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Cooling Load Calculation for Efficient Cold Storage of Fresh-Cut Yam Bean

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Abstract: Fresh-cut yam beans are highly perishable and required to be stored in a cold room that is maintained at 5°C and relative humidity of 90%. Nonetheless, the cold storage can be an unnecessarily high energy user if the refrigeration equipment is not selected appropriately to match the actual cooling load. This is not favorable for the fresh-cut processors that are mostly small and medium enterprises (SMEs). In this study, the design of cold storage for the fresh-cut yam bean was presented to comply the necessary requirement by food manufacturing standard. Based on the design, the correct calculation of the cooling load by considering all the possible heat sources was performed. The resulted cooling load was 53239.30 kW with 36% heat load sourced from fresh-cuts, 22% from transmission, 18% from infiltration, and the rest from workers, lighting, ventilation and defrosting. The designated cold storage for 240 kg fresh-cuts has the dimension of 4.9 x 2.5 x 3 m in length, width and height and accommodates adequate space for the workers and necessary equipment as well as features to minimize heat gains. The required refrigeration capacity was 3.33 kW and serve as basis for the selection of refrigeration equipment.

Keywords: Cold storage, cooling load, efficiency, Small and Medium Enterprises

I. INTRODUCTION

Fresh-cut fruits and vegetables (FFV) are identified as ready-to-eat consumption products. FFV are considered as products that have been peeled, cleaned, sliced or cubed and packaged for the consumer's convenience [1]. As the public's awareness for nutritious and fresh food improves recently, it can be observed that the trend for purchasing vegetable-based snack has increased globally particularly in Asia region [2]. The positive outlook for the vegetable snack gives an opportunity for this market to grow particularly for small-scale entrepreneurs. One of the classic vegetable snack that has become increasingly popular in Malaysia is fresh-cut yam bean or also known as jicama in several regions. The fresh-cuts are either prepared for ready-to eat snack such as yam bean stick or slices as shown in Fig.1, or can be supplied to downstream entities that require the fresh-cuts to prepare other dishes or products.

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High-quality fresh-cut yam bean should show white, crisp, juiciness and free from visible defects [3]. In addition, the fresh-cut should retain its fresh odor and flavor as well as not be microbiologically contaminated [3]. Despite being highly nutritious, it is well understood that vegetables start to deteriorate rapidly once harvested. In addition, the cutting or slicing process of the vegetables would disrupt the surface cells and cause injury to the tissue, thereby eliminate the natural barriers to pathogen colonization [4]. The wounded vegetables triggers the production of ethylene, stimulating the deteriorative responses such as aging and cell death [5]. As for yam bean, the common spoilage signs include browning, softening and texture loss, whereby this can lead to wastage and financial loss for the processors. Therefore, it is important to maintain their quality, by storing the fresh-cuts in cold room or cold storage, whereby the storage space is maintained at controlled low-temperature and high relative humidity [6, 7]. According to Yildiz et al. [3], the storage temperature of 5°C was able to impede the microbiological growth, reduce the production of ethylene, respirations and internal breakdown of enzymes for the yam bean. In comparison to other preservation techniques, the cooling avoids the addition of preservatives and prevent water loss as well as wilting [7]. Other advantages of cold storage include providing the buffer for the primary producer to avoid distress and rush sales, and regulating the market period [7]. It is however important to understand that the cold storage can be the most intensive energy user in the food facility, and thus, associates with high energy cost which is a burden for small-scale processors [8].

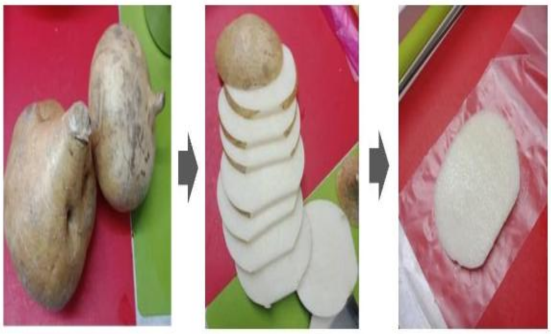


Fig. 1 Preparation of fresh-cut jicama

Nevertheless, according to [9, 10], significant opportunities for energy savings can be obtained from cold storage, especially when purchasing the correct refrigeration equipment as compared to improvement actions taken during the life of the cold storage.

One of the potential energy wastes is the wrong storage design and mismatch between the intended cooling load during the actual operation and the selected capacity of the refrigeration equipment during planning [11]. Cooling load is the total heat energy that must be removed from the cold room in order to lower the temperature to the desired level. This requires the designer to consider all the possible incoming heat load into the cold room that need to be removed. The total heat load is the required cooling load to be performed by the refrigeration system for a dedicated storage space. Sari and Pratami [7] have reported the total cooling load of 55601.98 Wh for storing spinach, water spinach and lettuce up to 260 kg per time. The obtained cooling load served as the basis for selection of the proper capacity of cold storage equipment and distribution system. If the selected capacity was less than the required cooling load, the system will run non-stop and may not achieve the required temperature regime and cause insufficient refrigeration that lead to food spoilage and wastage [7, 12]. Contrariwise, when the capacity was greater than required, the refrigeration equipment will be unnecessarily expensive. The temperature regime will be achieved very quickly so the system will work with a lot of stops and causes temperature fluctuation, which is inefficient. Their study has calculated the storage size based on volume difference calculation method, whereby the storage capacity was determined by subtracting the volume for structural construction (fan, shelf, wall) from the overall volume of cold room and has not considered the necessary space for cleaning, maintenance, and access for material handling equipment, whereby this is required in standards related to food processing such as Good Manufacturing Practice for Food (GMP). Another study by Sakare [13] demonstrated the calculation of cooling load for storing 1000 tons of potatoes, which is an important staple crop, with consideration of different heat load sourcing from structural heat gain, equipment load, incoming warm potatoes, respiration and human occupancies. The size of the cold storage, however was approximately conducted, by assuming the storage capacity to be 50 to 60% from the allocated volume of 4000 m3. Hence, the refrigeration requirement may be an approximate value. Nevertheless, the study helps the readers to appreciate the number of factors that have to be taken into account in calculating the heat load and intend to serve as a guide for cold room fabrication. Another case as reported by Food and Agriculture Organization (FAO) [14] showed that the total heat load of 653 448 Wh for cooling 35 ton fishes per day to -30°C. The heat load considers the heat gained from insulation leak (through walls, roof and floor), air changes, lighting, human occupancy, incoming fishes and equipment (fan and defrost).

Against the above backgrounds, this study discussed the heat load generating from different sources that impacted the required cooling load for the cold storage of fresh-cut yam bean. The yam beans were selected as the study object, as they are increasingly demanded by the downstream market as reported by [15] with market potential at compound annual growth rate (CAGR) of more than 7% in the period of 2018 to 2022. Nevertheless, the retailers and downstream require the yam bean to be delivered in the form of fresh-cuts as they are difficult to be safely peeled and consistently cut due to their large size and slippery flesh texture. Hence, the fresh-cuts need to be supplied in the cold condition in order to extend the shelf-life and prevent quality deterioration such as pathogen growth, browning and softening. This required the cold storage to be in-place at the producer's premise, which is mostly small processors. The study on the cold storage facilities specifically designed for yam bean fresh-cuts has not been found despite their positive market trend. In order to prevent the burden caused by high energy usage for such cold storage, this study was aimed to firstly, demonstrate the correct design of the cold storage that is able to comply requirement by the Good Manufacturing Practice for food (GMP) in term of sizing, spatial design, illumination requirement, easy-to-clean structures and hygiene practice, whereby, this has not been considered specifically in the previous works. The compliance of GMP is needed as this promotes hygiene and food safety in the premise as well as help the producers to be certified for accessing the premium market. The study then proceeds with the calculation of heat load from different sources in accordance to the developed cold storage design, whereby this lead to the required cooling load. The required cooling load serves as the basis for the selection of the correct refrigeration capacity and lead to efficient refrigeration process in the cold storage.

II. CALCULATION OF COOLING LOAD

Based on the clear design specification of the cold storage and the current actual operation, the related equations from the literature can be adapted to appropriately determine the heat load coming from all sources and thereby, makes up the required cooling load for the proposed cold storage. The required refrigeration capacity may therefore be determined to match up the determined cooling load and thus, enabling a proper selection of refrigeration equipment. The heat load of the cold storage was calculated using the total amount of heat produced from all sources comprising of the transmission heat (H_1), infiltration heat (H_2), products heat (H_3), other heat sources (H_4), unexpected and unknown heat (H_5) [13].

Transmission heat (H_1),

The transmission heat is thermal energy that flows through the warmer sides of walls, floor and ceiling into the cold room. Heat is always moving to enter the colder space. The following equations were used to calculate transmission heat [16].

$$H_c = U \times A \times (T_{out} - T_{in}) \quad (1)$$

Where

H_c = Heat transmission at the flat surface (W)
U = Total heat transmission coefficient (W/m^{2}K)
A = Area of the heat transmission (m^2)
T_{out} = Temperature of outside or surrounding (K)
T_{in} = Inside temperature (K)

$$\frac{1}{K} = \frac{1}{\alpha_i} + \sum_{i=1}^{n} \frac{X_i}{\lambda_i} + \frac{1}{\alpha_o}$$

(2)

Where

α_i = Coefficient of heat transmission of inside surface ($W/m^2 K$)
α_o = Coefficient of heat transmission of outside surface ($W/m^2 K$)
λ_i = Thermal conductivity (W/mK)
X_i = Material thickness (m)

$$K = \frac{\lambda}{x} \quad (3)$$

Infiltration heat (H_2)

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 [6, 7, 16]. This heat load can be calculated by using the following equation [17].

$$H_2 = z \times V \times \frac{1}{v} \times \Delta h \quad (4)$$

Where:
H_2 = Heat produced by air changing and leakage air (kJh^{-1})
z = Daily number of air exchanging
V = Volume of cold storage (m^3)
V = Specific volume of infiltrated air at a certain temperature (m^3)
$\triangle h$ = Specific enthalpy heat difference as obtained from the psychrometric chart ($kJkg^1$)

Products heat (H_3),

Product heat is the heat brought into the cold storage from the fresh-cuts that are initially at a warmer temperature. When new products enter the cold storage, the heat enters the storage and subsequently, the energy is required to cool them. There are several conditions must be taken into account when dealing with products heat. The stored products such as fruits and vegetables continue their vitality after harvesting and they diffuse heat due to some chemical reactions in the environment [6, 16]. Following equation adapted from Akdemir and Schwarze [16, 17] on the heat load created by stored product at the temperature above freezing point is as follows:

$$H_3 = H_{31} + H_{32} \quad (5)$$

Where:
H_{31} = Heat produced during cooling (Wh)
H_{32} = Heat due to respiration (Wh)

Heat load of products above freezing point (H_{31})

The heat produced by cooling above freezing points (H_{31}) can be calculated by the following equation [17]

$$H_{31} = m \times c \times \Delta T_{product} \quad (6)$$

Where:
H_{31} = Heat produced by cold stored product (Wh)
m = Mass of yam bean in cold room (kg)
c = Specific heat above freezing point ($kJ\ kg^{-1}\ K^{-1}$)
$\Delta T_{product}$ = Temperature difference due to cooling (K)

Respiration heat (H_{34})

Respiration heat produced by vegetable since they continue their vitality after harvesting and they diffused heat to the environment. The respiration heat (H_{34}) calculates by using equation [18] as follows.

$$H_{34} = m \times c_{respiration} \quad (7)$$

where:
H_{34} = Respiration heat (Wh)
$c_{respiration}$ = Specific respiration heat load of the product ($W\ kg^{-1}$)

Other heat sources (H_4),

Internal heat sources from people, lighting, equipment, machines and defrosting processes. Typically it contributes 10- 20% of the cooling load. Meanwhile, equipment heat sources from evaporator fans motor and evaporator defrost cycle, which contributes 1 – 10% of the cooling load. This heat load can be calculated as follows [16, 18]:

$$H_4 = H_{41} + H_{42} + H_{43} + H_{34} \quad (8)$$

Where:
H_4 = Other heat loads
H_{41} = Heat produced by humans working in the cold store (Wh)
H_{42} = Heat produced by lightening devices (Wh)
H_{43} = Heat produce by ventilation (Wh)
H_{44} = Heat produced by electrical defrost processes (Wh)

Heat produced by humans working in the cold store (H_{41})

The heat produced by humans working in cold store can be calculated using the following equation [16]

$$H_{41} = n_w \times c_w \times t_w \quad (9)$$

Where:
n_w = No. of workers
c_w = Heat load produced by a worker (W)
t_w = Average working time in the cold store ($h\ day^{-1}$)

Heat produced by lightening devices (H_{42})

The heat produced by lighting devices can be calculated using the following equation [16, 17]

$$H_{42} = n_l \times P_l \times t_l \quad (10)$$

Where:
n_l = Number of lamp
P_l = Lighting power (W)
t_l = Average daily working time of lighting

Heat produce by ventilation (H_{43})

The heat produced by ventilation can be calculated using the following equation [16, 17]

$$H_{43} = n_{fan} \times P_{fan} \times t_{fan} \quad (11)$$

Where:
n_{fan} = Number of fans
P_{fan} = Power of the ventilation system (W)
t_{fan} = Daily working time of the ventilation system

Heat produced by electrical defrost processes (H_{44})

The heat produced by electrical defrost processes can be calculated using the following equation [16, 17]

$$H_{44} = n_{def} \times P_{def} \times t_{def} \times F \quad (12)$$

Where:

n_{def} = No. of electrical defrost heating (number)
P_{def} = Power of electrical heating (W)
t_{def} = Time of the defrost for a day
F = Defrost factor (heat lost to cold room)

The resulted 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.

III. METHODOLOGY

Based on the customer order record and the production plan, the amount of the fresh-cut yam bean that should be ready in the designated cold room was 240 kg or 2400 slices. The fresh-cuts are packed using polypropylene (PP) tray with 5 slices/tray. The packing is performed using modified-atmosphere packaging technique, in which the technique involves displacing the normal atmosphere of the air inside the food package and replace it with nitrogen (N_2). The nitrogen gas does not support the growth of aerobic microbes, and thus, inhibits the growth of aerobic spoilage. The prospect location of the proposed cold room was given in Fig. 2. A premise is an intermediate unit in a terrace factory. Section 4.6.8 Malaysian Standard 1514:2009 Good Manufacturing Practice for Food (GMP) has highlighted the following requirement on the storage design [19]:

- Permit adequate maintenance and cleaning
- Avoid pest access and harborage
- Enable food to be effectively protected from contamination during storage
- Where necessary, provide an environment which minimizes the deterioration of food (e.g. by temperature and humidity control)

Another important general design requirement by GMP is that working spaces should be adequately unobstructed and of adequate width to permit employees to perform their duties [19].

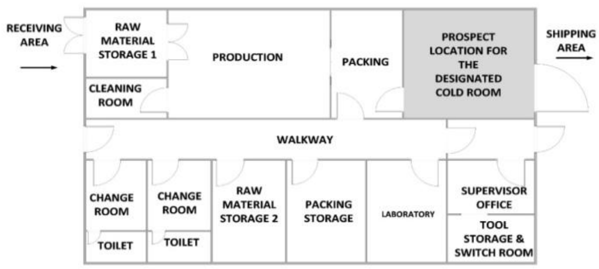


Fig. 2 Proposed location of the cold room in the factory premise

The storage condition is planned as follows:

(1) 5 slices of yam bean are packed in a polypropylene tray using MAP technique (0.5 kg/tray)

(2) 20 of polypropylene trays are placed inside one ice box (10 kg/box)

(3) The ice box has the outer size of 450 x 360 x 400 mm and inner size 400 x 310 x 320 mm that be able to accommodate 20 trays

(4) All ice boxes are placed on a warehouse rack with their size can be customized by the suppliers. The fully-loaded rack should give a minimum of 60 cm clearance from the ceiling

(5) Maximum two operators can occupy the cold room for handling the storage.

By respecting the GMP requirement in [19], the cold room was designed and the end volume (size) of the cold room was determined. The design was performed by respecting the following considerations.

- The fresh-cuts should be kept in the cold room with maintained at 5°C to retard the microbial growth and discoloration [3]
- All the ice boxes would be moved using trolley of size 720 x 470 x 1000 mm (in length, width and height). Hence , the width of aisle = 500 mm + width + 500 mm [20]
- Aisle should be minimally of 0.875 m for workers to conveniently move around when performing their duties [20]
- The optimum arrangement of racks to be accommodated in the cold room must allow the workers to conveniently perform the storing duties (onward flow from the entrance to exit door)
- Placement of evaporators: Clearance from ceiling and wall to evaporator is 40 cm, under evaporator is 30 cm [7]
- Clearance of 10 cm between ice boxes in the direction of air flow
- The highest shelf for practical use should be 2.1 m, and the lowest should be 15 cm from the floor to prevent contamination
- Clearance between the shelves should be at least 37.5 cm (air circulation)
- Clearance of 45 cm should be provided between the rack and the wall for inspection and cleaning (hygiene) [17].

Determining the cooling load and required refrigeration capacity

The air inside the cold room will absorb the heat from different sources and this heat must be removed in order to maintain the cold room at 5°C and 90% relative humidity. The source of the heat load is the transmission through cold room enclosures (4-sided wall, ceiling, floor, doors), infiltrated air from the surrounding, stored fresh-cut, workers, lighting, fan and electrical defrosting equipment. Hence, all the heat load was calculated by adopting the calculation from Equation 1 to 12 based on [7, 16, 17]. The resulted amount of the heat load that must be removed is the required cooling load that has to be performed by the designated cold room.

Nevertheless, 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 [15].

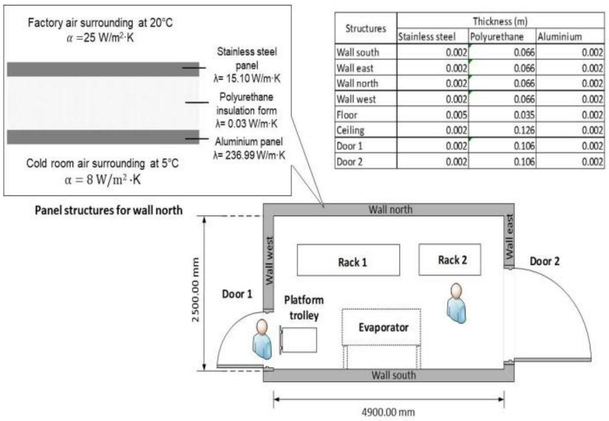
Having determined the required cooling load, the refrigeration capacity can be calculated using the following equation, by as the unit will run for 16 hours daily which is common for such type of vegetable storage.

$$Refrigeration\ capacity = \frac{Total\ cooling\ load\ (inc.\ safety\ \ factor)W\ h}{16\ h} \qquad (13)$$

IV. RESULTS AND DISCUSSIONS

Cold Room Design

The storage capacity requirement was determined to 24 boxes (=240 kg). The internal size of the cold room is designated to be 4.9 x 2.5 x 3 m (in length, width and height). The storage requires 1 set of evaporators with two fans, which are placed on one part of the wall. Two tube luminescent lamps (total illumination =200 lx) will be required for occasional lighting. Two racks are customized to accommodate 21 boxes at one time. The first rack has the dimension of 2.4 x 0.5 x 2.0 m while the second rack has the dimension of 1.2 x 0.5 x 2.0 m for length, width, and height respectively. The feature of the cold room illustrated in Fig. 3 below.



Structures	Thickness (m)		
	Stainless steel	Polyurethane	Aluminium
Wall south	0.002	0.066	0.002
Wall east	0.002	0.066	0.002
Wall north	0.002	0.066	0.002
Wall west	0.002	0.066	0.002
Floor	0.005	0.035	0.002
Ceiling	0.002	0.126	0.002
Door 1	0.002	0.106	0.002
Door 2	0.002	0.106	0.002

Fig. 3 Cold room layout for 240 kg yam bean

Cooling Load

The heat amount from all sources was determined and the measured as well as specified values were tabulated in Table 1. The heat load gained by transmission through enclosed structures composed about 22 % of the cooling load, while by infiltration was 18%, product (yam bean) 36% and another heat load such as ventilation, lighting, human and defrosting was 23%. When compared to previous studies as in Fig. 4, the result of this study agreed with most of their outcomes which involve the cold storage of potatoes, fishes and vegetables [7, 13, 14]. The heat load sourcing from the products themselves constitutes the highest percentage. Heat load gained by transmission through structures also makes up a significant portion of the total cooling load. Another heat load also contributes a high percentage to the total cooling load mainly due to heat caused by the fan (evaporator) operation that takes ≥ 16 hour per day. Similar to cold storage for potatoes and vegetables, the heat gain through infiltration was the least. The resulted total heat load for cold storage of fresh-cut yam bean was obtained as 46295.04 Wh, while this implied the cooling load that needs to be delivered by the refrigeration system was 53239.30 Wh after considering the safety factor of 15%. This consideration is important as the demand in the food sector was volatile and subjected to fluctuation, whereby occasionally producers might have to produce more fresh-cuts to cater to the market. In addition, the safety factor is necessary when considering there are warmer days that the entering fresh-cut temperature is higher than the average 22°C. Based on the resulted cooling load, the total refrigeration capacity was obtained as 3.33 kW and serves as the basis for determining the optimum coefficient of performance (COP) as well as sizing of the refrigeration equipment such as compressor, condenser and evaporator.

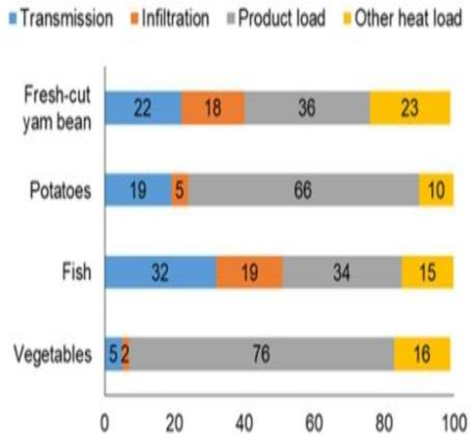


Fig. 4 Heat load percentages in cold storage for fresh-cut yam beans compared to other food products

Based on the detailed evaluation of individual heat load in Table 1, the design, operation and installation of the cold room were optimized to minimize the possible heat load as follows.

- Transmission heat load through enclosed structure was obtained as 10352.58 Wh and can be minimized by having the panel with high thermal conductivity at the inner side of the cold room to accelerate the heat transfer from the inside space to the outside surrounding. Based on the available specification for the cold room panels from literature and verified by the contractor, the prefabricated sandwich panels of the cold room were specified to be made of stainless steel (outer layer), aluminum (inner layer) and filled with polyurethane insulation (PUR). Their thermal conductivity and coefficient of heat transmission are given in Fig. 3.
- The cold room (Ti_n= 5°C or 278.15 K) is located inside the factory, whereby the outside temperatures (T_{out}) was measured on site in the factory at the prospect location of the cold room. Since it was known based on Equation 1 that the heat load increases with the larger surface area, the smaller wall surface (wall east) of the cold room was positioned to face the warm area (T_{out}= 25°C) while the larger wall surface was orientated to face the factory space that is maintained at 20°C through ventilation system.
- The cold room will be mounted (installed) on the concrete platform to minimize the heat gain through flooring from the soil (at least 30 cm above ground). Hence, the ramp

must be provided at the door to facilitate the movement of the trolley.

- The infiltration heat was obtained as 8501.90 Wh and can be further minimized by providing a plastic curtain at the doors. It is important to keep the door tightly shut all the time and minimize its opening as well as avoid leaked in the structures. An alarm can be installed to warn the operators if the temperature of cold room deviates above 5°C.
- The heat load gained from the entering fresh-cut yam bean was the highest (16828.56 Wh) and mainly due to high $\Delta T_{product,}$, since the fresh-cut were required to be cooled down from 22°C to 5°C. Hence, in order to minimize $\Delta T_{product,}$ the fresh-cuts were proposed to be pre-cooled by submerging the slices in a cold water tank about 0 to 1°C (to enhance crispiness and reduce microbial load) and then, brought onto dewatering station (using blower) before being packed and brought into the cold room.
- Other heat loads (10612.00 Wh) can be minimized by reducing the working time by operators and hence, the lamp on-time in the cold room to be less than 2 h. The defrosting system may also be specified to have better efficiency, so that the heat loss could be reduced.

Table. 1 The heat amount from all sources

Heat sources		Measurement	Resulted Cooling Load
Transmission through wall panels with inside (cold room) temperature, T_{in} =5°C throughout time 24 hr			
Wall north, H_{north}			2237.50 Wh
	Area of heat transmission, A_{north}	14.7 m^2	
	Heat transfer coefficient, U_{north}	0.42 W/m^2•K	
	Outside temperature, T_{out}	25°C	
Wall south, H_{south}			2237.50 Wh
	Area of heat transmission, A_{south}	14.7m^2	
	Heat transfer coefficient, U_{south}	0.42 W/m^2•K	
	Outside temperature, T_{out}	20°C	
Wall east, H_{east}			913.26 Wh
	Area of heat transmission excluding door , A_{east}	4.5 m^2	
	Heat transfer coefficient, U_{east}	0.42 W/m^2•K	
	Outside temperature, T_{out}	25°C	
Wall west, H_{west}			867.60 Wh
	Area of heat transmission excluding door, A_{west}	5.7 m^2	
	Heat transfer coefficient, U_{west}	0.42 W/m^2•K	
	Outside temperature, T_{out}	20°C	
Cold room door 1, H_{door1}			175.21 Wh
	Area of heat transmission, A_{door1}	3.0 m^2	
	Heat transfer coefficient, U_{door1}	0.27 W/m^2•K	
	Outside temperature, T_{out}	20°C	
Cold room door 2, H_{door2}			389.35 Wh
	Area of heat transmission, A_{door1}	1.8 m^2	
	Heat transfer coefficient, U_{door1}	0.27 W/m^2•K	
	Outside temperature, T_{out}	25°C	
Floor, H_{floor}			2185.12 Wh
	Area of heat transmission, A_{west}	12.25 m^2	
	Heat transfer coefficient, U_{west}	0.75 W/m^2•K	
	Outside temperature, T_{out}	14.90°C	
Ceiling, $H_{ceiling}$			1347.04 Wh
	Area of heat transmission, A_{west}	12.25 m^2	
	Heat transfer coefficient, U_{west}	0.23 W/m^2•K	
	Outside temperature, T_{out}	25.00°C	
	Total transmission load, H_1		10352.58 Wh
Infiltration through the entrance of the air throughout 24 hr			
	The volume of the cold room (to be refrigerated), V	36.75 m^3	
	Reference value for the daily number of air exchanging, z	5	

	Specific volume of air at 20°C, 60% relative humidity, *v*	0.8429 m^3	
	Specific enthalpy heat obtained from the psychrometric chart, Δh	39 kJ/kg	
	Total infiltration load, H_2		8501.90 Wh
Heat load of the fresh-cut			
During cooling to from 22°C to 5°C			
	Mass of yam bean in cold room, *m*	240 kg	
	Specific heat above freezing point, *c*	3.67 kJ/(kg·K)	
	Temperature difference, $\Delta T_{product}$	17 K	
	Heat load due to cooling, H_{cool}	14973.60 Wh	
Respiration throughout 24 hr			
	Specific heat load due to respiration, c_{resp}	77.29 mW/kg	
	Heat load due to respiration, H_{resp}	1854.96 Wh	
	Total fresh-cut load, H_3		16828.56 Wh
Other heat loads			
Workers			
	Number of workers at one time, n_w	2	
	Heat load produced by a worker with physical activities = c_w	250 W	
	Total daily working duration in cold room, t_w	2 hr	
	Heat load due to the worker, H_{41}	1000 Wh	
Lamp			
	Number of the lamp, n_l	2	
	Lightning power	18 W	
	Total daily working duration in cold room, $t_l = t_w$	2 hr	
	Heat load due to the worker, H_{42}	72 Wh	
Electrical defrost			
	Number of electrical defrost heating, n_{def}	1	
	Defrosting power	1800 W	
	Heat lost to the cold room	70% from the power input	
	Daily defrosting time, t_{def}	3 hr	
	Heat load due to defrosting, H_{43}	3780 Wh	
Ventilation system			
	Number of fan, n_{fan}	2	
	Fan power	180 W	
	Daily operating time, t_{fan}	16 hr	
	Heat load due to the fan, H_{44}	5760 Wh	
	Total other's load, H_4		10612.00 Wh
	Total heat load from all sources = required cooling load for refrigeration equipment		46295.04 Wh
	Cooling load after multiplying with safety factor (46295.04 Wh x 1.15)		53239.30 Wh
	Refrigeration capacity for operating time 16 hr (53239.30 Wh /16hr)		3.33 kW

V. CONCLUSIONS

This study demonstrated the procedural approach for sizing a cold room for storage capacity of 240 kg fresh-cut yam bean by considering all the necessary design details such as shelving, workspace for workers and trolley as well as the required GMP requirements. The calculation of cooling load for the designated cold storage was then proceeded by considering all the possible heat sources during operation in order to address the correct and matching refrigeration capacity. The information on the Correct refrigeration capacity would enable the appropriate selection of refrigeration equipment and hence, prevent the Common energy wastage among SMEs that can occur due to oversizing or undersizing of the cold room specifications.

The results obtained are in line with reports by other studies that show energy usage by cold room is largely influenced by the food heat followed by transmission, and infiltration or other heat sources.

In addition, the information on the heat load coming from different sources enables SMEs to take the necessary precaution during the storage process for preventing excessive energy usage. This includes strategic production planning that does not exceed the storage capacity, pre-cooling of fresh-cut before bringing into cold storage, minimizing door opening, controlling the surrounding cold storage temperature within the factory area and reducing man-hours working in the cold room.

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