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Cooling Load Model for Cold Storage of Tomato

Jona Vioren M. Ramos[1], Faith A. Banatao[1], Dona B. Estay[1], and Nemesio A. Macabale Jr.[2]

[1] Department of Agriculture and Biosystems Engineering, Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines
[2] Department of Information Technology, Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines

Email for correspondence: ramos.jona@clsu2.edu.ph

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Abstract

The use of cold storage is one of the effective methods for handling perishable crops. However, the effectiveness of this facility is greatly affected by its design making it a critical aspect of cold storage, thus, requiring technical knowledge of heat transfer. Hence, this study was conducted to develop a simulation model that can easily compute the total cooling load and refrigerating capacity of cold storage for tomatoes considering all heat sources namely; transmission heat, product heat, respiration heat, occupants' heat, lighting heat, ventilation heat, and infiltration heat. Additional design options were also provided for better accuracy of computation. This provides convenience and accuracy in designing cold storage to ensure its effectiveness. Results showed that by varying the length of the cold storage, the total cooling load and refrigerating capacity vary directly with cold storage dimension. Also, the use of the rule of thumb method generates bigger refrigerating capacity compared to the actual refrigerating capacity needed in cold storage causing higher energy consumption and eventually, higher costs. Moreover, varying the insulation material thickness shows that total cooling load and refrigerating capacity are inversely proportional to thickness of insulation material. Furthermore, using different insulation materials shows that total cooling load and refrigerating capacity increases with thermal conductivity of insulation material. Lastly, the simulation model generates more accurate results by providing options in wall components of the cold storage so that changes in design will be considered and reflected in the computed total cooling load and refrigerating capacity.

Keywords: Cold storage, Simulation, Total cooling load, Refrigerator capacity

Introduction

Tomatoes are among the most important vegetable crops in the Philippines. It is grown for both domestic and commercial purposes in practically every community across the country. According to research, the Philippines produces a high output of such crops. From July to September 2021, tomato production was 27.96 thousand metric tons, 1.6 percent greater than the 27.52 thousand metric tons produced in the same time in 2020. Northern Mindanao produced the most, accounting for 21.0 thousand metric tons, or

75.1% of the overall output for the quarter. SOCCSKSARGEN and Cagayan Valley followed with respective shares of 5.9% and 3.4% (PSA, 2021).

Tomato fruits, on the other hand, have a very short shelf life due to their perishability. Postharvest storage of tomato fruits is the principal source of seasonal variability in availability, deterioration in quality, and other socio-economic deficiencies (Babatola et al., 2008).

Following commercial packing, tomatoes are palletized and refrigerated to 20°C (68°F) for ripening or 12°C (54°F) for storage. While room cooling is widespread, forced-air cooling is more consistent and results in higher-quality fruit. Packed, palletized tomatoes with a pulp temperature of 28 °C (83 °F) increased by 2 °C (4 °F) immediately after being stored at 20 °C (68 °F) and only cooled to 23 °C (73 °F) after 24 hours of room chilling. However, using forced-air chilling, tomatoes cooled to 20°C (68°F) after 2.5 hours ripened more consistently throughout the pallet than those room-cooled (Hadad, 2016).

Furthermore, the optimum storage temperatures are determined by the tomato's maturation stage. Ideal conditions for ripening are around 19 to 21 °C (66 to 70 °F) and 90 to 95% relative humidity. Storage at temperatures above 27°C (81°F) diminishes red color intensity, while storing at temperatures below 13°C (55°F) slows ripening and can cause chilling injury, especially in mature green tomatoes. Red tomatoes can be preserved at 7°C (45°F) for a couple of days; however, tomatoes stored at 10°C (50°F) were rated poorer in flavor and aroma than those held at 13°C (55°F) (Hadad, 2016).

Relatively, cold storage is a popular approach for handling large quantities of perishables between production and marketing. It is one of the strategies for keeping perishable items fresh and healthy for an extended length of time by managing temperature and humidity within the storage system. In addition to retaining quality, postharvest refrigeration allows farmers to sell food at the optimal time. Having cooling and storage facilities eliminates the need to commercialize the produce soon after harvest. This is advantageous for producers who serve restaurants and grocery shops, as well as small growers who want to assemble truckload lots for shipping. Postharvest cooling is vital for delivering food of the finest quality to consumers (Krishnakumar, 2002).

Additionally, during storage, heat increases the deterioration of perishables, so the products are chilled by eliminating the heat. To remove the heat, we must first determine the cooling load to supply the necessary refrigeration capacity. Refrigeration installers typically rely on experience-based and commonly accepted 'rules of thumb': 15-20 watt/m3 for a large frozen storage room and 60-70 watt/m3 for a fresh fruit chilling room, which is handy and quick but not particularly precise (Alfa Laval, 2017). Moreover, some calculators can already be found on the internet but all of these calculators are limited to general room design only. Thus, this is generally applicable with the presumption that the building design will not make any difference. Table 1 shows the summary of the comparison of the related works and the simulation model. This includes the Heat Load Aircon Calculator, Heat Load Calculator, and Cold Room Calculator.

Daikin Philippines' Heat Load Aircon Calculator considers general design parameters such as room size (in the limited size category), number of people within the room, and situations such as whether the space is in a shaded area or receives direct sunlight (Daikin Philippines, 2017). Likewise, it is quite the same with another Daikin Heat Load Calculator from Malaysia which only differs in terms of value inputs (Daikin Malaysia, 2022). Another one is the Cold Room Calculator by Alfa Laval which is also used for cold room calculation (Alfa Laval, 2017). However, in this application, alternative insulation materials are not taken into account in the computation, leaving space for error if the cold storage is designed differently. In the calculation of heat transmission through walls, the letter "U" denotes the overall coefficient of heat transfer. The U-value determines how well a construction component retains heat within a structure. Calculating the U-value is frequently confounded by the fact that the overall resistance to heat flow through a wall composed of multiple layers is the sum of the resistances of the individual layers (Bhatia, n.d.). Thus, changing the materials consisting the wall of the cold storage will eventually, affect the cooling load. This is what is lacking with the Cold Room Calculator since it does not have options for other materials composing the walls of the cold room. Thus, with the proposed calculator, detailed computation was done to give more convenient and more reliable and accurate results.

With the existing methods and calculators, computations of cooling loads and refrigerating capacity can be quick and easy for the users but not very accurate. Furthermore, under sizing or oversizing of refrigeration equipment can only lead to common energy wastage as well as inefficiency of cold storage. Therefore, a more convenient and accurate computation is a must to serve the main purpose of cold storage.

Generally, the study aims to develop a calculator that can compute and generate total cooling load and refrigerating capacity of a cold storage for tomato. Specifically, it aims to develop a user-friendly and more accurate calculator of total cooling loads and refrigerating capacity for cold storage of tomatoes to reduce possible energy wastage in cold storage. Likewise, it also aims to provide more options for the cold storage design such as varying the insulation materials and its thickness.

Eventually, this cooling load model would be beneficial for tomato farmers or local businesses using cold storage for their produce. This would enable them to easily and accurately compute the total cooling load of their desired cold storage to have the proper refrigeration capacity, avoid energy wastage, and maximize cold storage efficiency. This also provides options in the insulation materials used for their cold storage walls which is an important factor in the design calculations. Likewise, this model could also be used in checking or comparing the effects of changing insulation materials and its thickness to the total cooling load and therefore its refrigerating requirement. Furthermore, this can also provide information to other students and researchers about computations of total cooling load for cold storage of tomato.

Table 1. Summary of Comparison of the Project to Related Works

PARAMETERS	RULE OF THUMB	HEAT LOAD AIRCON CALCULATOR	HEAT COLD CALCULATOR	COLD ROOM CALCULATOR	PROPOSED MODEL
Transmission heat	Not specific	Not specific	Not specific	Specific but limited	Specific & complete
Product Heat	Not specific	Not considered	Not considered	Considered	Considered
Respiration Heat	Not specific	Not considered	Not considered	Considered	Considered
Occupants Heat	Not specific	Considered	Considered	Considered	Considered
Lighting Heat	Not specific	Not considered	Not considered	Considered	Considered
Ventilation Heat	Not specific	Not considered	Not considered	Considered	Considered
Infiltration Heat	Not specific	Not considered	Not considered	Considered	Considered

Materials and Methods

Design and Implementation

For the design plan of the project shown in Figure 1, initial data gathering was made to collect information about the product, cold storage and the parameters needed for cold storage design and computations. Then, project design was formulated and formulas were incorporated. Programming activities were done for software development. Furthermore, the completed program was tested and evaluated by using sets of assumptions to highlight the difference of the project from the existing calculators. Results were verified with the values computed using Microsoft Excel Software. Lastly, project output was documented for presentation.

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Figure 1. Project Design Plan

Data Gathering

To calculate the heat load in cold storage, the heat amount produced by all sources are determined and summed. Different types of heat produced are heat conducted through walls, floor and ceiling, product heat, respiration heat, air change heat, occupants' heat and lighting heat (Tiwari, 2019). From a similar study, the heat load of the cold storage was calculated using the total amount of heat produced from all sources comprising of the transmission heat, infiltration heat, product's heat, other heat sources, unexpected and unknown heat (Yuzainee et al., 2019)

To compute heat loads from all sources, the user needs to input the following necessary details: a.) Storage dimension, m, b.) Insulation materials, c.) Insulation material thickness, m, d.) Outside storage temperature, °C, e.) Desired inside storage temperature, °C, f.) Product weight, kg, g.) Number of occupants and working hours, h.) Number of lighting devices, operating hours and power rating, W, i.) Number of ventilation equipment, operating hours and power rating, W and j.) Daily air exchange.

Upon entry of the needed data, the program will automatically compute and generate the following: a.) Transmission heat, KW, b.) Product heat, KW, c.) Respiration heat, KW, d.) Occupants' heat, KW-hr, e.) Lighting heat, KW-hr, f.) Ventilation heat, KW-hr, g.) Infiltration heat, KW, h.) Total cooling load, KW-hr and i.) Refrigerating capacity, KW.

Generally, this study describes the Cooling Load Model using the following formulas:

Transmission Heat

The calculation of the transmission heat created by walls and ceiling requires information on thickness and type of isolation material used in construction of cold room, construction of building, physical specifications of the cold storage volume, inside and outside environment temperatures and the effect of sunshine (Tiwari, 2019). It will be computed through Equation 1 and 2 from the fundamental formula of conduction (Moran et al., 2014; Bartsch and Blanlied, 1984) and is derived and used in other cold storage-related studies (Yuzainee et al., 2019; Tiwari, 2019; Bhatia, n.d.; Gross et al., 2016).

$$Q_T = U\,A\,(T_o - T_i) \qquad \textit{Equation 1}$$

Where:
Q_T = Transmission heat at flat surface (W)
U = Total heat transmission coefficient (W/m^2)
A = Area of heat transmission (m^2)
T_o = Outside temperature (K)
T_i = Inside temperature (K)

$$U = \frac{1}{K}; \quad K = \frac{1}{\propto_i} + \sum_{i=1}^{n} \frac{Xi}{Yi} + \frac{1}{\propto_o} \qquad \textit{Equation 2}$$

Where:
X_i = Material thickness (m)
Y_i = Thermal conductivity (W/m.k)
$\propto_o$ = Coefficient of heat transmission of outside surface (W/m^{2}K)
$\propto_i$ = Coefficient of heat transmission of inside surface (W/m^{2}K)

Product Heat

It is the amount of heat to be extracted from the product to maintain the product at desired temperature (Tiwari, 2019). Product heat is calculated by using Equation 3

(Yuzainee et al., 2019; Tiwari, 2019; Bhatia, n.d.; Gross et al., 2016):

$$Q_P = mC\,(T_o - T_i) \qquad \textit{Equation 3}$$

Where:
Q_P = Produced by cold stored product (W)
m = Mass of product stored in the cold storage (kg)
C = Specific heat above freezing point (KJ/kg.K)
T_o = Outside temperature (K)
T_i = Inside temperature (K)

Respiration Heat

It is the heat generated by the product during the respiration (Tiwari, 2019) and can be computed using Equation 4 (Yuzainee et al., 2019; Tiwari, 2019; Bhatia, n.d.; Gross et al., 2016):

$$Q_R = m\,r \qquad \textit{Equation 4}$$

Where:
Q_R = Respiration heat (W)
m = Mass of product stored in the cold storage (kg)
r = Specific respiration heat load of the product (W/kg)

Occupants' Heat

It is the heat generated due to people inside the building (Tiwari, 2019). Heat load due to human occupancy is given by Equation 5 (Yuzainee et al., 2019; Gross et al., 2016):

$$Q_O = n_w c_w t_w \qquad \textit{Equation 5}$$

Where:
Q_O = Occupants' heat (W-hr)
n_w = Number of workers
c_w = Heat load produced by worker (W)
t_w = Average working time in the cold storage (hr)

Lighting Load

Heat given up by the source of light (Tiwari, 2019) and is computed by Equation 6 (Yuzainee et al., 2019; Gross et al., 2016):

$$Q_L = n_L\, p_L\, t_L \qquad \textit{Equation 6}$$

Where:
Q_L = Lighting load (W-hr)
n_L = Number of lighting device
p_L = Power rating of lighting device (W)
t_L = Average working time of lighting device (hr)

Ventilation Load

The heat gain due to the exchange of air inside the building is called ventilation load (Tiwari, 2019). It is computed by using Equation 7 (Yuzainee et al., 2019; Gross et al., 2016):

$$Q_F = n_F\, p_F\, t_F \qquad \textit{Equation 7}$$

Where:
Q_F = Lighting load (W-hr)
n_F = Number of fans
p_F = Power rating of fans (W)
t_F = Average working time of fans (hr)

Infiltration Heat

The infiltration heat load sources from the entrance of the warm air to the cold storage when the door opens or deformation in structures such as windows, doors, walls and cracks in the building that lead to minor leakage (Yuzainee et al., 2019). This heat load can be calculated by Equation 8 (Evans, 2017; Gross et al., 2016):

$$Q_l = a\,V\,e\,(T_o - T_i) \qquad \textit{Equation 8}$$

Where:
Ql = Infiltration heat (W)
a = Daily number of air exchange
V = Volume of cold storage (m3)
e = Energy per cubic meter of air (KJ/ K)
To = Outside temperature (K)
Ti = Inside temperature (K)

The computed heat loads from all the sources represent the cooling load that needs to be delivered by the refrigeration equipment for maintaining the specified temperature and relative humidity. The required refrigeration capacity may be determined to match up with the computed cooling load and thus, enabling a proper selection of refrigeration equipment and hence, preventing the common energy wastage that can occur due to oversizing or under sizing of the cold storage specifications (Yuzainee et al., 2019).

Generally, with this model, the total cooling loads of a cold storage for tomato will be computed considering all heat sources and will be composed of the parameters namely; transmission heat from walls, floor and ceiling, product heat, respiration heat, occupants' heat, lighting heat, ventilation heat and infiltration heat. With the calculated cooling load, a safety factor of 15% will be applied to account for possible variations from the designed cold storage. It is typical to add 10 to 30 percent onto the calculated cooling load to cover for these variations (Evans, 2017). Likewise, it is often recommended that the sum of the heat load be multiplied with the safety factor of 10% to 15% to account for facility use beyond assumption (Yuzainee et al., 2019).

Furthermore, after determining the required cooling load, the refrigeration capacity can be now calculated by dividing it with the operating hours of the cold storage. Therefore, refrigeration capacity will be computed by Equation 9 (Yuzainee et al., 2019):

Refrigeration Capacity =

$$\frac{TotaTotal\ cooling\ load\ (safety\ factor)}{operating\ hours} \quad \text{Equation 9}$$

Other Parameters

Other parameters and values needed for the computation are given in Tables 2 and 3.

Software Development

For the development of the simulation model, formulas, equations, parameters and other necessary values are incorporated in the program. The program flow diagram is shown in Figure 2.

Testing and Evaluation

For initial testing of the simulation model, series of computations are done using Microsoft Excel Software. The same details are used for computation using the completed program. Results are then recorded and compared with the results generated by using the rule of thumb and the existing Cold Room Calculator.

Specifically, the simulation model, rule of thumb and existing Cold Room Calculator are compared from the following factors: a.) Varying Length of Cold Storage, b.) Varying Thickness of Insulation Material, c.) Varying Insulation Materials paired with Stainless Steel and Aluminum as wall components and d.) Varying Insulation Materials paired with Concrete and Cement Plaster as wall components.

Table 2. Thermal Conductivity of Insulation Materials

MATERIALS	THERMAL CONDUCTIVITY (W/m.K)
Cellular Glass (Greenspec, 2022)	0.041
Polyurethane (Greenspec, 2022)	0.023–0.026
Expanded polystyrene (Greenspec, 2022)	0.034–0.038
Extruded polystyrene (Greenspec, 2022)	0.033–0.035
OTHER MATERIALS	**THERMAL CONDUCTIVITY (W/m.K)**
Concrete slab (Tiwari, 2019)	2.15
Cement plaster (Tiwari, 2019)	0.72
Bricks (10") (Tiwari, 2019)	1.02
Stainless steel (Yuzainee et al., 2019)	15.1
Aluminum (Yuzainee et al., 2019)	236.99

Table 3. Properties of Tomato and Other Parameters

PROPERTIES OF TOMATO	VALUES
Specific heat (The University of Maine, 2001)	4.02 KJ/kg.K
Respiration rate (ASHRAE Handbook, 2006)	71.5 KJ/kg
Optimum storage temperature (Evans, 2017)	55°F or 13°C
OTHER PARAMETERS	
Heat load/person (Tano et al., 2005)	295 W
Convective heat transfer coefficient for air (The Engineering Toolbox, n.d.-a)	10 to 100 W/m^2.K
Energy/m^3/K of air*	1.3 kJ/m^3/K

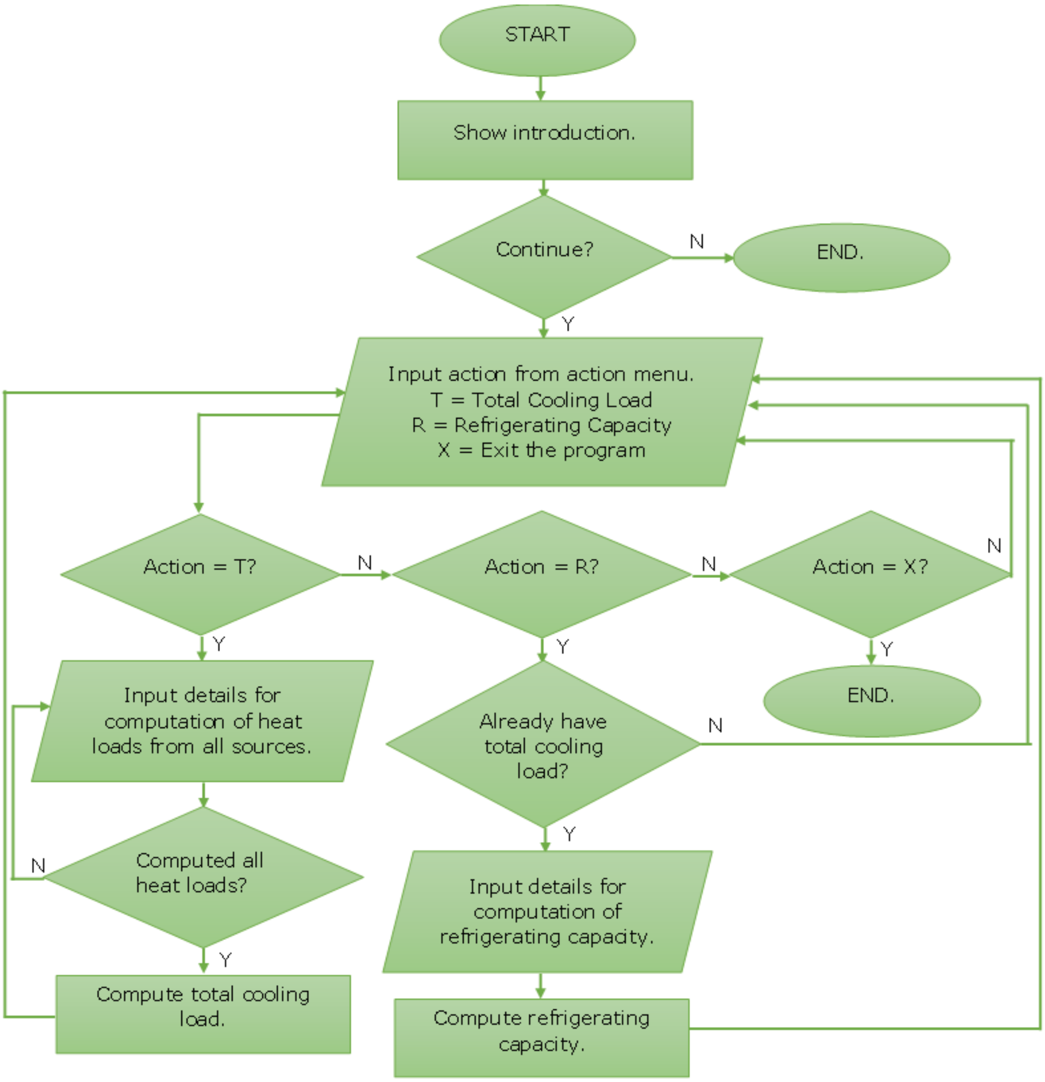

Figure 2. Program Flow Diagram

Result and Discussion

A simulation model was developed to easily and accurately compute the total cooling load and refrigerating capacity of a cold storage for tomatoes. Basic assumptions are set to check the performance of the model as shown in Table 4 and a series of computations were made for comparison and analysis. By simply inputting the assumptions through the simulation model, the cooling loads per parameter will be automatically computed. Eventually, the total cooling load and refrigerating capacity will be defined just by following the simple instructions provided by the simulation model. With this, the model provides a user-friendly and convenient method of computing the cooling load of the cold storage parameters.

Meanwhile, the total cooling load was generated using the simulation model while no data was specified by using the rule of thumb and the existing calculators. Thus, a comparison of the calculators was made based on refrigerating capacity only.

Through testing the program with varying lengths of cold storage from 3 to 7 meters, results showed that using the simulation model, rule of thumb method and calculator by Alfa Laval, total cooling load and refrigerating capacity are directly proportional with the length of cold storage as depicted in Figure 3 and 4. This is because, with a bigger room volume, more heat will be required to be removed for the area to cool down. Figure 4 also shows higher refrigerating capacity using rule of thumb method compared to the actual refrigeration requirement of the cold storage

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which can lead to higher energy consumption and costs.

Moreover, results of varying insulation material thickness from 0.01 to 0.10-meter showed that insulation material thickness is inversely proportional to the total cooling load and refrigerating capacity as shown in Figure 5 and 6. This is supported by the study of Wang et al. (2021) stating that thermal insulation has the greatest potential for reducing cooling requirements and electricity costs for cooling systems. Meanwhile, no data was recorded using the rule of thumb since changes made do not apply to the method and will only generate the same results regardless of change.

Table 4. Values for Computation

PARAMETERS	VALUES
Storage Dimension	
Length	4m
Width	3m
Height	3m
Wall Components	
Insulation A	Polyurethane
Thickness A	0.07m
Insulation B	Aluminum
Thickness B	0.002m
Insulation C	Stainless Steel
Thickness C	0.002m
Product Details	
Product Name	Tomato
Product Weight	250kg
Temperatures	
Outside temperature	30°C
Inside temperature	13°C
Other Heat Sources	
No. of Occupants	2
Working hours	4
No. of Lighting Devices	2
Power Rating of Lighting Devices	17W
Operating Hours of Lighting Devices	4
No. of Fans	2
Power Rating of Fans	100W
Operating Hours of Fans	16
No. of Air Exchange/day	5
Refrigerating Capacity	
Operating Hours of Cold Storage	16

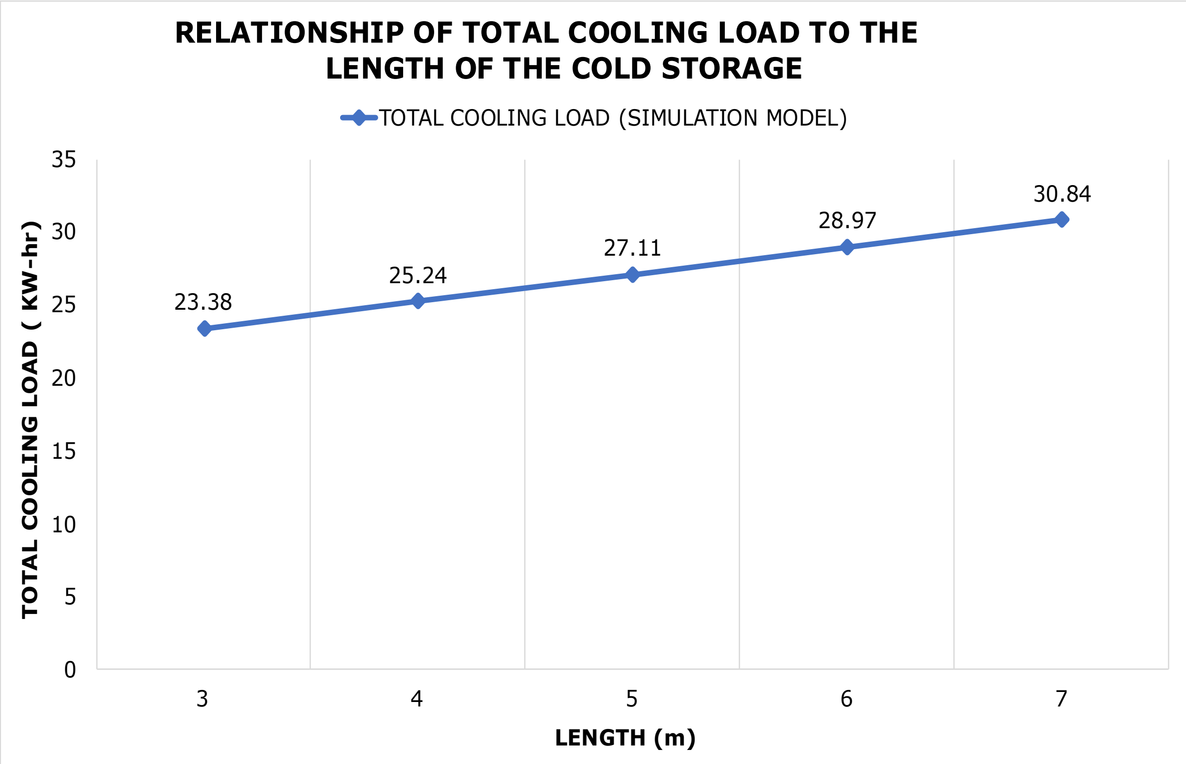
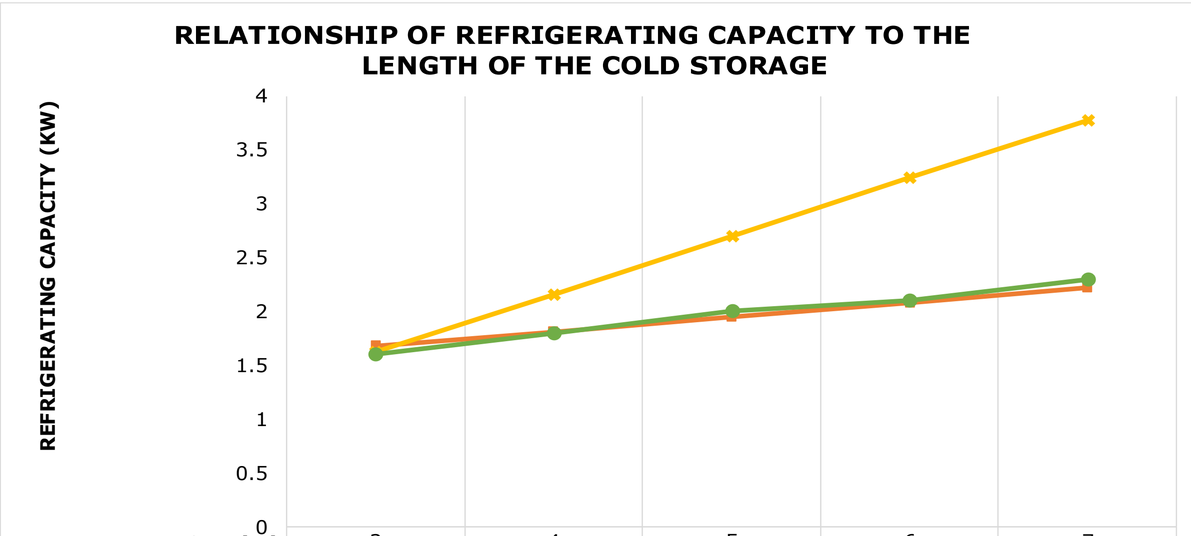


Figure 3. Effects of varying length of cold storage to total cooling load using the simulation model



LENGTH (m)	3	4	5	6	7
SIMULATION MODEL	1.68	1.81	1.95	2.08	2.22
RULE OF THUMB	1.62	2.16	2.70	3.24	3.78
ALFA-LAVAL	1.60	1.80	2.00	2.10	2.30

Figure 4. Effects of varying length of cold storage to refrigerating capacity using the simulation model, rule of thumb, and Alfa-Laval Calculator

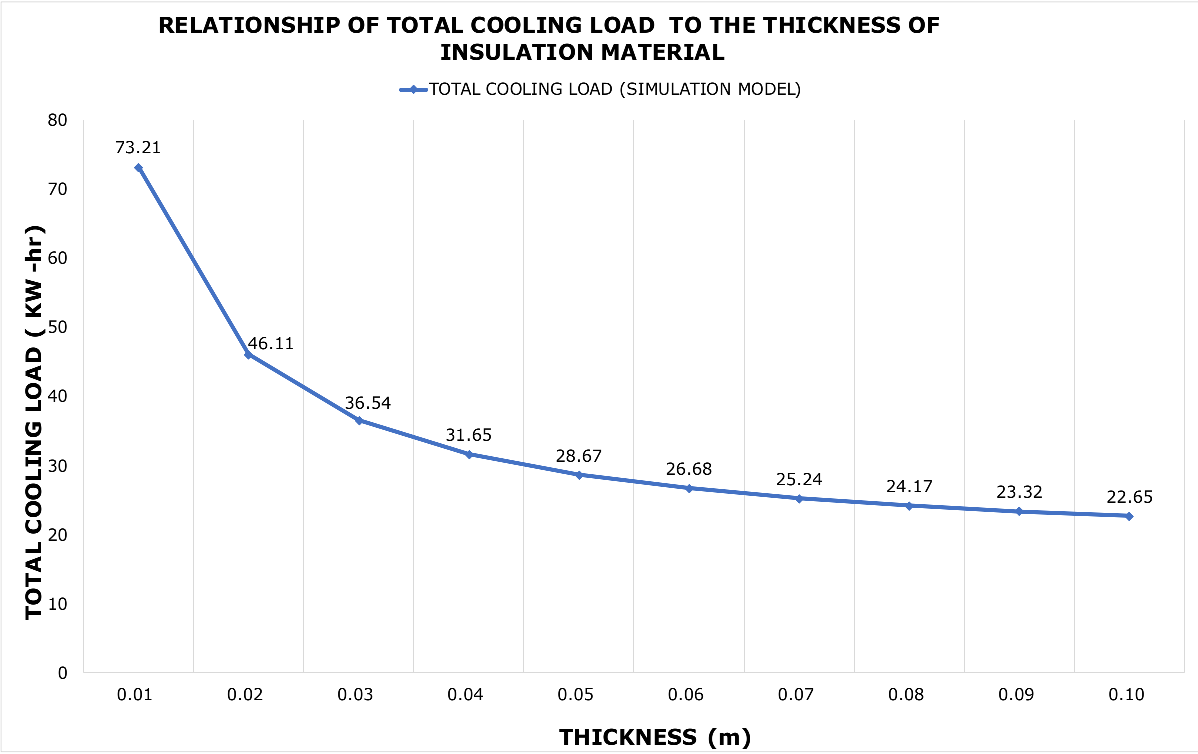
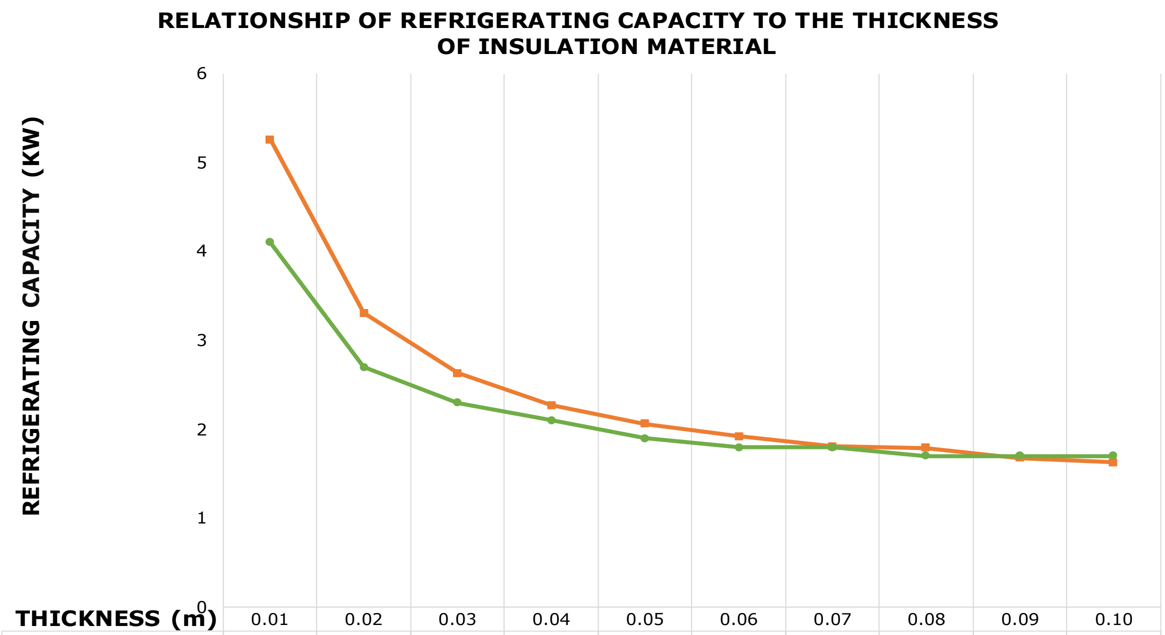


Figure 5. Effects of varying thickness of insulation material to total cooling load using the simulation model



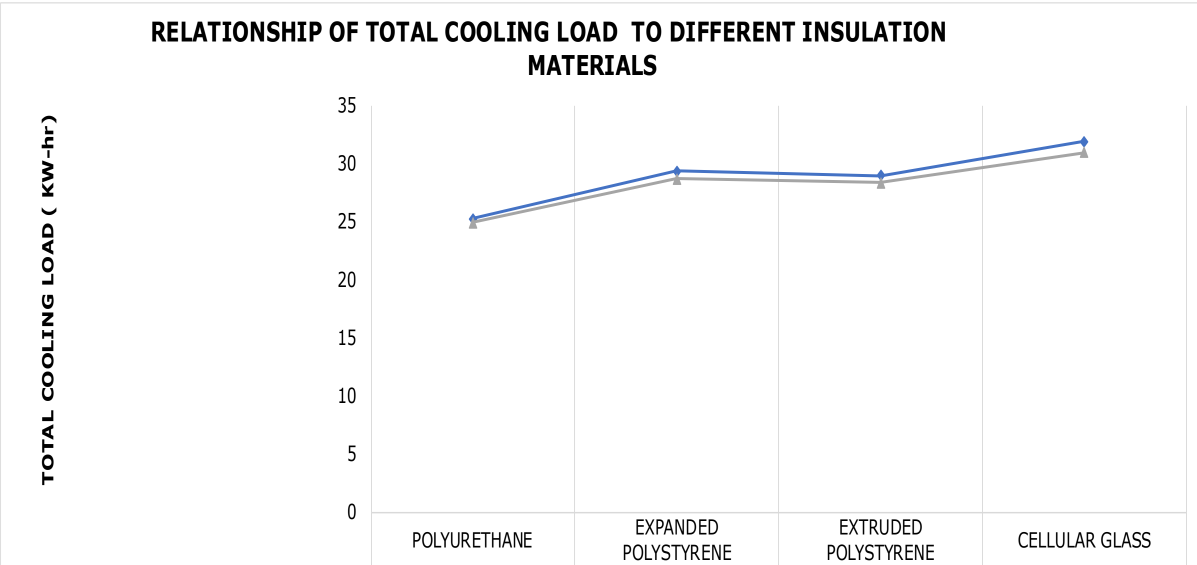
THICKNESS (m)	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
SIMULATION MODEL	5.26	3.31	2.63	2.27	2.06	1.92	1.81	1.79	1.68	1.63
ALFA-LAVAL	4.10	2.70	2.30	2.10	1.90	1.80	1.80	1.70	1.70	1.70

Figure 6. Effects of varying thickness of insulation material to refrigerating capacity using the simulation model and Alfa-Laval Calculator

Furthermore, the relationship of different insulation materials to the total cooling load and refrigerating capacity is shown by using the simulation model and calculator by Alfa Laval. It can be noted that by using the model, an option for the wall components is available, thus, comparing the materials using aluminum and stainless steel as well as using concrete and cement plaster as wall components. However, using the calculator by Alfa Laval, wall components are not specified.

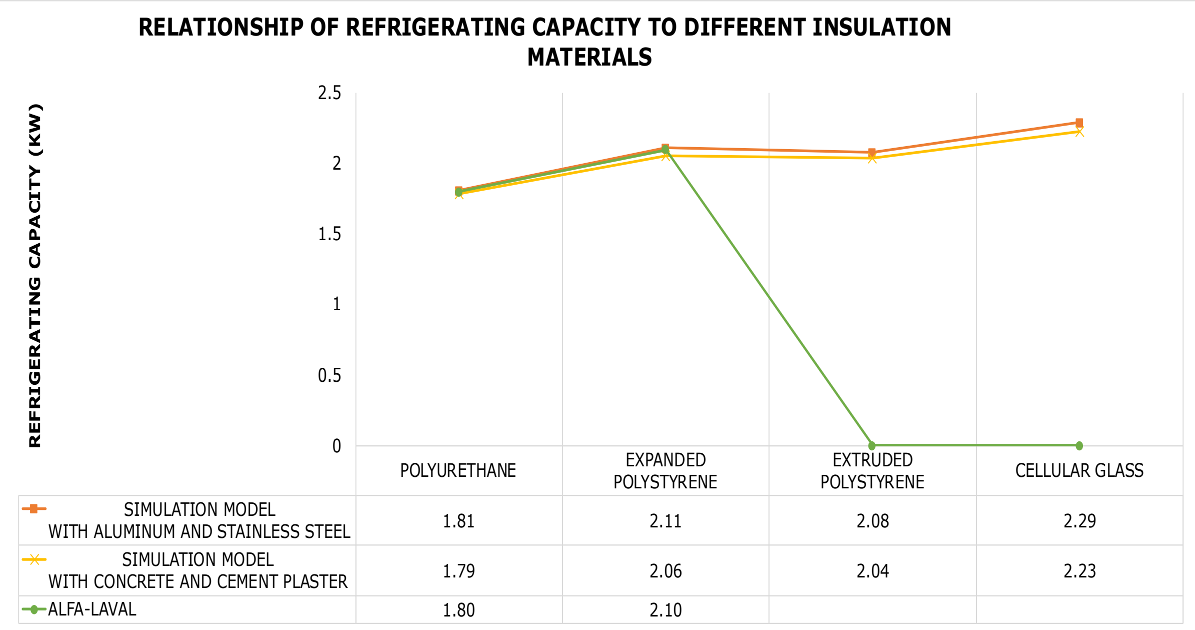
Nevertheless, Figure 7 and 8 showed that the lowest total cooling load and refrigerating capacity is generated for polyurethane which is the best insulating materials among the options, followed by extruded polystyrene, expanded polystyrene and the cellular glass. However, type of polystyrene is not specified and no data is generated for cellular glass in the Alfa-Laval calculator since it's not available in the program settings. Nonetheless, results generated are due to different thermal conductivity of the material with polyurethane having the lowest value of 0.023-0.026W/m.K and cellular glass having the highest thermal conductivity of 0.041 W/m.K. Polystyrene has thermal conductivity within range of 0.033-0.038 W/m.K. Therefore, it can also be concluded that the total cooling load and refrigerating capacity vary directly with thermal conductivity of the insulation material. With the high thermal conductivity of insulating material, more heat will be transmitted thus, a higher total cooling load will be expected. Hence, the results are in agreement with the statement that the best insulating materials have the lowest thermal conductivity to lower the overall coefficient of heat transmission (FAO, 2003).

Moreover, Figure 7 and 8 also showed that with the same insulation material, changes in wall components also affect the total cooling load and refrigerating capacity with lower values generated using concrete and cement plaster as wall components compared to using aluminum and stainless steel. Therefore, considering changes in the wall components in the computation using the simulation model gives more accurate results compared to using the rule of thumb and the existing Cold Room Calculator.



	POLYURETHANE	EXPANDED POLYSTYRENE	EXTRUDED POLYSTYRENE	CELLULAR GLASS
WITH ALUMINUM AND STAINLESS STEEL	25.24	29.34	28.97	31.92
WITH CONCRETE AND CEMENT PLASTER	24.93	28.67	28.34	30.96

Figure 7. Effects of varying insulation materials and wall components to total cooling load using the simulation model



	POLYURETHANE	EXPANDED POLYSTYRENE	EXTRUDED POLYSTYRENE	CELLULAR GLASS
SIMULATION MODEL WITH ALUMINUM AND STAINLESS STEEL	1.81	2.11	2.08	2.29
SIMULATION MODEL WITH CONCRETE AND CEMENT PLASTER	1.79	2.06	2.04	2.23
ALFA-LAVAL	1.80	2.10		

Figure 8. Effects of varying insulation materials and wall components to refrigerating capacity using the simulation model and Alfa-Laval Calculator

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Conclusion

Based on the results, the simulation model provides accurate results with little difference from that of the existing calculators given the same parameters. However, the results of the simulation model and Alfa Laval Calculator are closer to each other compared to the rule of thumb indicating that the simulation model is almost the same as the Alfa Laval Calculator except for the additional options provided in the insulation materials for the simulation model making it more convenient and accurate if other wall designs will be considered.

Generally, using the rule of thumb method generates higher refrigerating capacity than what is actually needed in the cold storage resulting in possible energy wastage and higher energy costs. Therefore, the simulation model offers a more accurate refrigerating capacity resulting in more economical cold storage operation. Moreover, the model provides complete details in terms of wall design and components, thus, giving more accurate computation compared to the rule of thumb and existing calculators. Furthermore, the results showed that the total cooling load and refrigerating capacity are directly proportional to cold storage dimension. Additionally, total cooling load and refrigerating capacity are inversely proportional to thickness of insulation material. Also, using polyurethane as insulation material generates the lowest total cooling load and refrigerating capacity compared to cellular glass and polystyrene. It can also be concluded that total cooling load and refrigerating capacity are directly proportional with thermal conductivity of the insulation material. Lastly, using concrete and cement plaster as wall components generates lower cooling load and refrigerating capacity compared to stainless steel and aluminum.

Likewise, for future works, it is recommended that more materials will be provided to expand options of the cold storage design and more fruits and vegetables will be added in the program settings so that the calculator would not be limited to tomatoes only and can be beneficial to more users.

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