Renewable and Sustainable Energy Reviews 67 (2017) 89–93

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Minimizing energy consumption in refrigerated vehicles through alternative external wall

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ARTICLE INFO

Article history:
Received 5 September 2015
Received in revised form
16 August 2016
Accepted 6 September 2016

Keywords:
Insulation
Refrigeration
Shelf life
Heat transfer
Vehicles

ABSTRACT

Transporting fresh foods and raw agricultural produce have been widely acknowledged as a critical aspect of food chain. Raw fresh food must be conveyed at a low temperature conditions to preserve quality and prolong the shelf life of transported food. This paper takes an insight look at food transport system and proffers a sustainable ways of reducing energy consumption in diesel engine driven vapour compression system. Many studies have reported that 15% of world total energy is used in food preservation while some authors have predicted additional 2% annual increment of energy demand to sustain food chain. In the course of this study, the authors pragmatically identified sources of energy demand in food transport and maintained that the best approach to minimise energy consumption in refrigerated vehicles is to find a light weight and low thermal conductivity material as the external wall of refrigerated vehicles. This research is of high interest in view of continuous rise in earth temperature occasioned by emission of carbon monoxide from fossil fuel. The authors further showed that the usage of aluminium sheet as external wall of refrigerated vehicles reduces the longevity of insulation which increases heat infiltration into the cooling chamber thereby aggravating energy demand.

Contents

1. Introduction

Refrigerated road vehicles are of considerable quantities worldwide as evidenced in the latest data released by Browne et al. [5] that over 400,000 food transport system exist and many thousands of other forms of refrigerated transport systems are used to distribute chilled and frozen foods throughout the world. This report presented a dire and grave situation in view of energy demand to sustain these refrigerated vehicles. Bahadori and Vuthaluru [3] were among many researchers to discuss the environmental implication of maintaining this high numbers of food transport without developing a road map to contain the attendant implication of fossil fuel consumption. Sustaining the shelf life of fresh food must be done with best international practises and it is of interest to protect the climate from further descending into dungeon. Refrigerated vehicles have been a key driving force in preserving quality and its importance cannot be overemphasised.

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http://dx.doi.org/10.1016/j.rser.2016.09.007
1364-0321/

Nomenclature

K = U	Overall heat transfer coefficient (W/m^2K).
h_i	Convective heat transfer coefficient for inside surface of refrigerated chamber(W/m^2K).
h_o	Convective heat transfer coefficient for outside surface of refrigerated chamber(W/m^2K).
U_{ins}	Overall heat transfer coefficient of an insulated wall (W/m^2K).
Q	Heat flux (W).
PCM	Phase change material.
R_{ins}	Internal resistance of wall (m^2K/W).
R_{wall}	Internal resistance of wall (m^2K/W).
X	Insulation thickness (m).
T	Temperature (K)
T_e	External temperature (K)
T_i	Internal temperature (K).
S	Mean surface (the geometric mean of external and internal surface) (m^2).

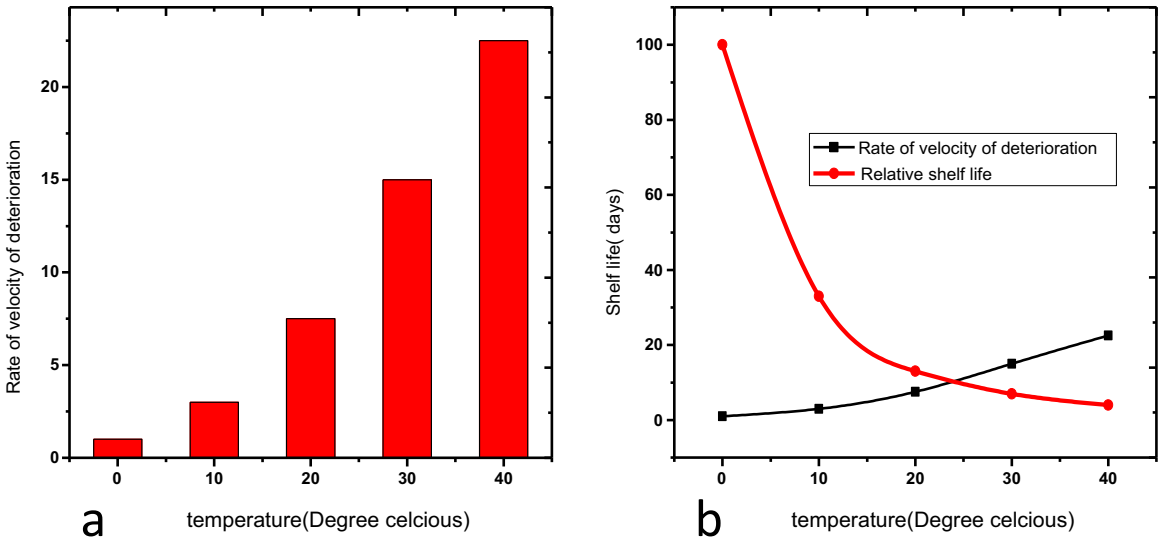

Fig. 1. (a) Impact of sudden rise in ambient temperature on rate of deterioration of perishable raw food (b) Prediction of shelf life after sudden rise in ambient temperature. Adapted from Salveit [25].

Fig. 1(a) showed that as the external temperature increases the rate of deterioration of perishable fresh food also increases while Fig. 1(b) further corroborated the fact that sudden rises in ambient temperature also affect the shelf life of fresh food. The temperature value at point of interception of the rate of deterioration and shelf life denotes the safe temperature value before minimum quality of fresh food is compromised. A lot of literatures have predicted that by 2030, global road freight transport will have grown by 2.5% a year [17,23,33,7] thereby resulting into high fossil fuel demand to maintain high thermal load. Therefore, in order to avoid the increased environmental impact of refrigerated vehicles, it would be of great interest to reduce their energy consumption, especially by improving and reinforcing insulation [13]. Insulated panel of refrigerated vehicles appeared to be only a medium to reduce heat infiltration into the cooling chamber [9,11]. Insulated panel are three layer plane structure where insulation typically polystyrene sandwiched between two thin layer of aluminium sheet [22]. Literature assessments have shown that many authors [28,31,32] have clearly reported various researches in insulating materials with low thermal conductivity, there seem no record on the impact of external wall on the insulation in one hand and on energy consumption in other hand.

Metallic external wall of the refrigerated vehicle is the conduit through which heat is transmitted into the cooling system of refrigeration system and every efforts must be directed to minimise the inflow of heat by improving insulation panel. Heat transmission through the external wall of most refrigerated vehicles continue to increase the thermal load of vapour compression system thereby resulting in energy demand in operational maintenance. These heat infiltrations remain a daunting challenges for most refrigerated vehicles [28]. Many researchers have proposed a more sustainable means of energy conservation in a refrigerated vehicles as the existing methods have not produced optimum results. Recent publications is also a testimony to the fact that the performance of insulation materials appear not to have produced a desirable results due to foaming properties of some insulations [1,24,34]. According to Tassou et al. [29], degradation of insulation properties through heat infiltration from external wall may lead to considerable rise in the thermal conductivity of such insulation. Söylemez and Ünsal [28] shows existing insulating materials and their respective thermal conductivity as illustrated in Table 1. Although, it is seen from the table that all the insulation value are low, this value may rise with continuous high ambient temperature.

Frequent door openings is also another widely-acknowledged medium of heat infiltration into the refrigerated chamber, resulting in the high thermal load [10,15]. The door opening must not be allowed to remain frequent as heat transmission could be aggravated which will increase the thermal load.

2. Thermal performance of refrigerated vehicles

The thermal load of insulated panel of refrigerated vehicles is measured by the value of its overall heat transfer coefficient (U-value) [14]. This value predicts the rate of heat infiltration through the external wall of a typical insulated panel and as the ambient temperature increases this U value tends to increase for metallic insulated panel. The implication of higher U value for metallic insulated panel is that the initial lower thermal conductivity value