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Experimental Study on Effect of PCM Material used in Chocolate Freezer

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Abstract— *There are large numbers of phase change materials that melt and solidify at a wide range of temperatures. Our study on the chocolate freezer in which we build a storage system which store the energy and provide it at the time of power failure because at the time of power failure in the chocolate freezer chocolate is melt or dissolve and their taste is change.*
Ice packs or cooling pack are used as a PCM material in chocolate freezer to build a thermal energy storage system. They provide latent heat energy for 4-5 hr. at 20 ℃. So that the main aim of this experimental study to choice such a PCM material which provide 4- 5 hr. storage capacity and inner side temperature of system maintain 20°C.
Keywords— Chocolate Freezer, renewable energy sources, PCM material.

I. INTRODUCTION

The researchers and scientists all over the planet are in search of new renewable energy sources. One of the options is to develop energy storage devices, which are as essential as developing new sources of energy. Thermal energy storage systems give the possibility to achieve energy savings, which in turn reduce the environment impact related to energy use. In fact, these systems provide a valuable solution for correcting the difference that is often found in the supply and demand of energy [1, 2, 3]. Latent heat storage is a relatively new area of study. Latent heat storage is one of the most resourceful ways of storing thermal energy. Unlike the sensible heat storage method, the latent heat storage method provides much high storage density, with a smaller temperature variation between storing and releasing heat [4]. There are large numbers of phase change materials that melt and solidify at a large range of temperatures. Ice packs or cooling pack are used as PCM materials to build a storage system in the chocolate freezer. So we developed a small thermal storage system. These ice packs will be available easily and are very economical PCM material at that range which provides a better result [5].
There some following reason to choice that system-

- Can easily replace dry ice or gel packs.
- Are reusable.
- Assure predictable and stable temperature control.
- Are available in a wide range of temperatures.
- Increase the temperature control duration during transportation.
- Reduce transportation cost.
- Easily available at economical price.

Ice pack provides latent heat energy for 4-5 hr. at 20^{o}C. So that backup or storage energy is available 4-5 hr. for this system which can be used at the time of power failure to prevent chocolate from melting [7].

II. OBJECTIVE

Today, power failure or shortage of electricity is a major problem. Since the population is increasing day by day with the increased use of technology, power consumption is also increasing [1].
One of the very popular retail products is chocolate and retains its quality if stored at desired temperature which is 18-20°C. The retailers are using a refrigerator to maintain the desired temperature [3]. But during a power failure, the temperature of the chocolate stack increase rapidly in summer and humid season and it resulted in the melting of the chocolate.
Therefore the objectives of the present project are-

(i) To study the existing chocolate freezer.
(ii) To estimate the heat losses for the freezer.
(iii) To design a cold thermal storage unit to maintain the temperature for 4 hr.
(iv) To study the performance of the chocolate freezer with and without cold storage unit.

2.1 Identification of cold thermal storage System and materials

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This study used data obtained from 7 May to 9June on chocolate freezer by myself. The chocolate freezer is the size of 50cm * 50cm. The small side of the chocolate freezer is 15cm and the bigger one is 35cm having an angle of 15°. The chocolate freezer has PUFF insulation covered by double sheet plastic inside and metal sheet outside. PUFF insulation size has 30cm of whole sides. The upper side is covered with glass sheet of 5 mm thickness.

III. SPECIFICATION

Size of the chocolate freezer – 50cm x 50cm.
Smaller side (height) – 15 cm
Bigger side (height) - 35 cm
Angle -15°
Insulation used – PUF (polyurethane foam)
Thickness – 30 mm
Compressor

- Make – Videocon industries Ltd.
- Volt – 220v
- Capacity – 1/8 hp
- Frequency – 50/60 Hz

IV. CALCULATIONS

Upper surface glass area = 50 x 50 cm^2 = 0.25m^2
Glass thickness = 5mm
Coefficient of glass K_g = 0.8 w/mk

$$\frac{1}{U} = \frac{1}{h1}+\frac{1}{h2}+\frac{L}{K}$$

Where -

U = overall heat transfer coefficient
$h_1$and h_2 convective film coefficients
h_1 = 20 W/m^{2o}C
h_2 = 10 W/m^{2o}C
K = K_g = 0.8 w/mk

Upper side heat transfer coefficient-

1/U = 1/20 + 1/10 + 1/0.8/0.005
1/U = (0.05+0.1+0.006)
1/U = 0.16
U = 6.4W/m^{2o}C

Side thickness = 30mm
L_1 = 30mm
L_1 = 0.03m
Coefficient of metal (K_1) = 0.04 w/mk

$$\frac{1}{Us} = \frac{1}{h1}+\frac{1}{h2}+\frac{L1}{K1}$$

1/U_s = 1/20 + 1/10 + 0.03/0.04

Heat transfer coefficient U_s= 0.9 W/m^{2o}C
U_s= 1.3 W/m^{2o}C is heat transfer coefficient of remaining sides.

Top side losses **(Q) = U*A*Δt**
Q = 6.4*0.25*15ºC
= 24 watt

Total 4 hrs. Backup is required so = 24 * 4 = 96wh = 0.096kwh = 346 KJ

Q = m*L

Where L = 150 KJ/Kg. (latent heat of PCM)
m = Q/L
m = 346/150
m = 2.31 ≈ 2.5 kg

So required PCM material quantity is 2.5 Kg.

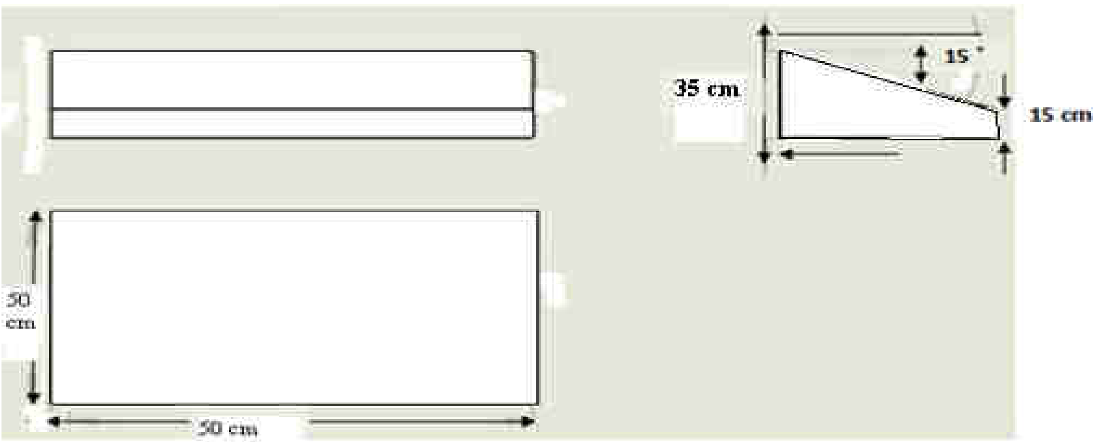

Fig.1: Experimental set up of chocolate freezer

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V. PROCEDURE

The study examines the performance of the chocolate freezer from data collected during eight separate testing conditions.

1. Without ice pack and compressor first ON and OFF in regular interval.
2. Without ice pack and compressor ON.
3. With ice pack and compressor ON.
4. With an ice pack, compressor ON and OFF.
5. With ice pack and compressor OFF.
6. With an ice pack, compressor ON and OFF in regular interval.

VI. OBSERVATIONS TABLE

Table 1: The performance of the chocolate freezer without ice pack and compressor ON and OFF regular time interval

Time	Inner side air Temp. (˚C)	Room Temp. (˚C)	
9.00	39.4	35.1	Power ON
9.30	28.5	35	“
10.00	17.3	35.2	“
10.30	15	35.5	“
11.00	13.9	35.6	Power OFF
11.30	19.5	35.7	“
12.00	30.2	35.9	“
12.30	36.1	36	“
1.00	37.5	36	“
1.30	38	35.9	Power ON
2.00	16.9	35.6	“
2.30	14.4	35.4	Power OFF
3.00	28.5	35.1	“

Table 2: The performance of the chocolate freezer without ice pack and compressor ON

Time	Inner side air Temp. (˚C)	Room Temp. (˚C)
9.00	35.6	37
9.30	17.4	37
10.00	15.8	37.2
10.30	15.2	37.2
11.00	14.6	37.8
11.30	14.5	38
12.00	14.8	38
12.30	15.0	38.3
1.00	16.8	37.9
1.30	15.9	37.6
2.00	15.8	37.4
2.30	15.7	37.1
3.00	15.4	36.7

Table.3: The performance of the chocolate freezer with ice pack and compressor ON

Time	Inner side air Temp. (˚C)	Room Temp. (˚C)
9.00	35.4	38
9.30	20.0	37.7
10.00	17.2	37.5
10.30	16.9	37.6
11.00	16.5	37.8
11.30	16.2	38
12.00	16.1	38.2
12.30	15.9	38.3
1.00	15.3	38.5
1.30	15.1	38.2
2.00	14.9	38
2.30	14.8	37.7
3.00	14.4	37.2

Table 4: The performance of the chocolate freezer with ice pack, compressor first ON and OFF

Time	Inner side air Temp. (˚C)	Room Temp. (˚C)	Condition
9.00	40.3	36	Power on
9.30	17.6	36.1	Ice pack store
10.00	14.6	36.3	Power off
10.30	12.1	36.4	Power off
11.00	17.7	36.6	Power off
11.30	20.1	36.8	Power off
12.00	20.6	37	Power off
12.30	21.0	37.2	Power off
1.00	21.9	37.5	Power off
1.30	22.7	37.3	Power off
2.00	23.8	37	Power off
2.30	24.8	36.7	Power off
3.00	25.1	36.4	Power off

We calculate the rate of heat loss of PCM material at that particular heat difference at half an hour time interval.

$\Delta t = 17.7 - 12.1 = 5.6^{o}C$

The rate of heat loss = $11.2^{o}C/hr$.

We again calculate the value of heat loss at 4 hr. time duration when the compressor is OFF condition.

$\Delta t = 25.1 - 17.7 = 7.4^{o}C$

Rate of heat loss = $1.85^{o}C/hr$.

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Table 5: The performance of the chocolate freezer with ice pack and compressor OFF

Time	Inner side air Temp. (˚C)	Room Temp. (˚C)	Condition
9.00	43.3	36.9	Power off
9.30	27.5	36.9	Power off
10.00	18.5	37	Power off
10.30	17.7	37	Power off
11.00	17.9	37.2	Power off
11.30	18.2	37.3	Power off
12.00	18.7	37.5	Power off
12.30	18.9	37.5	Power off
1.00	19.3	37.9	Power off
1.30	20.1	38	Power off
2.00	20.4	37.8	Power off
2.30	21.5	37.6	Power off
3.00	21.8	37.5	Power off

From:- Temperature 18.5°C to final temp. 21.8°C for 5 hr. time interval.

(Temp. difference) $\Delta t = 21.8 - 18.5 = 3.3$°C

Rate of heat loss = 0.66°C/hr.

Table.6: The performance of the chocolate freezer with an ice pack, compressor ON, and OFF at regular interval.

Time	Inner side air Temp. (˚C)	Room Temp. (˚C)	Condition
9.00	41.8	35.7	Power on
9.30	26.8	35.7	Power on
10.00	16.5	35.5	Ice pack store
10.30	12.3	35.6	Power off
11.00	17.7	35.8	Power off
11.30	18.9	36	Power off
12.00	19.0	36.4	Power off
12.30	19.1	36.5	Power off
1.00	19.2	35.9	Power off
1.30	19.3	35.6	Power on
2.00	10.4	35.4	Power off
2.30	19.3	35.1	Power off
3.00	20.5	35	Power off

From:- Temperature 12.3°C to 19.3°C for 3 hr. time interval.

(Temp. difference) $\Delta t = 19.3 - 12.3 = 7$°C

The rate of heat loss = 2.33°C/hr.

Last one hour again we find the value of the rate of heat loss from temperature 10.4°C to 20.5°C.

(Temp. difference) $\Delta t = 20.5 - 10.4 = 10.1$°C

The rate of heat loss = 10.1°C/hr.

VII. GRAPH OF THE PERFORMANCE OF THE CHOCOLATE FREEZER WITH AND WITHOUT ICE PACK AND COMPRESSOR ON AND OFF

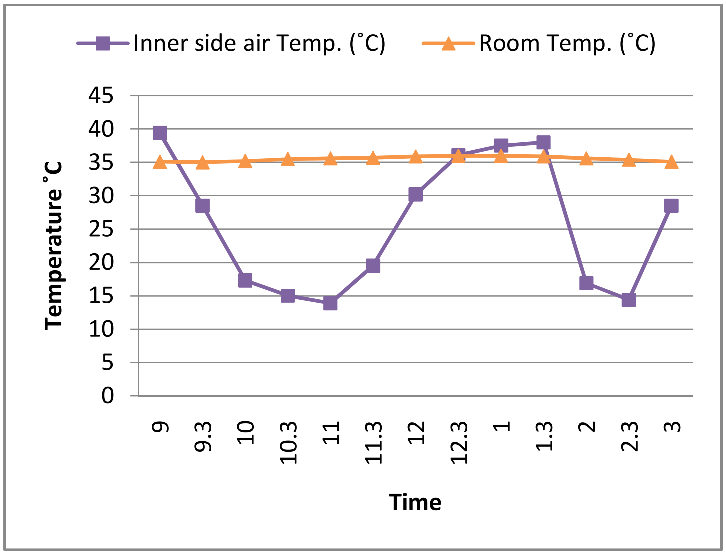

Fig. 2: The performance of the chocolate freezer without ice pack and compressor ON and off

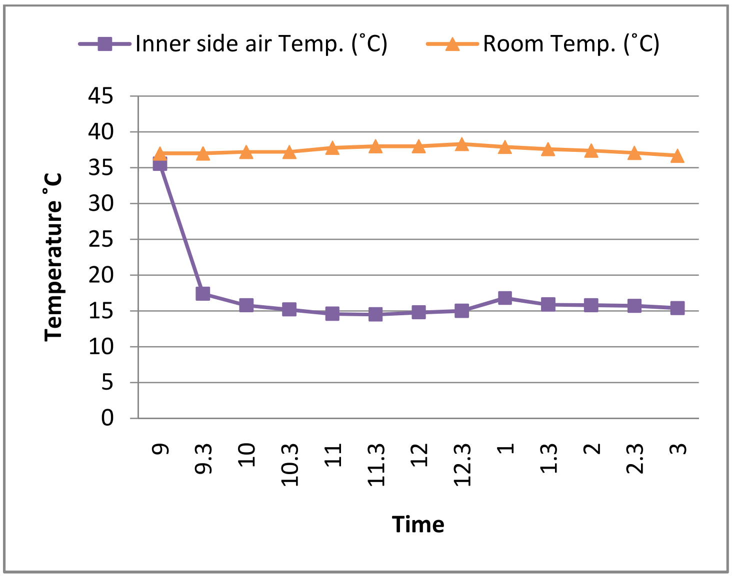

Fig. 3: The performance of the chocolate freezer without ice pack and compressor ON

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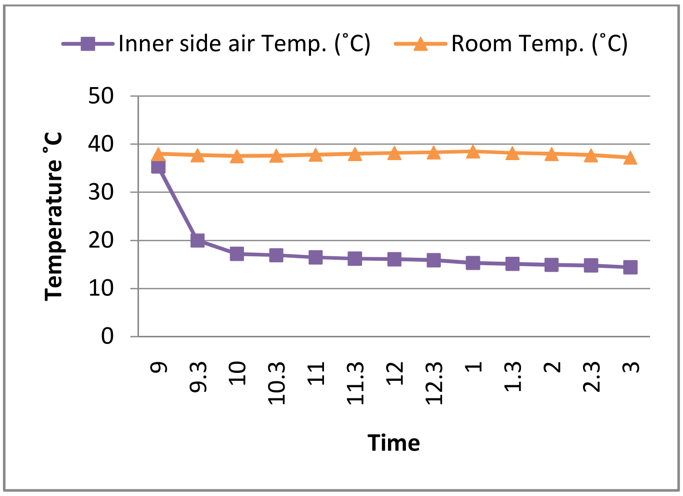

Fig. 4: The performance of the chocolate freezer with ice pack and compressor ON

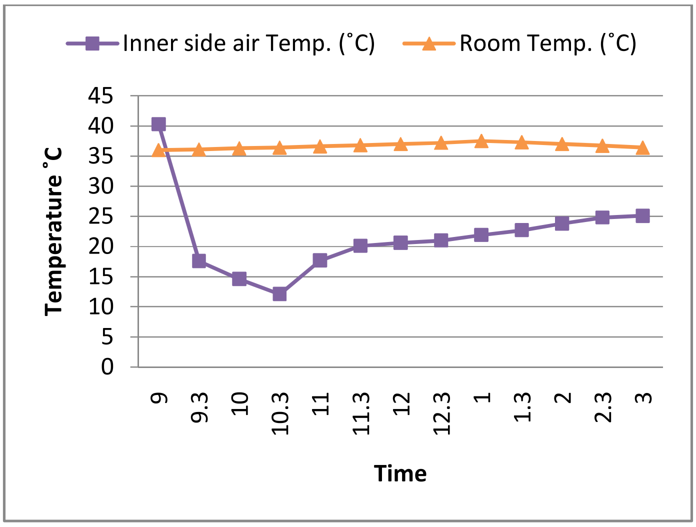

Fig. 5: The performance of the chocolate freezer with ice pack, compressor ON, and OFF

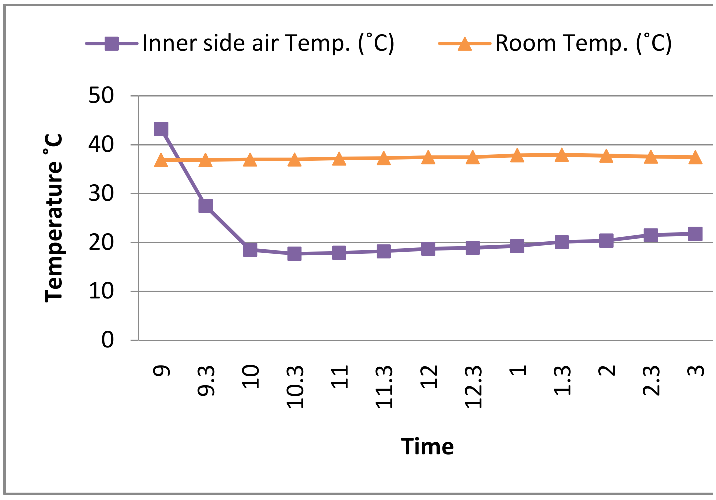

Fig. 6: The performance of the chocolate freezer with ice pack and compressor OFF

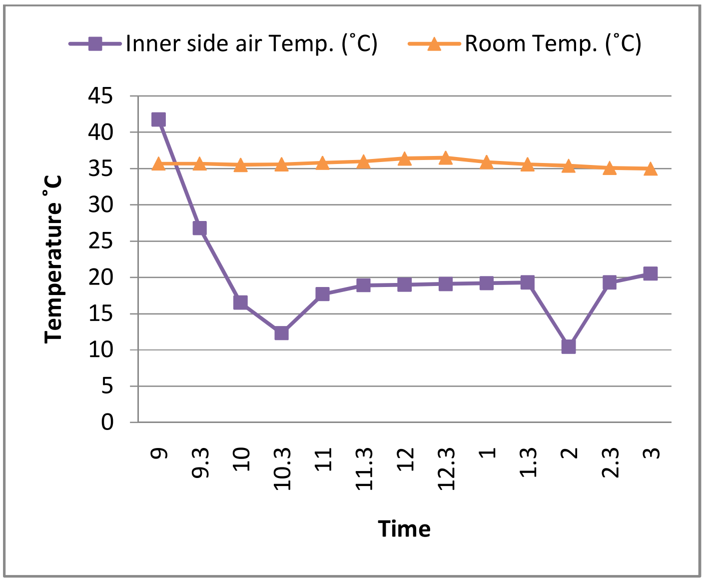

Fig. 7 : The performance of the chocolate freezer with an ice pack, compressor ON, and OFF at regular interval.

VIII. RESULT

In this experimental study, a cold thermal storage unit is built and ice pack use as a PCM material (vinyl-coated silica gel). Our focus is to select the PCM material which provides 4 to 5 hrs. storage capacity backup at temperature 20ºC and ice pack are fulfilled these requirements at very economical prices. This PCM material provides 4 to 5 hr. thermal storage capacity in this storage system. We perform this experimental study at different-different conditions and record their data.

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