Climatic Weather Changes on Food Cold-Chain and Evolving Mitigating Strategy

By

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ABSTRACT

Transportation of fresh raw produce is an unbroken handling of raw fruits within a low temperature conditions during the postharvest period of the value chain. This process involves the transporting of these fresh fruits until it reaches the final destination with un-altered shelf life. The environmental impact of preserving raw fruits remains a source of concerns amid deteriorating climatic weather conditions in most developing countries. In this study, attempts were made to x-ray the environmental impact of unbroken cold chain in the face of rising ambient temperature. Any slight increase in ambient temperature as a result of climatic change will have a negative impact on the current and developing cold-chain thereby increasing global CO_2 content. This short communication discusses key of the lapses fuelling excessive thermal load in cold chain and evolving mitigating strategy.

Keywords: cooling chamber, cold chain, raw fruits, environment, energy.

INTRODUCTION

Studies (Galos, Sutcliffe, Cebon, Piecyk, & Greening, 2015; Hutter et al., 2015) have shown that, between 1900 and 2005, there has been a slight rise of about 0.45°C in global temperature. This increase appears to be proportional to about 0.1 °C rise in last 9 years. In developing countries, these increases is much higher, as evident in the extreme temperature rise and worsening climate weather condition. However, such changes could be as a result of other factors and natural variability. Prediction in other published works(Browne, Allen, & Anderson, 2005; García-Álvarez, Pérez-Martínez, & González-Franco, 2013) showed that Australia may be heading toward temperature rise in the range of 0.4–2 °C by 2030, and 1–6 °C by 2070. Climate change has been described as a unifying risk factor facing the world in the face of food scarcity. Its contributing effect on food chain is putting all researchers in a difficult situation considering the impact of climate change on food availability. Findings from Adekomaya and his co-workers (Adekomaya, Jamiru, Sadiku, & Huan, 2016) has shown that food poisoning in cold chain is affected by seasonal changes, with major incidence occurring in the summer while fewer cases during the winter.

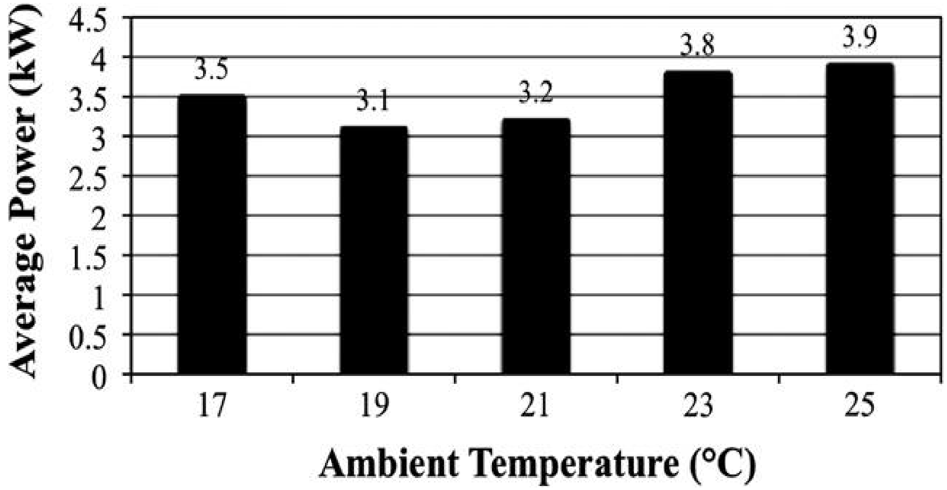

Figure 1: Rising ambient temperature and the corresponding power demand. Adapted from James (2010)

Transportation of perishable fresh raw food in the UK, accounted for about 30 billion vehicle kilometres in 2002, of which 82% of these transported raw foods lost their freshness. Road transport of these fresh food is being hindered by rising ambient temperature as depicted in Figure 1. Prediction from other works have shown that road freight vehicles produced 19 million tons of CO_2 in 2002, of which 10 million tons of these CO_2 were generated in the UK. Improvements in energy utilization would not only reduce distribution chain, but also minimize atmospheric gas emissions. The use of diesel-engine driven refrigeration equipment largely increases the level of emissions per ton of product distributed. Key of the advantage of refrigeration system is that it reduces the rate at which changes occurring in fresh food. These changes may sometimes be microbiological, physiological, and physical (e.g. moisture loss). In a comprehensive review work conducted by James e tal 2010, it was shown that the energy requirement in every stages of food storage is high as depicted in Table 1. This was further discussed elsewhere (Hoang, Laguerre, Moureh, & Flick, 2012) with similar data corroborating previous findings that 10% of perishable foodstuffs are currently refrigerated (Coulomb, 2008).

Table 1: Energy saving potentials of top ten food refrigeration processes. Adapted from (James & James, 2010)

Sector		Energy		Saving	
		'000 t CO_2/year GW h/year		% GW h/year	
1	Retail display	3100–6800	5800–12,700	30–50	6300
2	Catering – kitchen refrigeration	2100	4000	30–50	2000
3	Transport	1200	4800	20–25	1200
4	Cold storage – generic	500	900	20–40	360
5	Blast chilling – (hot) ready meals, pies	167–330	309–610	20–30	180

6	Blast freezing – (hot) potato products	120–220	220–420	20–30	130
7	Milk cooling – raw milk on farm	50–170	100–320	20–30	100
8	Dairy processing – milk/cheese	130	250	20–30	80
9	Potato storage – bulk raw potatoes	80–100	140–190	~30	60
10	Primary chilling – meat carcasses	60–80	110–140	20–30	40

Rising heat load through external wall materials

The rising ambient temperature and the weight of articulated road freight are the contributing factors to increasing energy demand and varying climatic weather conditions. One of the popular methods for predicting the energy required in cold chain is the degree-time method. This method was first applied in regulating heat infiltration in building as reported in other works (Dombaycı, 2007; Mahlia, Taufiq, Ismail, & Masjuki, 2007). The method basically says that the energy needed in maintaining equilibrium cooling status in building are proportional to the difference between the ambient temperature and the base temperature. The summation of heating loads applied to a building envelope can be calculated as

$$D_h = \sum_{j=1}^{N} (T_b - T_o), \text{for} \left(T_o \le T_b\right) \qquad (1)$$

Where T_o and T_b are the ambient and the indoor temperatures while N is the number of heating hours provided by the ambient temperature. It can also be estimated from Eq. (1), that D_h values may be positive based on the existing temperature conditions. Some other published works (James & James, 2010; Kayfeci, 2014; Kaynakli, 2008) have referred to outdoor temperature as only boundaries where heating is prevalent. In other works, the total heat transfer in a building envelope may be adopted to estimate the heat losses in the cold chain using the Eq. (2) as calculated

$$L = \sum_{i=1}^{M} UA + 1\left({}^{\circ} C_p \right)_{air} V / 3600 \qquad (2)$$

In some cases, M is often refers to the boundary where heat losses is most prevalent i.e. outside wall and basement areas. $\left({}^{\circ} C_p \right) air$ is the thermal capacity of air and it often used in the literature as 1200Jm^{-3}K^{-1} (Bakos, 2000; Hasan, 1999; Mohsen & Akash, 2001). The volumetric heat losses may further be expanded as shown in Eqn. (3)

$$L = U_{o,w}(162 - A_{wd}) + U_{wd}A_{wd} + U_{bm}A_{bm} + U_{c}A_{c} + IV/3 \quad (3)$$

In the light of the above, the volumetric heat losses can be used to predict the consumption patterns of fossil fuel demand in cooling chamber thereby assisting to mitigate the attendant climatic variation.

Mitigating heat losses in cold chain

Part of the concept developed in past works were harmonized in this section. Kayfeci, Keçebaş, and Gedik (2013) did an expansive work on heat infiltration and energy demand in building and their results showed a better way of minimizing thermal load in cold chains. In the work of Hoang et al. (2012), detail works were carried out to establish mitigating strategy of air infiltration during door openings. This led to the development of various models couple with the calculation of product temperatures with those obtained from transport of fruits and frozen foods in a semi-trailer. Good agreement was also established between the experimental and calculated results. In another paper, Dragano, Rossi, Bison, and Panozzo (2009) evaluated the absorption coefficient of the sandwich insulated panel as a basis of energy saving potential in refrigerated vehicles. Part of the conclusion drawn from the work indicated that this absorption coefficient may be expanded in the complex study of thermal balance of the cold refrigerated vehicle. In another work, Kayfeci and his co-workers investigated two medium of heat infiltration into the building envelope thereby establishing foundational models in heat load in cold chains. They also showed in their work the convective thermal transmission between ambient air and the inner surface of the cold chain which may be useful in the analysis of carbon emission in the atmosphere. This further led to the analysis of heat gain through cooling chamber as estimated as

$$Q_w = UA\left(T_{o,des} - T\right)_s = UA\Delta T \quad (4)$$

This equation may be expanded depending on the external wall structure and the variation in climatic weather conditions.

Evolving Mitigating strategy and Future Trends.

In many published works, food packaging in refrigerated vehicles has been cumbersome as a result of long distances from their point of origin to final destination. However, this must be addressed if raw fruits must be transported in an unbroken cold chain. Impacts of packaging materials on the shelf life of raw food has also been investigated in other works. Humbert, Loerincik, Rossi, Margni, and Jolliet (2009) did an experimental work using plastic pot and glass jar as packaging materials for baby food products and concluded that the plastic pot system tends to reduce carbon footprint by 28%–31% than the existing glass jar system. In another paper, Poovarodom, Ponnak, and Manatphrom (2012) demonstrated that the retort cup system for tuna products reduced the entire overall GHG emissions by 10% and 22% if compared with metal can and retort pouch systems, respectively. To further analyze the relevance of plastic packaging materials in prolonging the shelf life of fresh raw food, De Monte, Padoano, and Pozzetto (2005) appraised the environmental performances of alternative packaging systems for retail sales of coffee. Finding from their works showed that the use of polylaminate bags was a sustainable alternative option to metallic cans, even though some shortcomings were noted in the recycling of these packaging materials. In other published works (Calderón, Iglesias, Laca, Herrero, & Díaz, 2010; Iribarren, Hospido, Moreira, & Feijoo, 2010; Meneses, Pasqualino, & Castells, 2012), size of the parking materials were identified as a factor that influences the carbon footprint of food packaging. Trienekens and Zuurbier (2008) corroborated this finding in their work by concluding that 30% reduction in bottle weight for wine production may result in 4%–23% reduction of their total life cycle emissions. In a similar work,Vinyes et al. (2017) also illustrated that the carbon footprint of packing boxes decreased largely by reducing the crown as a result of increase of numbers of pineapples per box. In furtherance to the work of De Monte et al. (2005), they also affirmed that bigger packaging options had a smaller impact with respect to the functional unit of 1 kg of packed coffee. It is therefore believe that packaging design and sustainable material with practicable recyclability can reduce the deteriorating impact of raw food on environment. Pimentel et al. (2008) confirmed that multiple layers arrangement for cereals should be abandoned by adopting single and more durable package materials, while Hospido, Vazquez, Cuevas, Feijoo, and Moreira (2006) recommended an increase in the percentage of the recycled material which has the tendency to reduce environmental impact of canned-tuna product.

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