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Drying Of Pepper with the Aid of Solar Energy Dryer

John .U. Manukaji
Solar Energy Research Centre Federal Polytechnic P. M. B 55 Bida Niger State

Abstract: - Using the sun to dry crops and grains is one of the oldest and most widely used applications of solar energy. The simplest and least expensive technique is to allow crops to dry naturally in the field, or to spread grain and fruit out in the sun after harvesting. More sophisticated solar dryers protect grain and fruit, reduce losses, dry faster and more uniformly, and produce a better quality product than open air methods.Pepper is a universal spicing agent used to add flavor to many delicacies. It is grown universally throughout the world. It could be used both fresh and dried. In advanced countries where good storage systems occur, farmer that experience bumper harvest could easily preserve their product in its fresh state for a very long time. Whereas in Africa where good, effective and efficient storage systems are lacking, most farmers that experience bumper harvest preserve most of their pepper in dried state. The current process of drying pepper in the rural African setting is crude, unhygienic and exposes the pepper to birds, rodents and other animals. A designed and constructed solar pepper dryer was able to dry50kg of fresh pepper to preservation level within three days. The dryer comprised of two chambers (the air heater and the storage bin). Using natural convection, an average wind speed of 4.50m/s and an average solar intensity of 776w/m^2 , it dried 50kg of fresh pepper, reducing its moisture content by 83% from its original value. The dryer could also be used to dry other related fresh crops.

I. INTRODUCTION

Peppered delicacy is one of the foods enjoyed by most people in the World in general and Nigeria particular. Pepper is a seasonal crop unless in places where intensive irrigation is practiced. When not in season, and where effective and efficient storage systems are not available dried pepper is used to spice another type of delicacy. The drying process adopted by most rural farmers throughout the world involved drying the pepper in the sun by spreading it either on cemented floor or on trays thereby exposing it to rodents, insects, bacteria and fungal attack. To prevent this unhygienic method of drying, a device was constructed to perform the same action but this time in a better, more hygienic and predetermined manner.

Although moisture may be extracted from various substances in a variety of ways the method universally adopted in farm crop dryers is vaporization with the removal of the moisture in a stream of drying air. Vaporization does not necessarily involve boiling the water and converting it to steam, in fact many farm dryers operate at temperatures well below boiling point and some at atmospheric temperatures**Bliss (1959).** The temperature will always be controlled and monitored in order to preserve the life of the seeds in the crop.

The picking up of moisture by a stream of drying air depends on the fact that the moisture in the crop tends to come into a state of equilibrium with the drying air. The power of the air to dry the crop depends on the difference between the amount of water vapor it already contains and the amount it can hold saturated.

The amount of water that a given volume of air can carry increases rapidly with temperature**Brooker 1974**. It may therefore, be seen that if there is a given amount of water to be removed from a material by an air-stream, this may be achieved either by a small volume of air-stream leaving the dryer at high temperature or by a larger volume exhausted at a lower temperature. It would of course be useless merely to increase the temperature of air used for drying if this air remained saturated with water vapor. Heating a given volume of atmospheric air which contains a definite amount of water vapor, in fact reduces its relative humidity. Heating the drying air is therefore, a common method of speeding up the crop drying process and incidentally of increasing thermal efficiency. Drying temperatures employed are usually as high as they can safely be, without causing damage to the material being dried or leading to inefficient operation in other ways**Close 1963**.

II. DESIGN ANALYSIS

Drying grains and other agricultural products is a very energy-intensive process. The variation in drying methods and equipment is due to the type of dryer used, airflow rate, drying air temperature, ambient conditions, product conditions and types, and the type of energy used. Solar drying is technically feasible but still not economically competitive at this time. This is because most solar crop dryers employ the services of a back-up during the heavy rains.

The air heated in the solar collector moves, either by natural convection or forced by a fan, up through the material being dried. The size of the collector and rate of airflow depends on the amount of material being dried, the moisture content of the material, the humidity in the air, and the average amount of solar radiation available during the drying season.

Solar dryers have many configurations sizes and shapes and these are very much influenced by the type of crop to be dried and the quantity of the crop to be dried as well as the drying rate. The Pepper dryer designed was solely operated with solar energy and used naturalconvection.

III. EXPERIMENTAL RESULT ANALYSIS.

The natural convection circulation solar crop dryer is simulated to include the effects of varying ambient conditions of air temperature and humidity and diffuse and beam components of solar radiation. The total daily entropy generated by the system, comprising contributions from absorption of solar radiation at the crop temperature, heat transfer in the system, moisture evaporation from the crop, fluid friction generated by the working fluid and the energy stored in the thermal mass of the system, is calculated. It is shown that operating the dryer at conditions of minimum entropy generation yields a useful criterion for choosing dryer dimensions and is compatible with the desire to maintain allowable limits on crop temperature.

The fundamental laws of heat and mass transfer during drying of grains as presented by **Brooker(1974)** was used. After some convenient transformations as a result of the differences in environmental conditions, a simple and accurate model was derived. This is because it can be shown by elementary energy balance that

$Qu = Qc - Ql$…………………1

Where Qu is energy used, Qc is energy collected and Ql is energy lost.

For a flat plate collector, energy collected is given as

$Q = AI(To - Ta)$……………………..2

Where A is the collector area, I is insolation , To is temperature rise and Ta is ambient temperature.

Following **Threlkeld (1970)**, the temperature rise of ambient air passing through solar collector having uniform flow on a flat plate absorber is given by:

$To=Ta + (\tau\alpha)I\varepsilon/U_F^1$ ----------------3

Where

$\varepsilon = I-\exp.[-U_F^1/(G\ C_p(I+U_f/hk))]$…………………..4

Ta = ambient air temperature °C

To =air temp leaving collection °C

$(\tau\alpha)$= effective transmittance- absorptance product of cover and absorber combinations and essentially equal to the fraction of incident solar radiation that is absorbed by the absorber plate.

I = total (direct + diffused) insolation normal to the collector

U_f = combined convection and radiation heat loss coefficient between absorber and the outdoor environment.

h = Convection heat transfer coefficient from the inside wall of a circular duct to the air flowing through the channel.

K= Factor by which h is increased to account for heat transfer augmentation due to fins attached to the absorber plate and due to radiation across the air channel.

$U_F^1= U_f + U_B\ (1+U_f/hK)$……………………..5

is the effective heat loss coefficient, including the losses through the insulation around the air channel.

U_B = overall heat conductance between the moving air and the outside environment via the insulation air channel walls. This was calculated to be 7.588KJ/hrm² °C. (based on absorber area and material) for the configuration shown in figure 1.

C_p= specific heat of air taken as (1+1.84w)KJ/Kg °C where w is the absolute humidity (Kg water per Kg air)

G= mass flow rate of air per unit area of collector surface exposed to the sun.

The average absorber plate temperature Tpa is required to determine U_f and can be obtained from a relationship derived similarly to equation 1, but derived by **Bliss (1959) and Whillier (1964)**

$Tpa=Ta+(\tau\alpha)(I/U_f^1)(1-G\varepsilon C_p/U_f^1)$………………..6

In determining U_f, it was taken as the sum of the conductance through the glazing as determined by **Whillier (1967)** and the overall conductance through the walls and was calculated as 4.38KJ/hrm² °C, based on the absorber area. It was assumed that the black painted absorber and glazing emmissivities were 0.80 and 0.86 respectively, while the Kalwalltransmissivity to thermal radiation was assumed to be zero.

The convective heat transfer coefficient h was estimated using Reynolds analogy in the form $(St)(Pr)^{\circ}=F/8$, where the Moody friction factor F was determined from the experiment estimation. Substituting this into the heat transfer equation yields $Nu=0.033\ Re^{0.8}Pr$ and was used to evaluate the coefficient h with all properties evaluated at the filn temperature. Following the environmental conditions prevailing in Bida around the time of the experiment a value of K = 1.8 was assumed. Following **Whilliers(1967)** experiment, (0.91) was assumed for $(\tau\alpha)$ to include the glazing transmissivity. The calculations were based on a wind velocity of 4.50m per second , ambient temperature of 28°C , an insolation of 776W per meters ² and an area of 8.79m² was derived.

This derived area was multiplied by a factor of safety of 2 in order to take care of other thermodynamic and heat transfer parameters that were mistakenly not taken care of. The new area used for the construction should be 17.58m^2but it was approximated to 18m^2. A number of Pepper physical properties and some psychometric relationships were also used to size the complete system.

IV. MATERIAL SELECTION

At the end of the design 50kg of fresh pepper was estimated for drying. The materials selected for the construction were:

S/N	DESCRIPTION	DIMENSION	QTY
1	Plane glass	0.6 x 0.9 m	4
2	¾ " Plywood	1.22 x 2.44 m	6
3	Wire gauze	1.22 x 2.44 m	1
4	Black paint	4 litres	1
5	Grey paint	4 litres	1
6	Aluminum sheet	1.22 x 2.44 m	2
7	Angle iron	0.08 x 5.5 m	2
8	Hinges	0.05 x 0.05 m	6
9	Fly-proof	1.22 x 2.44 m	4
10	Screws	0.05 m	3pkt
11	Nails	0.05 m	3kg

Constructional techniques

The pepper dryer consists of two major parts. The air heater and the bin.

The air heater is a flat plate collector with plywood as sides, plain glass as cover and black painted aluminum sheet as absorber plate. After assembling the parts, with the aid of nails, a box like gadget was produced. The box like air heater has four 4cm square holes each on two sides of the box forming the width. These holes acted as inlet and outlet for the air. The box is 91.5cm x 183cm x 30cm.

The bin 91.5cm x 122cm x 152.5cm is also constructed with ¾" plywood. One of the sides of the bin housed a door for loading and unloading the bin. One of the walls of the bin has an opening 91.5cm x 30cm at its lowest part where the flat plate collector connects the bin. It also contains four stack made of wire gauze for spreading the fresh pepper. There is chimney at the top of the bin for the escape of the moist air. It also acted as a draft for the continuous escape of the moist air from the bin. An angle iron stand was constructed for both heater and bin and the assembly drawing is as shown in figure 1.

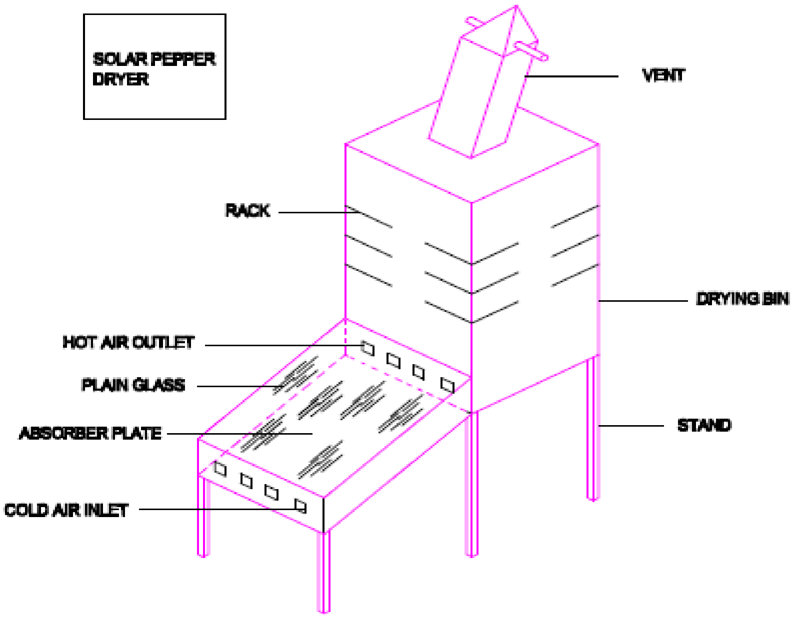

Figure 1

V. PERFORMANCE TEST.

The dryer was tested with 50kgs of fresh Pepper and when the tests were going on four temperature readings were recorded and plotted on the graphs below. The temperatures are, the minimum temperature, the maximum temperature (sole air temperature at the inlet of the air heater), the heated air temperature between the air heater and the bin and the temperature at the outlet chimney of the bin (exit temperature). The dryer was tested using twenty batches of fresh Pepper. Each of the batches were properly dried at an average of three days. The specimen from each of the twenty batches were tested for moisture content and it was discovered that the moisture was reduced to an average of 83% of the original level. The temperature of four batches were plotted as a representative of the temperature readings for the twenty batches since they were almost similar. The temperatures plotted showed that the differences in value between the inlet and outlet temperatures of the bin were much during the first drying days of any of the batches, but closed up during the last days of any batch. This shows that the amount of moisture carried by the drying air reduces consequently as the drying days increased.

VI. CONCLUSION

Dried Pepper had been made available for years by the local farmers through the crude and unhygienic method. The constructed gadget has acted as an innovation and if commercialized will go a long way in helping the rural farmers improve their local processing techniques of Pepper and many other related crops. The device can also be increased in size as designed to cope with increased yield of Pepper.

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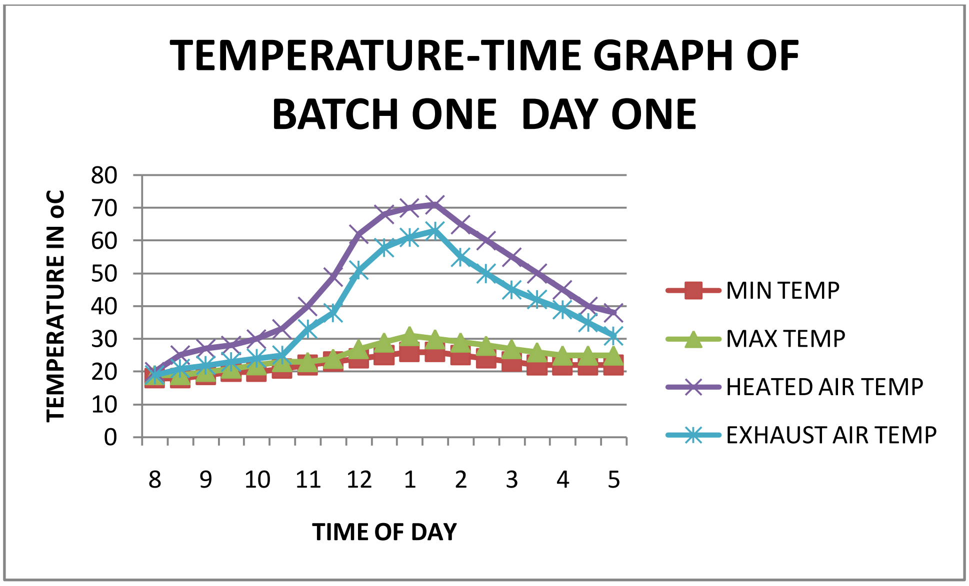

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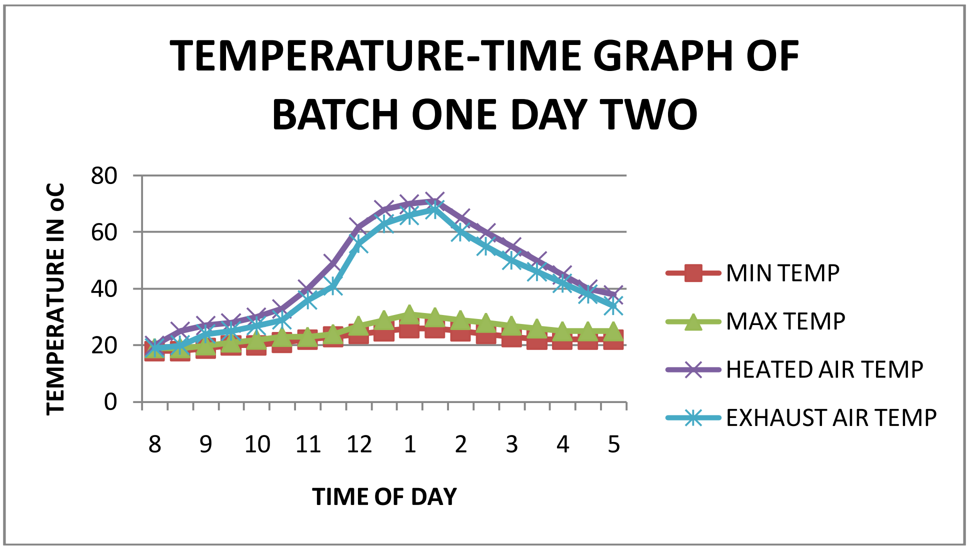

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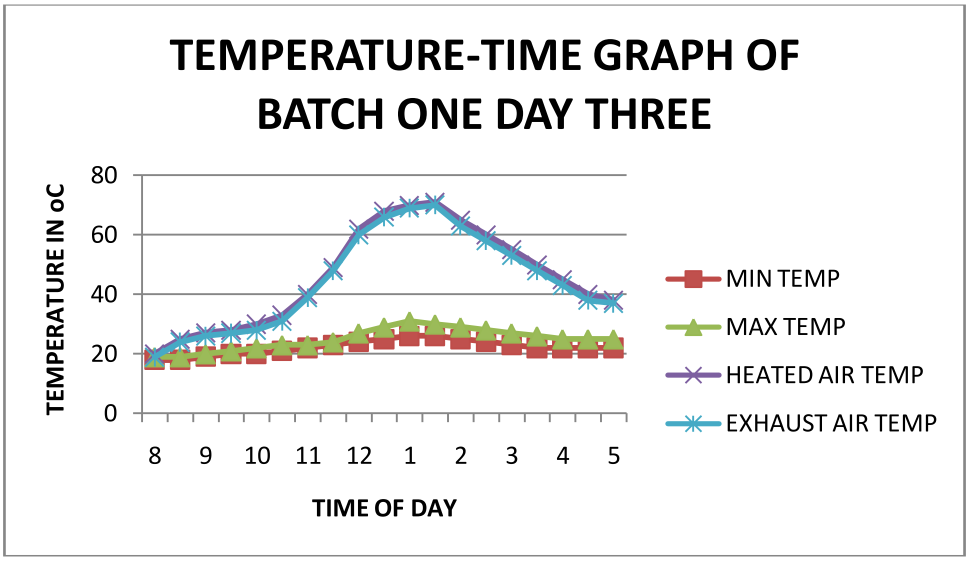

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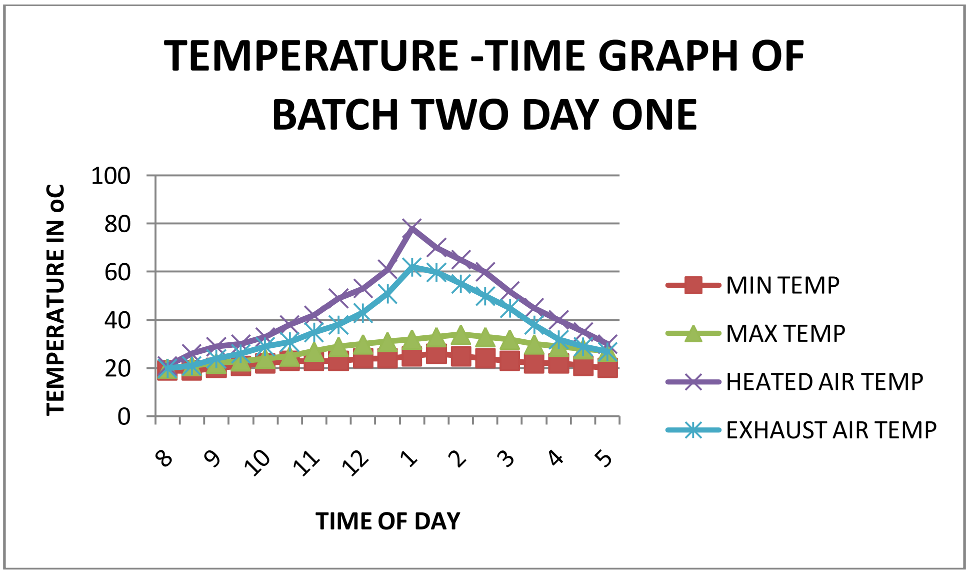

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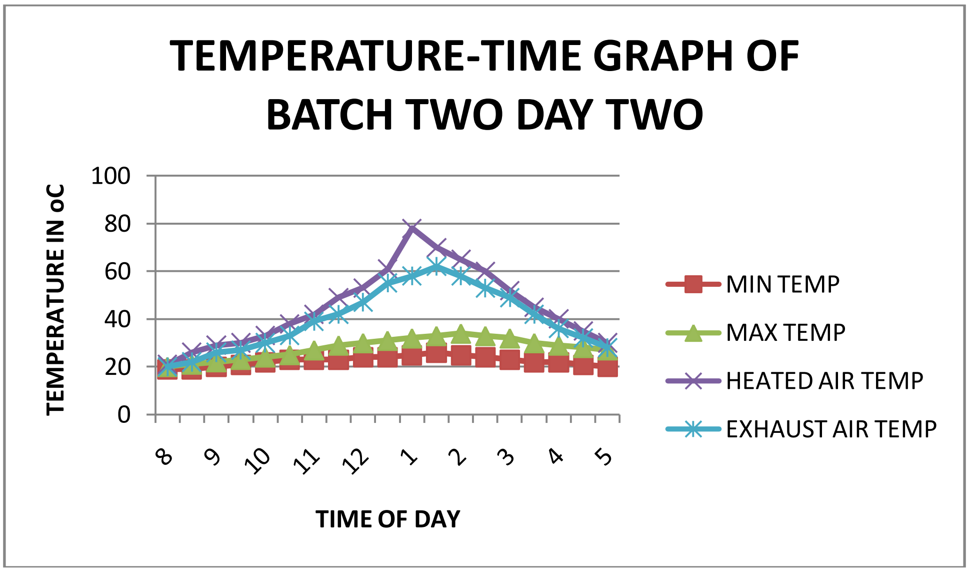

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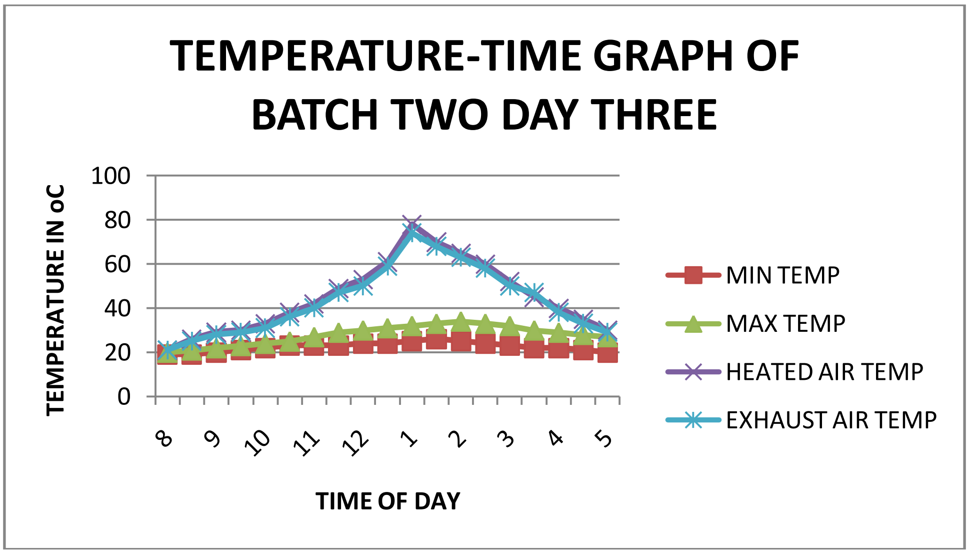

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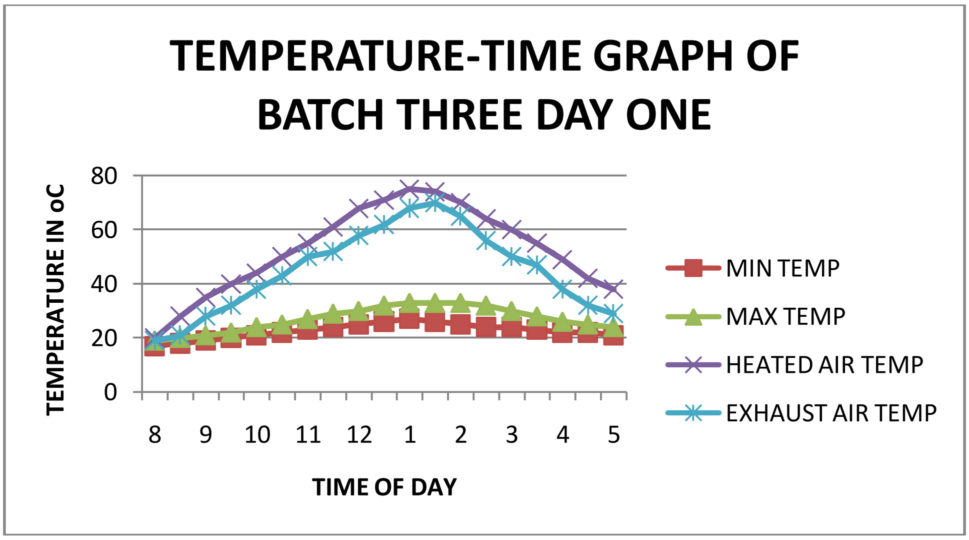

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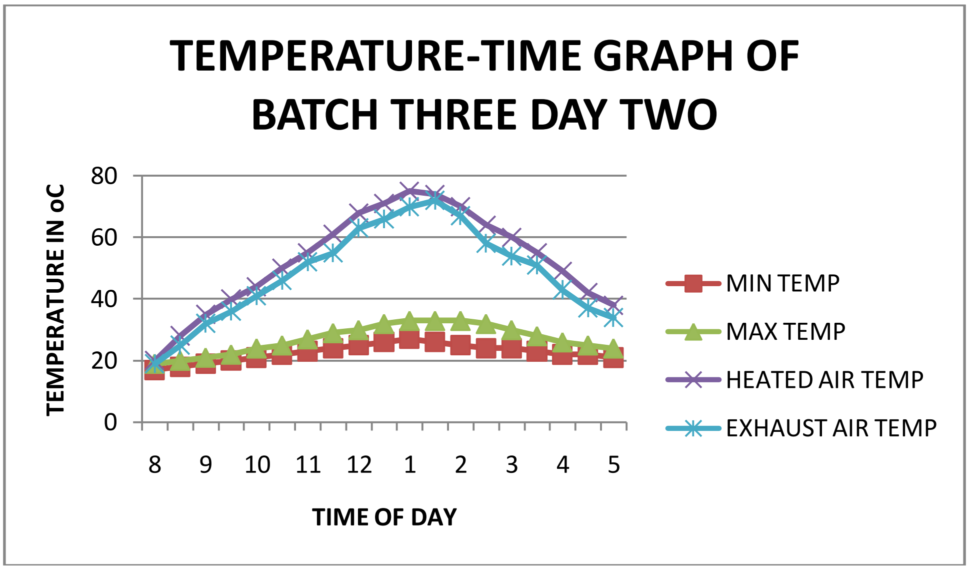

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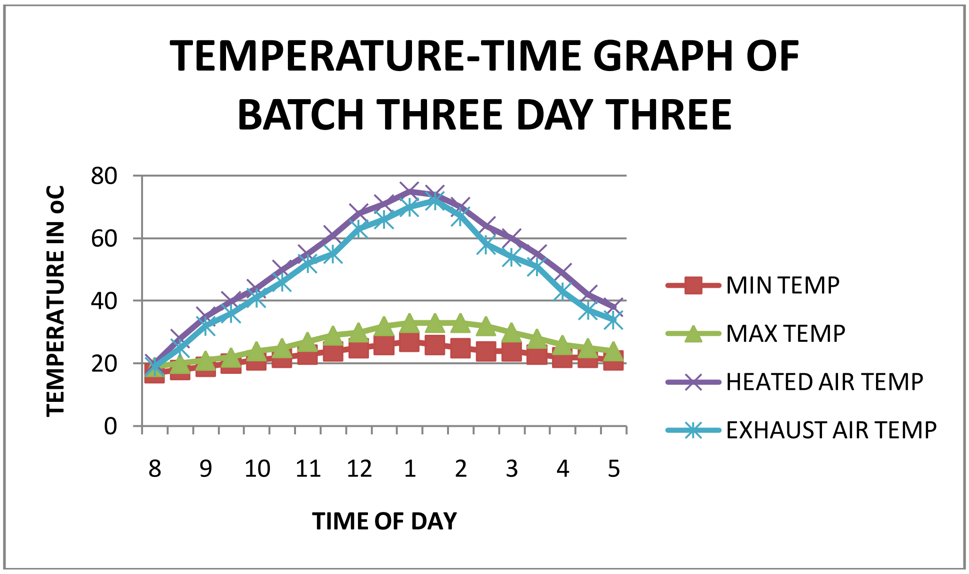

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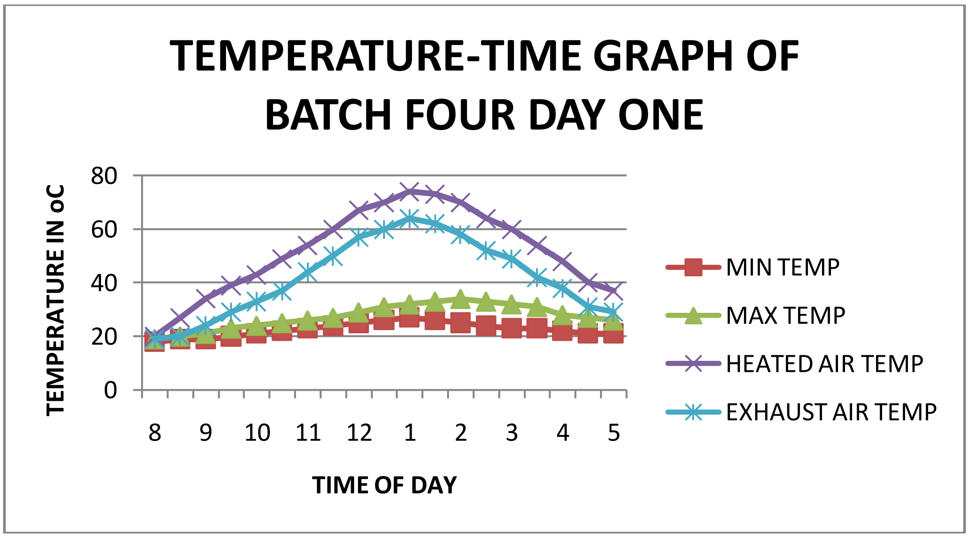

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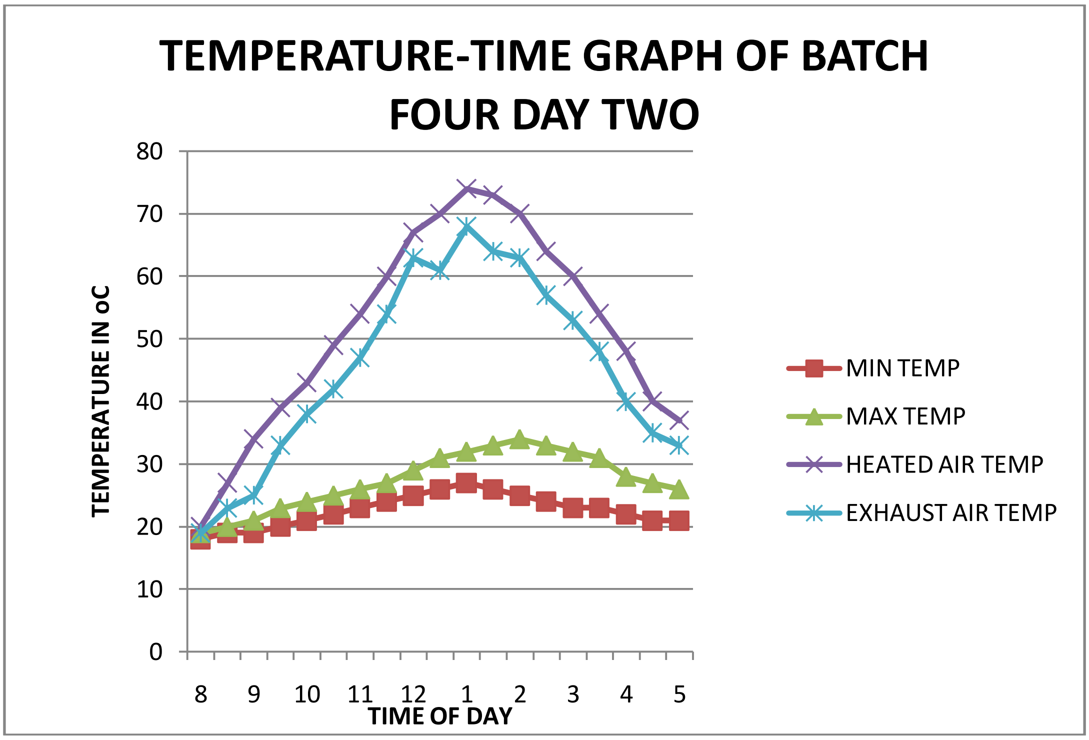

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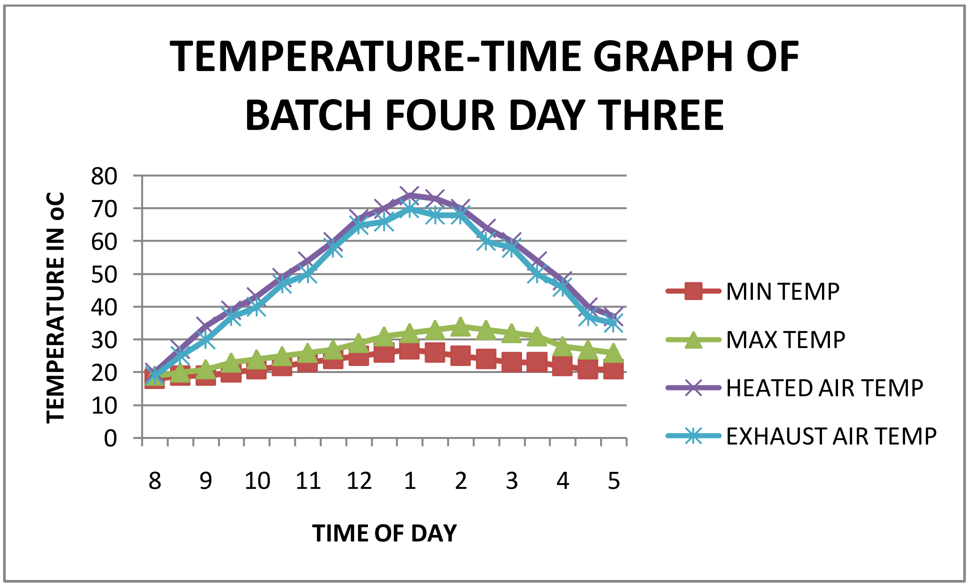

Figure 13