microorganisms, reduce enzyme activity and slow the rate of meat deterioration (Ren et al 2022). Combining chilling and frozen storage has extended the meat’s shelf life to over a year (Nastasijević et al 2017). However, any interruption of temperature and/or humidity beyond the tolerable ranges at any stage of the meat supply chain renders the entire cold chain useless (Ndraha et al 2018). Suppose the cold supply chain is absent or breached, the meat will suffer from a range of quality problems such as shrinkage, rotting, trim loss, unpleasant odour, colour and texture changes, as well as health risks from pathogens such as Salmonella or food poisoning from toxin-producing E. coli and Listeria monocytogenes (Zhou et al 2010; Ren et al 2022). Thus, uninterrupted temperature and humidity conditions in cold chains are essential for ensuring meat quality and safety.

Han et al (2021) outlined five nexuses in the cold chain that are vital for maintaining the quality and safety of fresh agricultural products to reduce food loss and waste, namely: i) Precooling, ii) refrigerated warehouse, iii) refrigerated transport, iv) Retail refrigeration, v) Domestic refrigeration. Precooling (PCL) is used to lower carcass temperature immediately after slaughtering before storage in a low-temperature environment (Duan et al 2020). The carcass core temperature is reduced to below 7 °C to prevent large temperature fluctuations in the subsequent cold chain stages. Studies have shown that PCL is the most important and critical stage of all operations in the supply chain for the successful maintenance and storage of fresh and perishable produce (Duan et al 2020; Han et al 2021). Refrigerated warehouses (RWH) provide a suitable, stable, and long-term low-temperature environment to preserve fresh meat quality after PCL. RWH provides centralized storage and management of fresh meat, allowing vendors to balance supply and demand. The temperature of RWH usually is maintained at -18°C, which is achieved either by using cold air alone or a modified storage atmosphere (Oliveira et al 2015). In modified atmosphere storage, the atmosphere’s composition is altered to inhibit microbial activity and physiological and biochemical processes of food deterioration to extend food shelf life further.

Refrigerated transports (RFT) connect the upstream and downstream nodes in the cold chain. RFT is mainly responsible for maintaining a stable and uniform temperature and humidity condition of precooled meat throughout transportation to preserve its quality, safety, and shelf-life (Tassou et al 2009). Although the modes of RFT vary from marine, air, and road to railway, road transport using refrigerated vehicles is the most common mode of meat transport (Francis et al 2017). The set temperature in the RFT depends on whether the transported meat product is frozen (-18 °C) or chilled (0 - 2°C).

Refrigeration at retail stores is the final and last line of defence in the meat supply chain before the meat reaches the consumer (Wu et al 2017; Talbot et al 2020). Refrigeration at this stage can be done in refrigerated display cabinets or frozen storage. However, refrigerated display cabinets are the most extensively used in retail stores worldwide to store, display, and sell chilled meat products (Chaomuang et al 2017; Lindberg 2020; Talbot et al 2020). Retailing meat is the most vulnerable stage, and a lack of strict supervision of the cold chain at this stage can make the whole cold chain inadequate to maintain meat quality and safety. Thus, any abuse in the cold chain in the early stages of meat handling impacts the quality and safety of meat in retail stores negatively.

Once fresh meat has been purchased from retail stores, its quality and safety are determined by how consumers handle, transport, and store it in their domestic refrigerators (James et al 2017; Jofré et al 2019). Meat may spend a considerable portion of its shelf life in household storage; therefore, domestic refrigeration is a critical link to the cold chain. Its proper implementation is vital to reducing meat waste and the risk of foodborne diseases. Temperature fluctuations in domestic refrigeration strongly affect meat quality and shelf-life because the growth rate of spoilage bacteria increases exponentially with temperature (James et al 2017; Han et al 2021). Studies have shown that most domestic refrigerators are not maintained at temperatures required to inhibit microbial growth. Some studies show that 50 % of domestic refrigerators have the internal temperature maintained above 6 °C in a 24 h period (Roccato et al 2017; Owca et al 2021). Greater temperature fluctuations lead to more significant reductions in shelf life. The number of door openings and time of the day affect temperature fluctuation in domestic refrigeration. The warmer part of the day leads to a greater change in refrigeration temperature due to the more
significant difference between ambient and refrigerator temperatures. Thus, to reduce temperature fluctuations and microbial contaminations in domestic refrigerators, regular temperature verifications, cleaning, and disinfection of refrigerators are essential (Ye et al 2019; Jofré et al 2019).

Overall, each link in the cold chain is interrelated and interdependent on the other links. Any interruption in any of the links may accelerate the rate of food spoilage and render subsequent application of the cold chain irrelevant with concomitant meat loss and waste (Han et al 2021; Ren et al 2022). Thus, maintaining the integrity of the cold chain along the meat supply chain is crucial in reducing meat loss and waste.

5. Quality improvement during cold storage of meat

Meat is immediately tender at slaughter, toughens at rigour due to myofiber’s shortening, and tenderizes during ageing due to proteolytic activities of endogenous enzymes (fig. 3) (Prates 2002; Warner et al 2022). Cold storage of meat above freezing temperatures improves meat tenderness, a process known as ageing or conditioning (Herrera-Mendez et al 2006; della Malva et al 2022). Ageing of meat postmortem in an anaerobic environment allows proteolysis to proceed and flavour, tenderness and dry matter content to improve (Warner et al 2017; Gagaoua et al 2021). Postmortem meat storage at optimum refrigerated conditions allows proteolytic enzymes (mainly calpains and cathepsins) to fragment key myofibrilla and associated proteins responsible for maintaining myofiber’s structural integrity (Herrera-Mendez et al 2006; Warner et al 2022). These are proteins involved in inter- (e.g., desmin and vinculin) and intra-myofibril (e.g., titin, nebulin, and troponin-T) linkages or linking myofibrils to the sarcolemma (e.g., vinculin and dystrophin) or attachment of muscle fibers to the basal lamina (e.g., laminin and fibronectin) (Koohmaraie and Geesink 2006; Gagaoua et al 2021). Proteolytic breakdown of these myofibrilla proteins during ageing is responsible for the weakening of muscle integrity and increased meat tenderness.

On the other hand, during postmortem ageing, proteolysis and lipolysis break down large, flavourless molecules into smaller flavourful fragments like branched-chain fatty acids, phenols, sulphur compounds, and heterocyclics (Holman et al 2020; Zhang et al 2022). These degraded compounds provide specific aromas and flavours or become important precursors to drive complex biochemical reactions during cooking. In addition, drip loss and evaporative water loss during cold storage increase dry matter content and nutrient concentration. Therefore, aged meat gives more nutrients per unit weight than warm meat. However, appropriate ageing time and environment (e.g., temperature, humidity, ventilation, and aeration) should be observed during meat ageing for optimum outcomes. In this connection, it is recommended that beef should be aged for 10 – 14 days, goat and lamb for 7 – 10 days, pork for 4 -10 days, and chicken for 0.3 days at 0 – 4 °C to maximize the benefits of postmortem storage of meat (Sentandreu et al 2002; Zhang et al 2022).

6. Meat supply chain in Tanzania

The meat supply chain in Tanzania involves primary producers who sell animals in the primary markets either directly or through middlemen. From the primary markets, animals are moved to either secondary markets for aggregation or directly to slaughter facilities. Animals from the current 504 primary and 14 secondary markets in Tanzania are slaughtered in 1,286 rural slaughter slabs, 194 rural or urban slaughterhouses, and 22 abattoirs (TMB 2022). Most slaughter slabs and slaughterhouses are generally old, have dilapidated infrastructure, and often, the number of animals slaughtered exceeds the installed capacity, posing a risk to animal welfare and meat hygiene (Wilson 2015). A small proportion of marketed animals are slaughtered in the
existing public or private abattoirs. Carcasses from slaughter facilities are moved to retail outlets or processing plants for value addition. In Tanzania, meat is retailed mainly through butcher shops. Because of the preferential demand for warm undifferentiated meat, meat is sold “warm” to consumers through an array of small butcher shops in villages, towns, and cities of the country.

Currently, there are 6,395 butcher shops of varying levels of infrastructure (TMB 2022). However, a growing market segment of the urban middle-income group, which is more discerning in its purchasing habits, demands better quality meat for which they are willing to pay a premium price. In addition, the fast-growing tourist industry in Tanzania, partly due to the famous "Royal tour", poses further demand for quality meat in tourist hotels, specialized restaurants, and supermarkets. To serve that niche market, there are 111 premium butchers and 22 super-butchers in Tanzania (TMB 2022). Premium and super-butchers are well managed and have improved infrastructure, including cold chain, compared to standard butchers.

The value-added meat and meat products constitute only a small fraction of Tanzania’s meat supply. The country’s critical outlets for processed products are supermarkets, some specialist urban butcheries (premium and super butchers), hotels, and other food service areas (Wilson 2015). However, the market for value-added meat is expected to grow with the ensuing increase in wealthier urban dwellers, the emerging middle-income class, and the growing tourist industry. In response to this trajectory, the number of meat processing plants in Tanzania has increased almost three-fold (Table 1) compared to only seven (7) plants recorded in 2015 (Wilson 2015).

Table 1 Number of meat processing facilities in Tanzania with installed cold chain

<table>
<thead>
<tr>
<th>Current status</th>
<th>Number of premises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of abattoirs present</td>
<td>31</td>
</tr>
<tr>
<td>Operational abattoirs</td>
<td>22</td>
</tr>
<tr>
<td>Abattoirs Certified for export processing</td>
<td>6</td>
</tr>
<tr>
<td>Operational meat processing plants</td>
<td>19</td>
</tr>
<tr>
<td>Non-operational abattoirs/meat processing plants</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: TMB (2022)

Abattoirs in Tanzania are designed mainly to supply the export market. Therefore, they are well managed, fitted with requisite infrastructure for hygienic meat handling, equipped with cold chain facilities (chillers, freezers, and refrigerated trucks), and observe recommended procedures to preserve meat quality and safety. Six (6) abattoirs have export certification (Table 1). The number of abattoirs certified for export processing has increased with a concomitant increase in quantities of meat exports (Fig.4). Despite this improvement, these abattoirs are facing marketing difficulties, and generally, they operate at less than their installed capacity. Currently, the main export markets for meat from Tanzania include Qatar, United Arab Emirates, Bahrain, Kuwait, Oman, Comoro, Hong Kong, Jordan, Saudi Arabia, and Zanzibar. In the 2021/2022 financial year, Tanzania exported 10,415 tons of meat worth USD 42 million. This is a big leap compared to quantities exported in previous years (Fig. 4). However, Tanzania has the potential to gain preferential access to additional export markets with discerning consumers by selling such meat from grass-fed animals as organic.

Figure 4 Quantities of meat exported from Tanzania from 2015. Source: Annual Technical reports from the Tanzania Meat Board
7. Use of cold chain in the meat industry in Tanzania

Cold chains are more pronounced in abattoirs and meat processing plants, focusing mainly on a niche market (Table 1). Based on the existing infrastructure for cold chains in abattoirs, meat processing plants, supermarkets, and premium and super-butchers in Tanzania (TMB 2022), the current cold storage capacity is estimated at 6,700 tons of meat per day, equivalent to 39 kg per capita per year. This capacity is about two-fold higher than the capacity reported for Iran (Ranaei et al 2021). However, because consumers in Tanzania prefer fresh “warm meat”, most meat outlets sell meat that is chopped directly from the hot carcass. Except for the specialist retail outlets, only a small amount of frozen meat is sold in retail outlets, where freezing is mainly done in chest freezers for the meat not sold on the day of slaughter (Wilson 2015).

The consumer preference for warm meat is based on the general thinking that warm meat is fresh and has not gone bad. However, as indicated above, spoilage of cold meat before reaching consumers may occur due to unhygienic handling of meat along the value chain or inadequate cold storage due to interruptions in storage temperature and humidity beyond tolerable limits (Ndraha et al 2018; Han et al 2021). It is envisaged that comprehensive training of value chain actors on hygienic meat handling and proper management of cold chains will eliminate potential breaks in the cold chain in Tanzania and increase customer acceptance of cold meat. On the other hand, frequent power outages in the past might have negatively impacted Tanzania’s cold chains. However, the current power supply from the national grid is fairly stable due to additional investment in power generation and rehabilitation of power supply infrastructure (Chambile et al 2021; Dye 2021). To encourage further investment in the cold chain and proper use of the existing cold chain at different nodes of the meat value chain, the government of Tanzania should also review electricity tariffs implemented by the national electric supply company (TANESCO) from time to time to make electricity affordable (Alananga and Igangula 2022; Twesigye 2022).

8. Proposed interventions to promote the use of cold chain in Tanzania

To scale up the use and further investment in the cold chain in Tanzania, interventions are required at various stages of meat production, processing, storage, transportation, sales, and at the point of final consumption, as outlined below.

8.1. Abattoir level

As indicated above, most of Tanzania’s 1,286 slaughter slabs and 194 slaughterhouses are characterised by poor infrastructure, unskilled workforce, and unhygienic conditions. As mentioned above, cross-contamination of meat before storage renders the cold chain ineffective. Proper training of operators of slaughter facilities is key to circumventing the problem of cross-contamination of carcasses and increasing the acceptability of cold meat by consumers. Proper handling of animals during slaughter, evisceration, and dressing operations is very important in preventing microbial cross-contamination, especially on the meat surface, via contact with equipment, tools, hands, clothes, and objects, among others (Nastasijević et al 2017; Ranaei et al 2021). Usually, meat from healthy animals handled hygienically during slaughter is considered practically aseptic. However, during slaughter, evisceration, and dressing operations, microbial cross-contamination usually occurs, especially on the surface of the meat, via contact with equipment (Kayikci et al 2020; Ranaei et al 2021). Therefore, operators of slaughter facilities should be trained in hygienic handling of carcasses to ensure the set minimum standards are achieved.

The gradual transformation of rural slaughter slabs and municipal slaughterhouses into modern slaughter facilities fitted with requisite infrastructure for meat handling and storage is critical to reducing postharvest meat losses at this point of the supply chain. One way to achieve this transformation is by creating a conducive environment to attract the private sector to invest in cold chain slaughter facilities. To achieve this goal, the Government should consider providing tax incentives for infrastructure needed to support the efforts to transform slaughter facilities in the country. In addition, this transformation will require government intervention through relentless enforcement of regulations under the Meat Industry Act Cap 421, which prohibits the production and supply of meat from unregistered or poorly designed and equipped slaughter facilities. However, implementing this intervention may be difficult as the local government owns all municipal slaughterhouses.

8.2. Distribution level

Inadequate storage, distribution, and retail temperatures can significantly reduce shelf life and early spoilage of meat and meat products. Temperature abuses can occur in the cold chain during chilling, storage, transportation, and transferring meat products from one actor to another and during consolidation and deconsolidation at retail (Nastasijević et al 2017). Such abuses may cause meat spoilage before the use-by date is reached, leading to food waste and economic losses. Thus, using proper temperature regimes for chilling and freezing meat in supply chains is vital for delivering products that consumers will accept for their freshness and safety levels (Nastasijević et al 2017).

Thus, training operators in the meat value chain on proper handling of meat and storage conditions (e.g., temperature and humidity) are important determinants of the meat quality, shelf life and acceptability to consumers. Operators should be informed of the effects of the size and capacity of chilling facilities at a retail establishment, the initial temperature of incoming meat, meat handling procedures (cutting, mincing), temperatures of surroundings, location of refrigeration machinery, number of door openings, ventilation and light on the effectiveness of the cold chain. Raising awareness of the consequences of abuse...
of the temperature and humidity conditions in any node of the cold chain and the efficacy of subsequent cold chain nodes will also help recover otherwise wasted meat.

8.3. Processor level

About 19 active meat processing plants in Tanzania are well-equipped, approved by the Tanzania Bureau of Standards, and registered by the Tanzania Meat Board. Provided that areas of meat loss in processing plants are known, operators of meat processing plants should be retooled to be able to take action to reduce meat waste and loss at this point (Ranaei et al 2021). Although very little data is available on this group of actors, estimates show that edible food waste is only 1–2 per cent of total production (Halloran et al 2014). Implementing hygienic handling of meat during processing and storage are key points to reducing contamination and assuring the final product is fit for human consumption.

8.4. Consumer-level

As indicated earlier, most consumers in Tanzania prefer to purchase “warm meat” and even have an aversion towards cold meat. This consumer behaviour in Tanzania also reflects the situation in most Sub-Saharan African countries. Although old habits die hard, running consumer awareness campaigns on the proper use and advantages of the cold chain can change this consumer behaviour. Developing platforms for knowledge sharing and dissemination, including proper meat handling and storage, will accelerate consumer behaviour changes, especially on how they consume food. It is envisaged that the change in consumer behaviour will offer the comforting confidence on a return to investment that cold chain operators will be looking for.

Raising consumer awareness of the environmental consequences of meat loss and waste may mitigate further postharvest meat losses (Stefan et al 2013). Consumers should know that any wasted meat, wastes resources that go into meat production, distribution, and marketing, including land, water, and energy (Stefan et al 2013; Halloran et al 2014; Wilson et al 2017). This realization is anticipated to change consumer attitudes toward wasting meat and build a sense of environmental responsibility (Wikström et al 2016).

8.5. Policy level

Suppose Tanzania’s determination to achieve its industrialization goals is to be realized. In that case, creating a market-driven solution to address the low utilization of cold chains in the meat industry is imperative, with the initial focus placed on establishing an “appropriate policy framework.” The barrier against the purchase of cold meat in Tanzania can only be overcome through market-driven change, which, in turn, necessitates the implementation of revised and well-executed legislation. The enactment of proper legislation to promote the adoption of cold chains in the meat value chain will have a significant impact on reducing postharvest meat losses, mitigating economic losses, and curbing unnecessary Greenhouse Gas (GHG) emissions, thereby contributing to climate change mitigation (Kayikci et al 2020; Ren et al 2022).

Researchers and policymakers should lead in developing mechanisms and specific policies to encourage the adoption of cold chains in Tanzania. The policy framework may adopt various forms, such as gradually mandating particular market segments to procure exclusively cold meat or formulating policies that actively promote the use of cold chains. For instance, to properly utilize existing cold chains at different points along the meat value chain, the Tanzanian government should review the electricity tariffs imposed by the national electricity supply company to ensure affordability. Unaffordable tariffs may lead cold chain operators to shut down the cold chains as a cost-saving measure intermittently. Such practices can disrupt the temperature and humidity within the cold chain, adversely affecting the quality and safety of meat stored under cold conditions (Nastasijević et al 2017).

9. Final considerations

The export and niche markets primarily benefit from the current utilization of cold chain storage capacity for meat in Tanzania. The willingness of the private sector to invest in the cold chain is hindered by consumers’ reluctance to purchase cold meat. Efforts are needed to alter the attitudes of local consumers towards cold meat to enable comprehensive investment and utilization of the cold chain in the meat industry for reducing postharvest meat losses. Further research is necessary to understand the social, economic, and environmental consequences associated with meat loss and waste in Tanzania, including the total volume of postharvest meat loss and the efficacy of the proposed mitigation strategies.

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