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Design and Fabrication of Efficient Solar Dryer

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Abstract
Sun drying is still the most common method used to preserve agricultural products in most tropical and subtropical countries. However, being unprotected from rain, wind-borne dirt and dust, infestation by insects, rodents and other animal, products may be seriously degraded to the extent that sometimes become inedible and the resulted loss of food quality in the dried Products may have adverse economic effects on domestics and international markets. Some of the problems associated with open-air sun drying can be solved through the use of a solar dryer which comprises of collector, a drying chamber and sometimes a chimney.
The conditions in tropical countries make the use of solar energy for drying food practically attractive and environmentally sound. Dryers have been developed and used to dry agricultural products in order to improve shelf life. Most of these either use an expensive source of energy such as electricity or a combination of solar energy and some other form of energy. Most projects of these natures have not been adopted by the small farmers, either because the final design and data collection procedures are frequently inappropriate or the cost has remained inaccessible and the subsequent transfer of technology from researcher to the end user has been anything but effective. Drying may be an interesting method in order to prevent fresh fruit deterioration. There is spoilage of fruits and other fresh foods that could be preserved using drying techniques in India and other developing countries. Seasonal fruits like mangoes are not presently dried for export, or for local consumption during period of scarcity.
Keywords: Solar Energy, Alternative Energy, Drier, Design and Fabrication.

I. Introduction

This section comprises of the literature review on studies in the past in relation to solar dryer and present. It also discuss the different types of solar dryers, its advantages and disadvantages, comparison of using open sun drying and solar drying technology.

II. Conventional solar drying

"Sun drying" is the earliest method of drying farm produce ever known to man and it involves simply laying the agricultural products in the sun on mats, roofs or drying floors. This has several disadvantages since the farm produce are laid in the open sky and there is greater risk of spoilage due to adverse climatic conditions like rain, wind, moist and dust, loss of produce to birds, insects and rodents (pests); totally dependent on good weather and very slow drying rate with danger of mould growth thereby causing deterioration and decomposition of the produce. The process also requires large area of land takes time and highly labour intensive.

With cultural and industrial development, artificial mechanical drying came into practice, but this process is highly energy intensive and expensive which ultimately increases product cost. Recently, efforts to improve "sun drying" have led to "solar drying". In solar drying, solar dryers are specialized devices that control the drying process and protect agricultural produce from damage by insect pests, dust and rain. In comparison to natural "open drying", solar dryers generate higher temperatures, lower relative humidity, and lower product moisture content and reduced spoilage during the drying process. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying method.

Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and artificial mechanical drying. The solar dryer can be seen as one of the solutions to the world's food and energy crises. With drying, most agricultural produce can be preserved and this can be achieved more efficiently through the use of solar dryers.

III. EXPERIMENTAL SETUP

The most commonly seen design types are of cabinet form, some types are even improved making use of cardboard boxes and transparent nylon or polythene .For the design being considered, the greenhouse effect and thermo siphon principles are the theoretical basis.

There is an air vent (or inlet) with guide ways to the solar collector where air enters and is heated up by the greenhouse effect, the hot air rises through the drying chamber passing through the trays and around the food, removing the moisture content and exits through the air vent (or outlet) near the top of the shadowed side.

The hot air acts as the drying medium, it extracts and conveys the moisture from the product (or food) to the atmosphere under free (natural) convection, thus the system is a passive solar system and no mechanical device is required to control the intake of air into the dryer. "Here is an additional cabin for heat exchanging at the air exhaust door".

"There is a lot of heat wastage at the air outlet, so to accomplish that here we have one heat exchanger and it consists of copper tubes for water heating system; there is a hole at the top side of the cabin for air outlet".

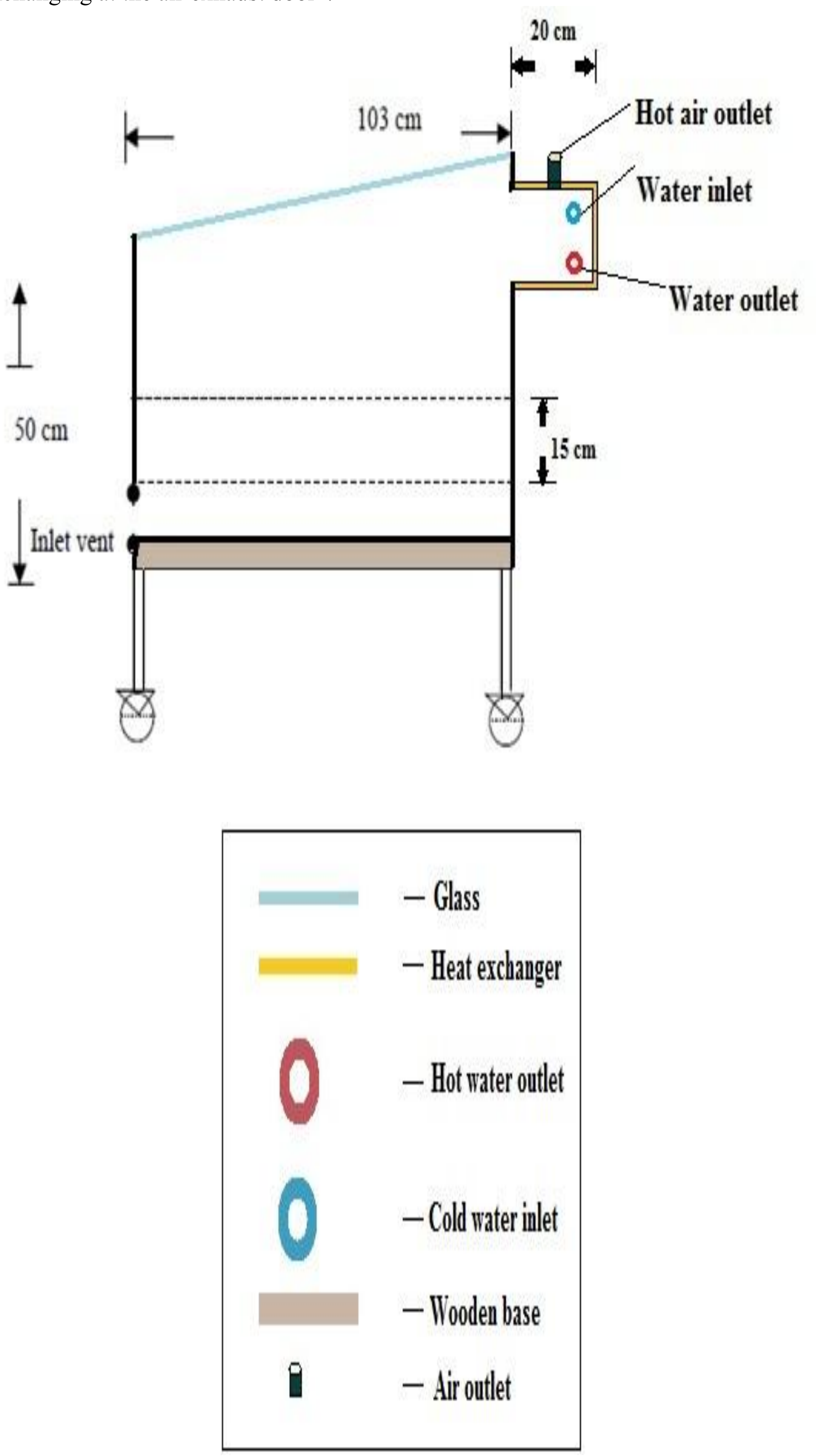

Fig: Side view of the constructed solar dryer

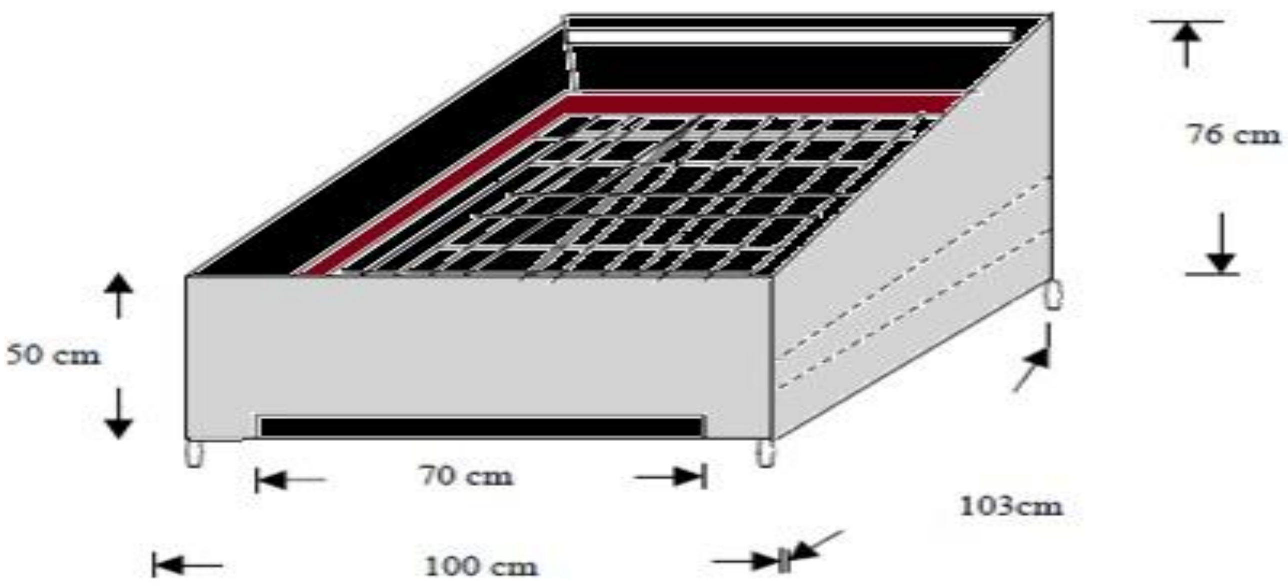

Fig: Isometric view of the constructed solar dryer

3.1 Materials Used for fabrication of solar dryer

The following materials were used for the construction of the efficient solar dryer:

- Wood
- Glass
- *Galvanized* steel (GS).
- Nails and glue
- Hinges and handle
- Paint (black and grey)
- Copper tubes
- Mesh wire
- Wheels.

Fig: Sheet Metal Work

Fig: Wood work

Fig: Tray work

Fig: Tray after painting

3.2 Design consideration:

1. Temperature

The minimum temperature for drying food is 30°C and the maximum temperature is 60°C, therefore. 45°C and above is considered average and normal for drying vegetables, fruits, roots and tuber crop chips, crop seeds and some other crops .

2. Design

The design was made for the optimum temperature for the dryer. T0 of 60°C and the air inlet temperature or the ambient temperature T_1 = 30°C (approximately outdoor temperature).

3. Air gap

It is suggested that for hot climate passive solar dryers, a gap of 5 cm should be created as air vent (inlet) and air passage.

4. Glass or flat plate collector

It suggested that the glass covering should be 4-5 m thickness. In this work, 4mm thick transparent glass was used. He also suggested that the metal sheet thickness should be of 0.8 – 1.0 m thickness; here a Galvanized steel of 1.0mm thickness was used. The glass used as cover for the collector was 103 × 100cm^2.

5. Dimension

It is recommended that a constant exchange of air and a roomy drying chamber should be attained in solar food dryer design, thus the design of the drying chamber was made as spacious as possible of average dimension of 100 ×103 × 76 cm^3 with air passage (air vent) out of the cabinet of 90 × 10cm^2. The drying chamber was roofed with glass of 100 × 103 cm^2.

This is to keep the temperature within the drying chamber fairly constant due to the greenhouse effect of the glass.

6. Dryer Trays

1cm^2 Net was selected as the dryer screen or trays to aid air circulation within the drying chamber. Two trays were made having wooden edges. The tray dimension is 96 × 98 cm of 2.5cm × 2.5cm wooden sticks used as frame. The design of the dry chamber making use of GS sheet wall sides and a glass top (tilted) protects the food to be placed on the trays from direct sunlight since this is undesirable and tends to bleach colour, removes flavour and causes the food to dry unevenly.

4. Results and discussions

Table 1: Design Conditions and assumptions

1	**Location**	**Anantapur(Latitude 14^o 65'N)**
2	**Crop**	**Chilly**
3	**During Period**	**February to march**
4	**Drying per batch(2 days/batch),loading rate(m_p)**	**100 kg sliced potatoRESULTS AND**
	Initial moisture content(moisture content at	**DISCUSSIONS**
5	**harvest),M_i**	
	Final moisture content (moisture content for	**81.4% w.b.**
6	**storage),M_f**	
	Ambient air temperature, T_{am}	**13 % w.b.RESULTS AND**
7	**Ambient relative humidity, RH_{am}**	**DISCUSSIONS**
8	**Maximum allowable temperature, T_{max}**	
9	**Drying time(sunshine hours),t_d**	**30^{o}c (Average for February)**
10	**Incident solar radiation, I**	**44% (Average for February)**
11		**50^{o}c**
	Collector efficiency, η	**10 hours (Average for February)**
12	**Wind speed**	**20MJ/m^2/day(average for past 30 years)**
13	**Thickness of Sliced potato**	**30%**
14	**Vertical distance between two adjacent trays**	**2 m/s**
15		**3mm**
		15cm

Table 2: Values of design parameters

Sl.no	Parameter	Value	Data or Equation used
1	Initial humidity ratio, w_i	0.0026kgH_2O/kg dry air	T_{am}, RH_{am}
2	Initial enthalpy, h_i	61.28kJ/kg dry air	T_{am}, RH_{am}
3	Equilibrium relative humidity, h_f	44%	M_f (2)
4	Final enthalpy, h_f	120.4kJ/kg dry air	w_i and T_f
5	Final humidity ratio, w_f	0.012kgH_2O/kg dry air	RH_f and h_f
6	Mass of water to be evaporated, m_w	78.62kg	Equation (1)
7	Average Drying rate, m_{dr}	7.862kgH_2O/hr	Equation (8)
8	Air flow rate, m_a	416.7kg dry air/hr	Equation (9)
9	Volumetric air flow rate, V_a	365.89m^3/hr	m_a, air density (ρ)
10	Total useful energy, E	137.19MJ	Equation (6)
11	Solar collector area, A_c	1.03 m^2	Equation (11)
12	Vent area, A_v	0.035m^2	V_a, wind speed
13	Air pressure, P	0.68Pa	Equation (14)
14	Vent length	0.7m	
15	Vent width	0.056m	Equation (13)

0

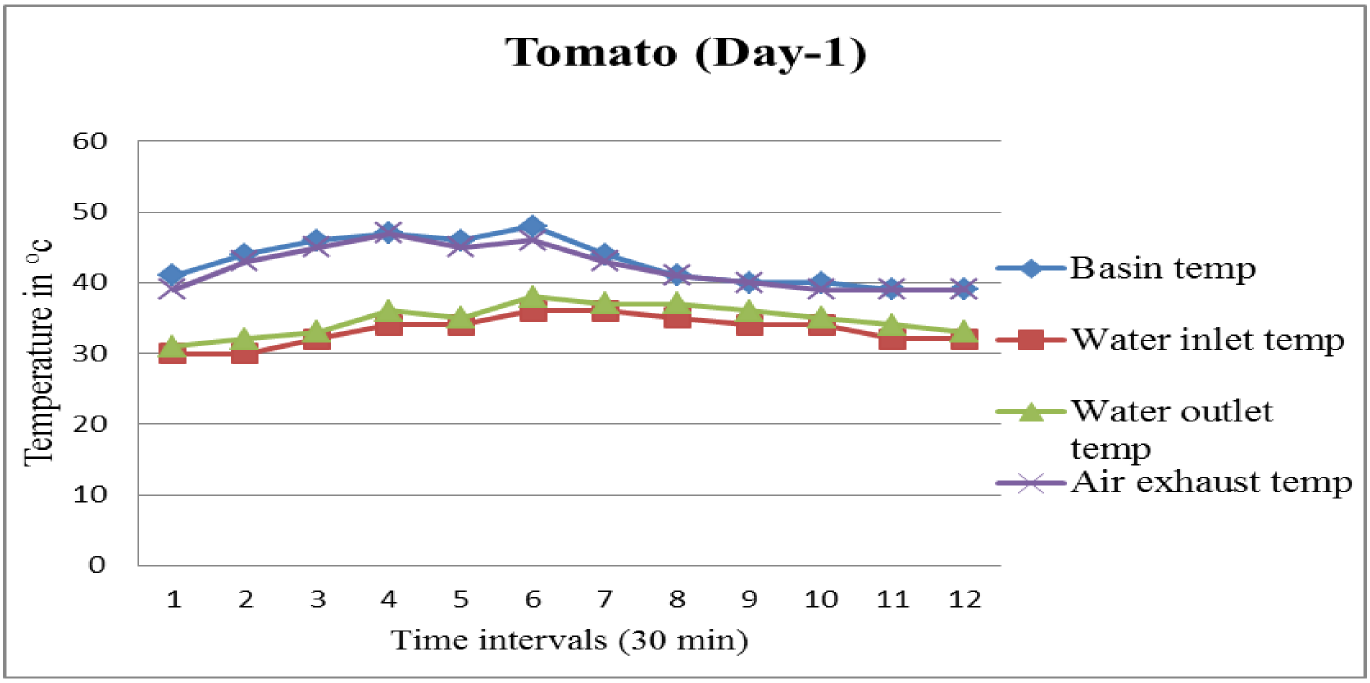

Fig: Temperature variation in the dryer (day-1, Tomato)

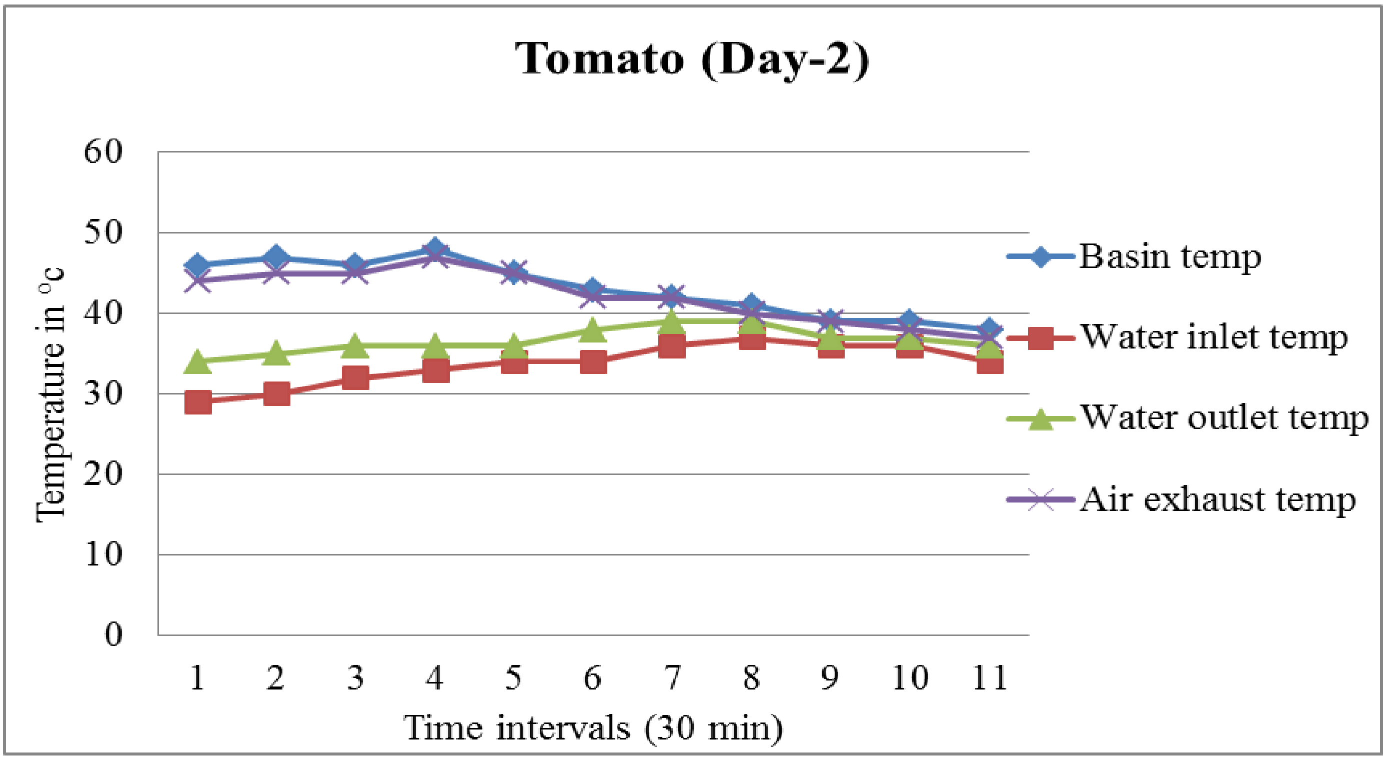

Fig: Temperature variation in dryer (Day-2, Tomato)

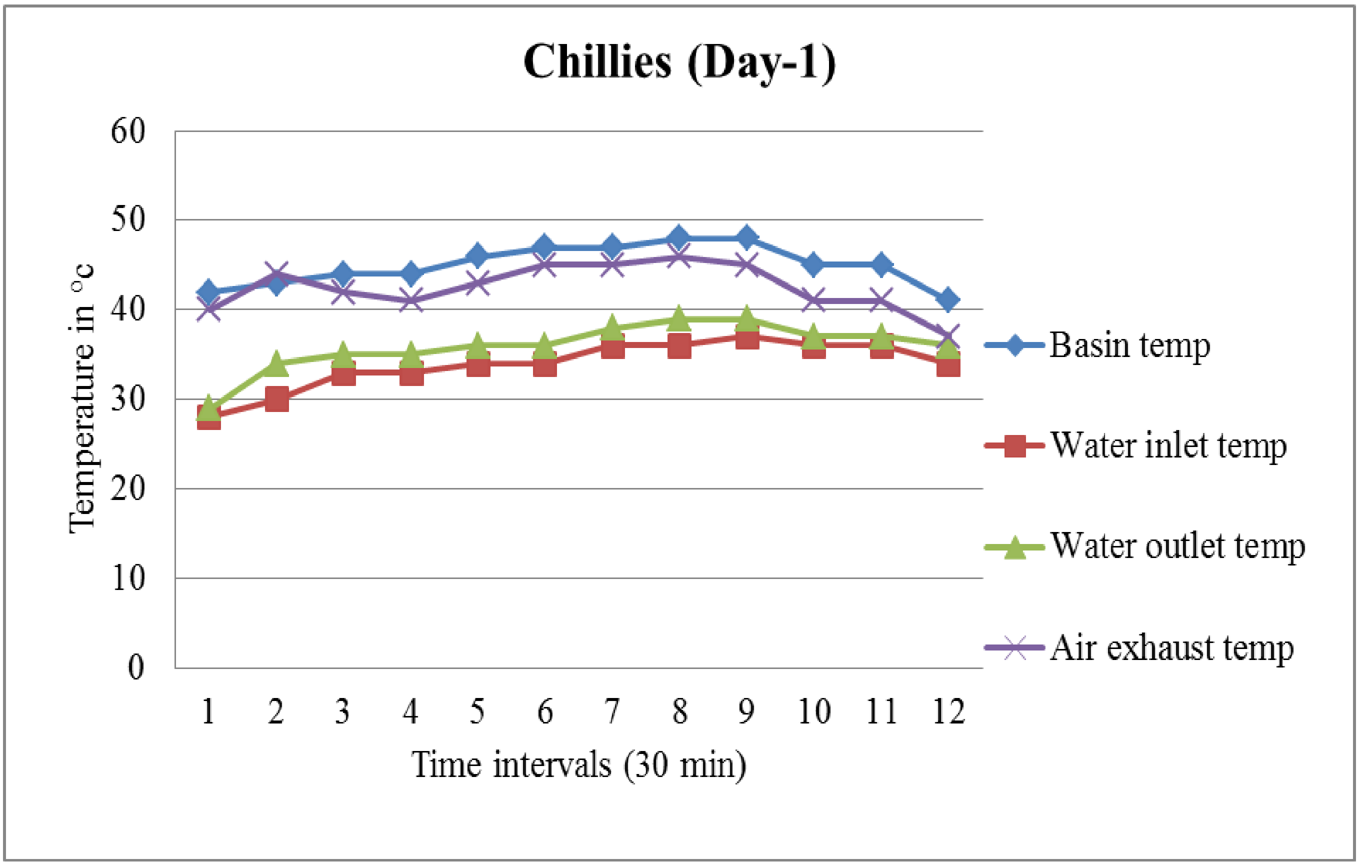

Fig: Temperature variation in the Dryer (Day-3, Chillies)

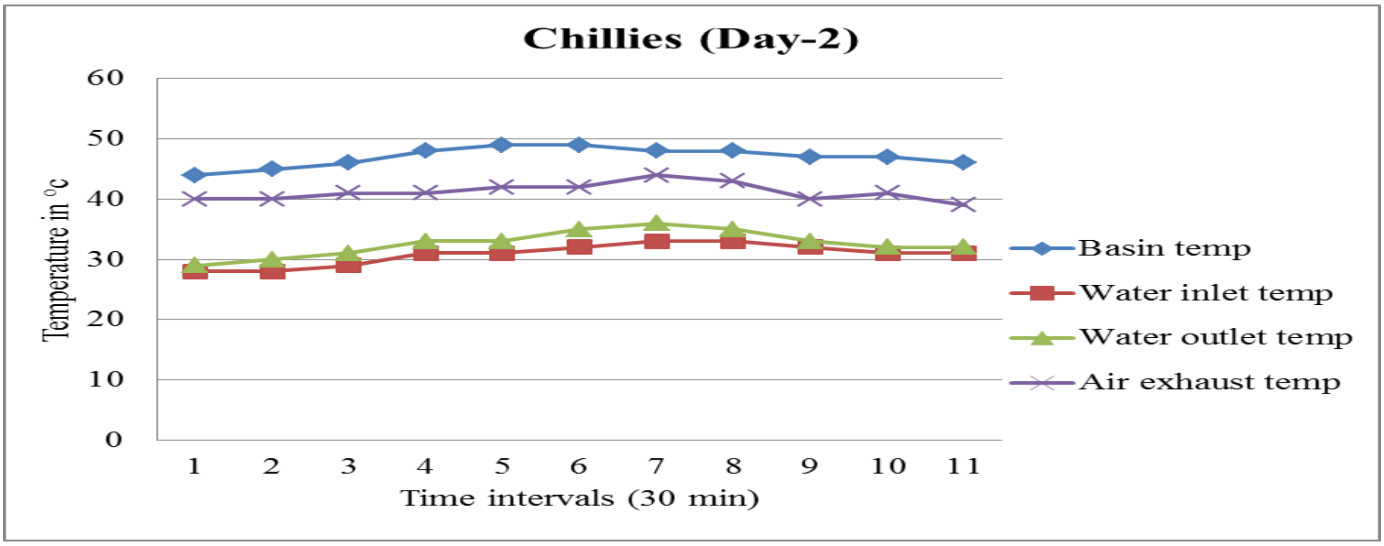

Fig: Temperature variation in the Dryer (Day-4, Chillies)

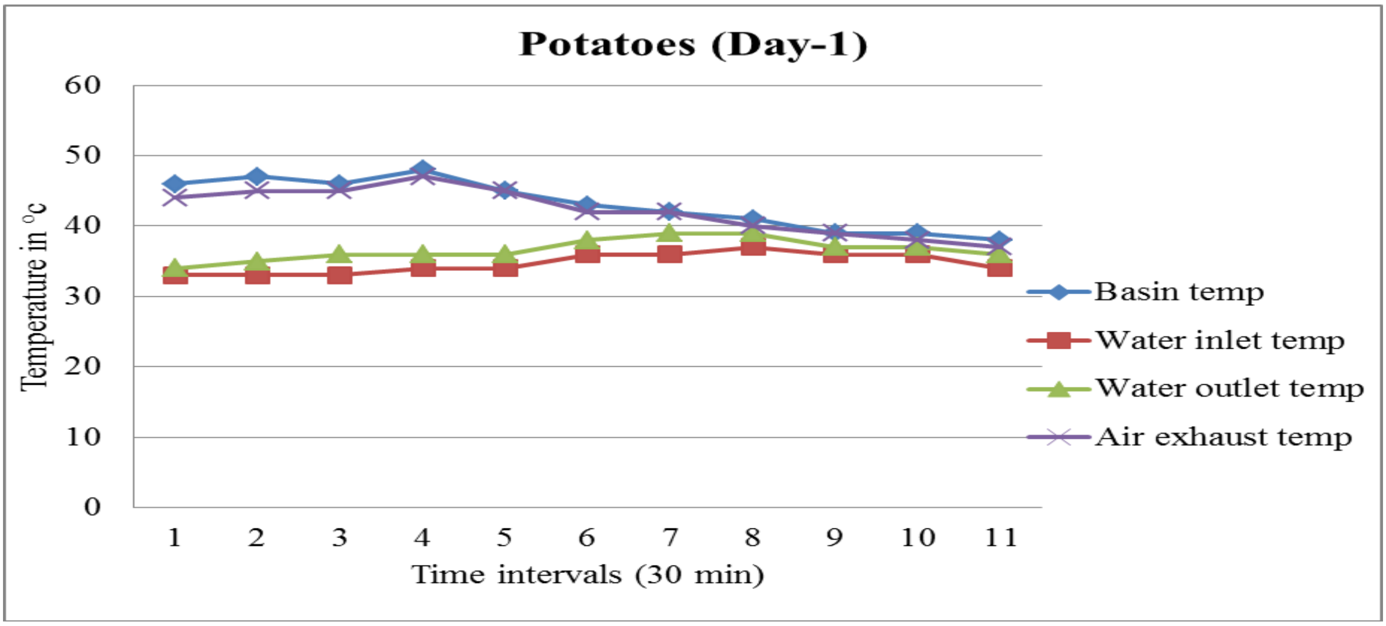

Fig: Temperature variation in the Dryer (Day-5, potatoes)

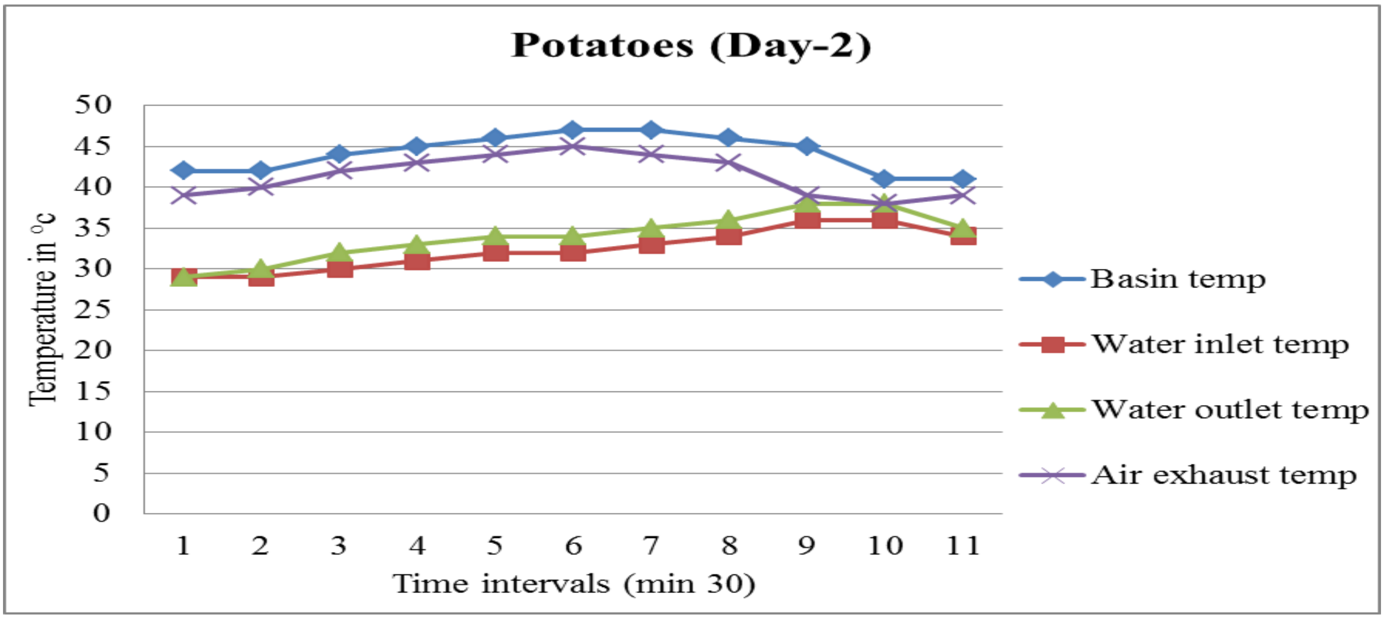

Fig: Temperature variation in the Dryer (Day-6, Potatoes)

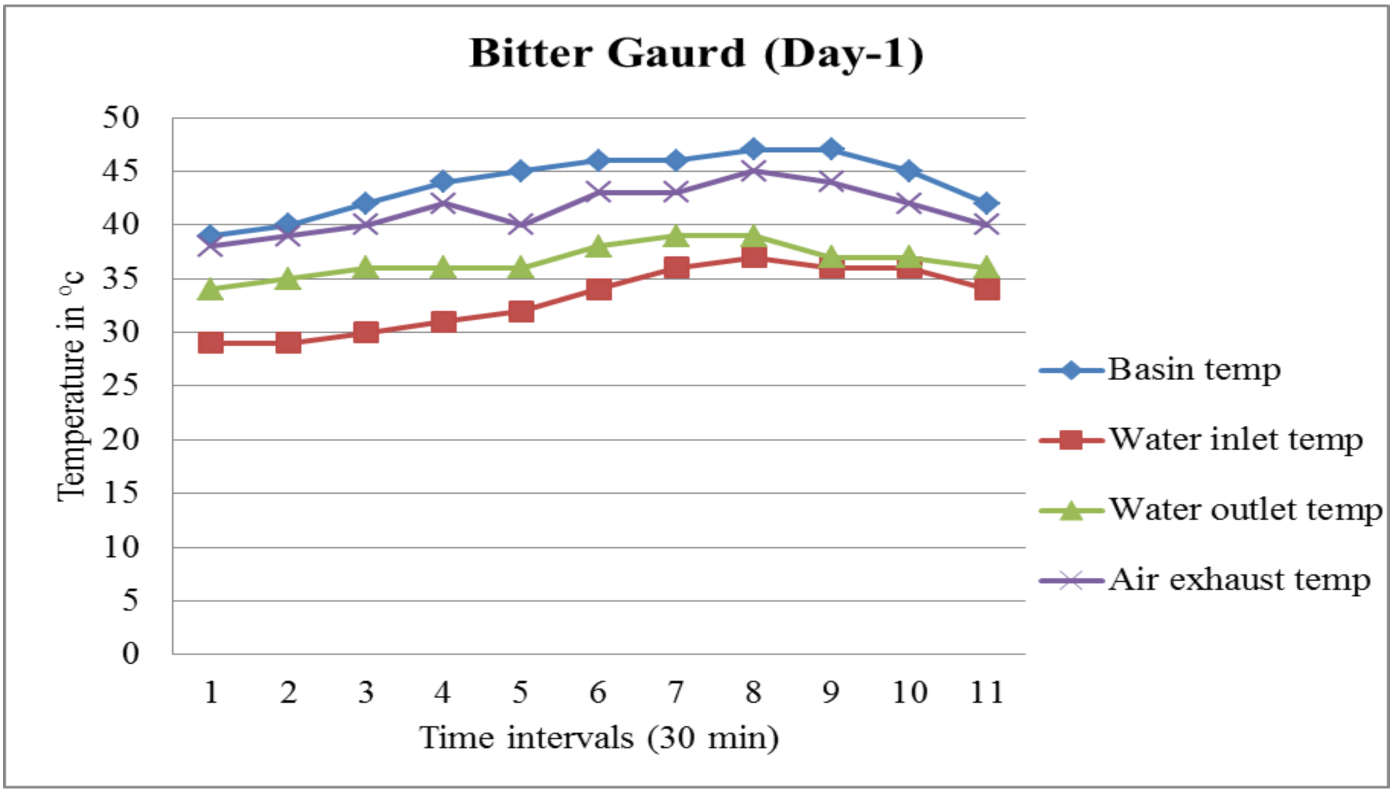

Fig: Temperature variation in the Dryer (Day-7, Bitter guard)

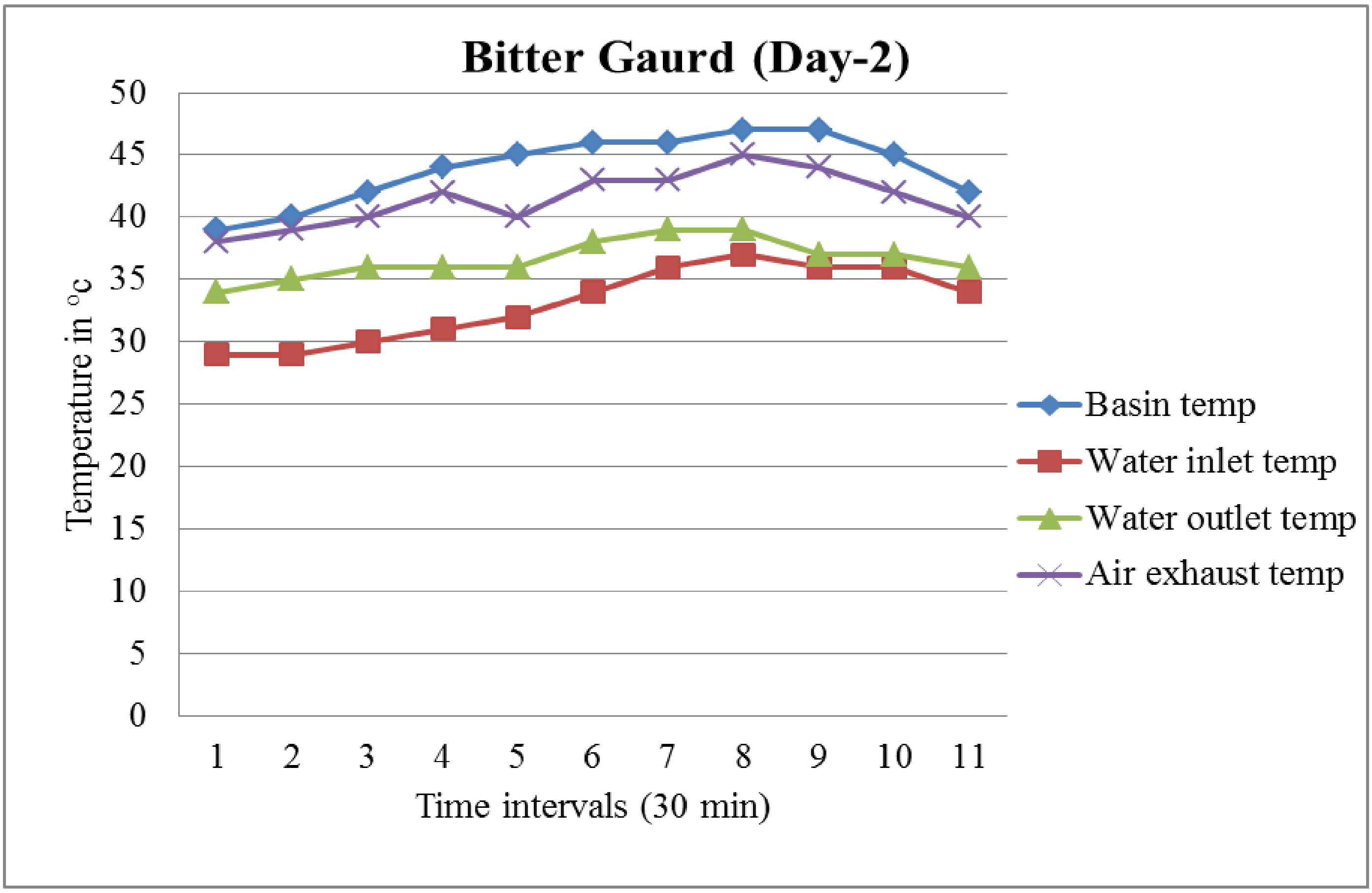

Fig: Temperature variation in the Dryer (Day-8, Bitter guard)

4.3 Comparison:
1. Potato

Fig: Open Drying Vs Controlled Drying

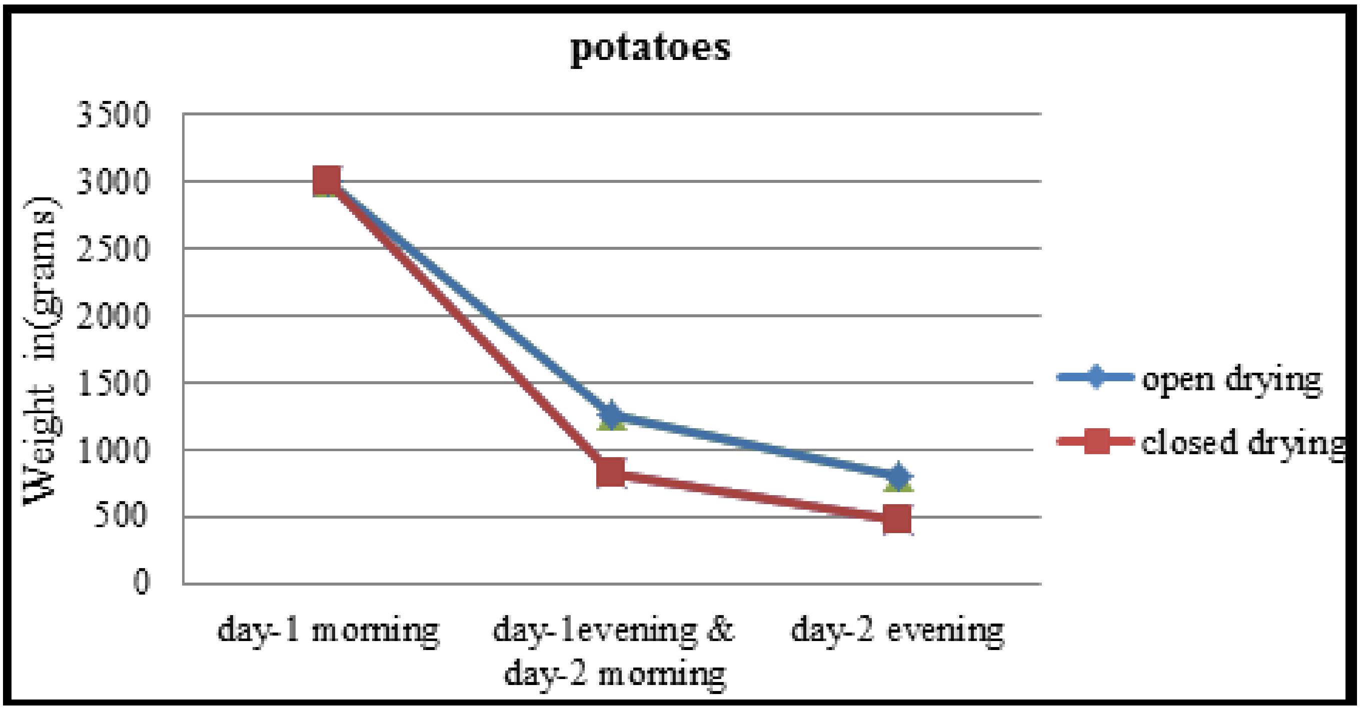

Fig: Open Drying Vs Controlled Drying graph

- At first day 3000 grams of potato was placed to dry in open drying system and solar (closed) drying system.
- The weight of potatoes were found at evening**;** in open drying 1550 grams and in closed drying it was 1180 grams.
- Then this item is placed drying for next day morning and by the end of the evening it was found to be that as in open drying 920 grams and closed drying as 550 grams.

2. Bitter guard:

Fig: Open Drying Vs Controlled Drying

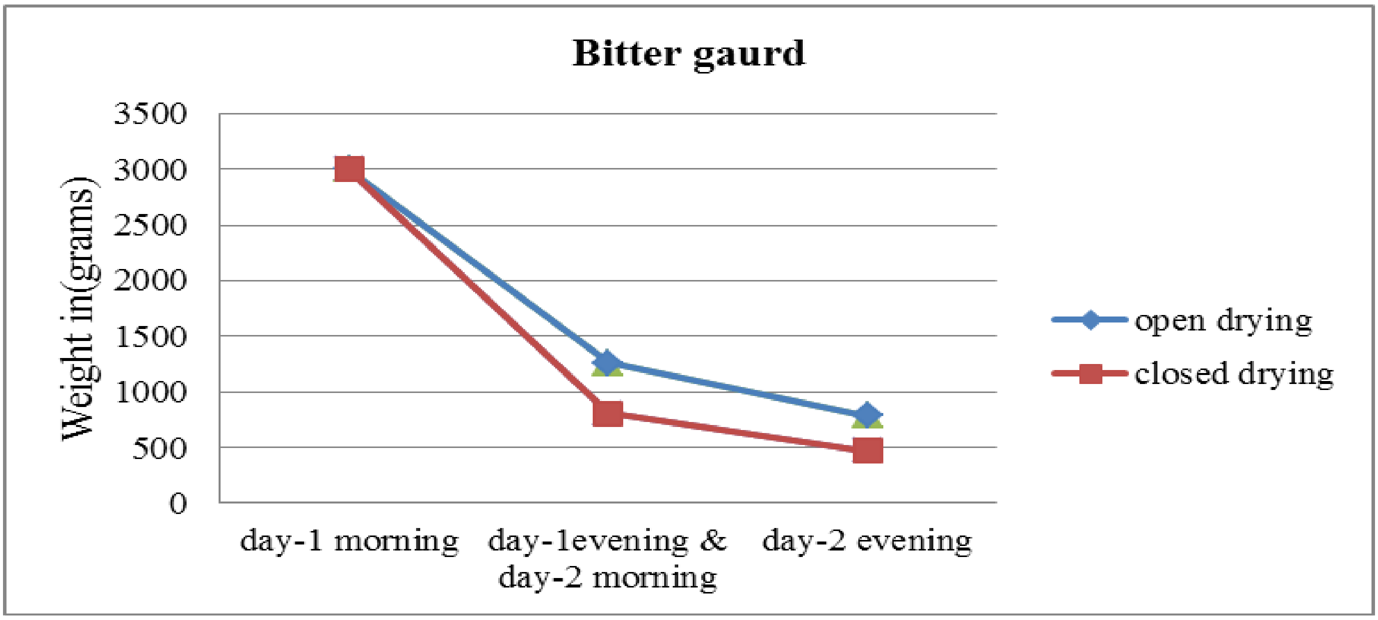

Fig: Open Drying Vs Controlled Drying graph

- At first day 3000 grams of potato was placed to dry in open drying system and solar (closed) drying system.
- The weights of potatoes were found at evening; in open drying 1260 grams and in closed drying it was 860 grams.
- Then this item is placed drying for next day morning and by the end of the evening it was found to be that as in open drying 790 grams and closed drying as 470 grams.

1. Chillies:

Fig: Open Drying Vs Controlled Drying

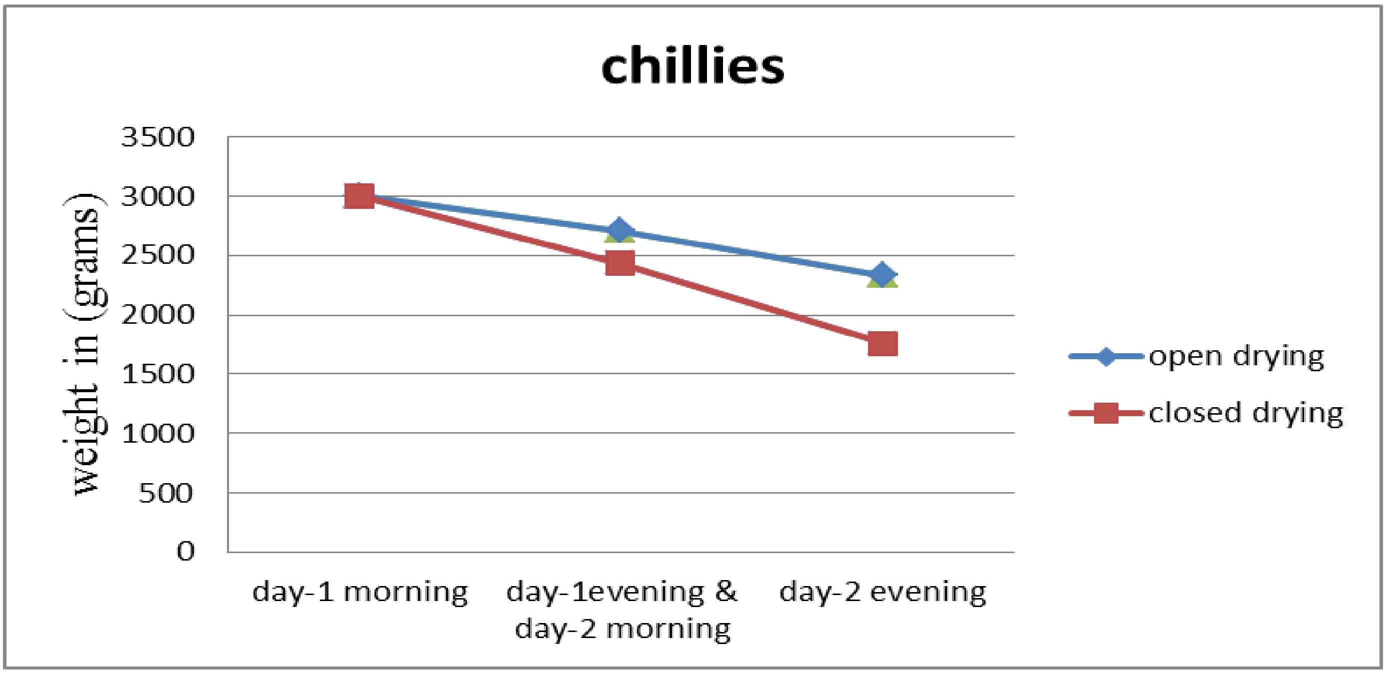

Fig: Open Drying Vs Controlled Drying graph

- At first day 3000 grams of potato was placed to dry in open drying system and solar (closed) drying system.
- The weights of potatoes were found at evening; in open drying 2710 grams and in closed drying it was 2330 grams.
- Then this item is placed drying for next day morning and by the end of the evening it was found to be that as in open drying 2430 grams and closed drying as 1755 grams.

IV. Conclusions

A solar dryer is designed and constructed based on preliminary investigations of drying under controlled conditions (laboratory dryer). The constructed dryer is to be used to dry vegetables under controlled and protected conditions. The designed dryer with a collector area of $1m^2$ is expected to dry 20kg fresh vegetables from 89.6% to 13% wet basis in two days under ambient conditions during harvesting period from February to March. A prototype of the dryer with $1.03m^2$ solar collector area was constructed to be used in experimental drying tests. Along with this the water heating system is also employed to the dryer to recover the waste heat getting from the dryer. Hence the practical usage of dryer is greatly increased by employing the water heating system along with dryer.

V. Suggestions for future work

- ✓ The present work can be extended by arranging copper tubes to the side walls of dryer to recover heat from the side walls.
- ✓ Double slope passive solar dryer can be fabricated to attain higher efficiencies.
- ✓ In place of heat exchanger (water) phase change material can be placed to recover total waste heat coming from the dryer.

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