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EXPERIMENTAL INVESTIGATION OF FOOD DRYER USING SOLAR AND EXHAUST GAS WITH FINNED COPPER TUBES

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ABSTRACT

Drying is a method used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years. Almost in all countries of the world, the application of solar thermal energy is required to use in agricultural sector and marine food in to conserve mainly perusable food items like raw vegetables, normal &dry fruits, coffee, sea foods and other crops has shown to be practical, economical for both farmers and country. Along with these spices, meat, fish, nuts and beverages such as tea leaves, coffee nuts are dried and consumed in very large quantities around the world. The main aim of our requirement irrespective of crop is to remove water content from fresh crop to extend its life before storage in all seasons. At finally a new product is obtain varying from actual crop, distinctly differs from original form like dried form of grapes. Global population is increasing rapidly beyond predictions and calculations. Therefore food production must be increased and preserved accordingly to meet the rising demand.

KEYWORDS: *Solar drying, wooden cabin, Absorption refraction, Exhaust gas heat, new design, copper tubes.*

I. INTRODUCTION

Researchers claim right from 3000–5000 years ago agriculture was widespread in the Indian peninsula. The total production and economic value of horticultural produce, such as fruits, vegetables and nuts has doubled in India over the 10-year period. In 2012, the total horticulture produce reached 277.4 million metric tone and acquired a position as second largest producer of horticultural products. Even in species of winter cereals like barley, oats, and wheat continuous with good production .India in 2013 produced 81 million tonnes of fruits, 162 million tonnes of vegetables, 5.7 million tonnes of spices, 17 million tonnes of nuts and plantation products cashew, cacao, coconut etc. But we should keep in mind that India is country where 70% of farmers cultivate monsoon rains. So failed monsoon for one of the world's biggest producers of horticulture and grains could add to pressure on global food prices. This results in high burden on the farmer mentally and economically. Activists and scholars have offered a number of conflicting reasons for farmer suicides, such as monsoon failure, high debt burdens, genetically modified crops and not reaching of government policies. Every year we spend crore's of rupees out of public exchequer for preventing decay and then spend a fortune again to dispose of the piled up waste .This results in inflation on particular crop. To overcome these problems preservation is need i.e. by removing the moisture content in food .So these high produced horticultural products are transformed to dry one to reach the demand for increasing population, balances the demand at monsoon failures.

To remove moisture direct, indirect mode solar drying methods are available .In direct method the crop is directly exposed to solar radiation. But in the case of incident method crop is place in closed system and solar radiation is absorbed by some transparent surface - usually a solar collector where it is converted into heat by refraction in system. But this method is applicable at sunny days only. So here we use exhaust gas as heat source for drying with the help of copper heat exchangers irrespective

of seasons. This method has a capability of reducing the drying time by up to 50 percent compared to traditional drying

Various Methods of Solar Drying

1. Direct Sun drying.
2. Indirect Sun drying.
3. Mixed Mode drying.
4. Hybrid food drying.

1.1 Drying Fundamentals

Drying mainly involves the removal of moisture in solar and thermal drying .So this process where we apply the heat to the product then heat increases vapour pressure of moisture in the product which is above to the surrounding air .By this pressure and thermal gradients results to move both liquid and vapour moisture moves to surface of product. Especially in crops there is a combination of free (unbound) and bound moisture particles.

II. EXPERIMENTAL SETUP

Crops like cerals, grains, paddy, wheat, corn and dry nuts. All these crops have dry content in their weight when crop yields .So without proper removing of this moisture results in growth of moulds, fungi and damage the grain quality results in loss of crop. Harvest grain moisture content varies between 18-25% wet basis, if not dried quickly will reduce the quality of grain. Drying to reduce the moisture content to about 14% wet basis so that grain can be stored for longer, facilitate the milling process and to produce good quality grains.Similarly in horticulture crops like vegetables, fruits are facing a large scarcity in production and preservation for the balance of growing population .At less production and monsoon failure cases it results in Inflation. Under this circumstances farmer is unable to produce right crop at right time. Though production is more at good rains farmer is unable to get reasonable prize. Mostly these crops are perishable crops i.e. life time or durability is very less .So to get rid of this problem we have to store and protect the extra cultivation in various forms up to next good monsoon. By this we can control the scarcity of food as well as Inflation.

Figure 1 Experimental Setup

III. DRYER DESIGN CONSIDERATIONS

For the purpose of preservation we designed a chamber to remove moisture from food. Wooden cardboard is a material having low thermal conductivity and acts as insulation wall, acts as closed system. According to the preliminary investigation with the cabin designed we take 2.6kg per m^2 (tray loading). And the vegetables used for this setup is cut in to 3mm thick. Design of this cabin is in a way that cool air at bottom of surface circulates and enters in to chamber with an angle of the slope of the dryer cover is 15º for the latitude of location by natural circulation. In cabin air gets heated by reflected solar rays through the glass. Here glass acts as good refractor i.e. rays won't reflect back in to the atmosphere once they entered in to chamber .So a trap is arranged for maximum heat with solar rays.

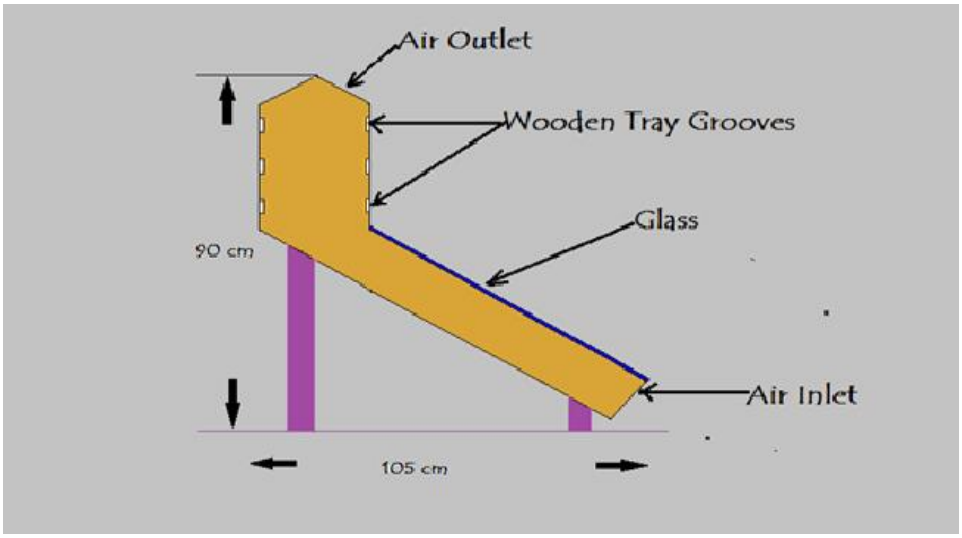


Figure 2 Side View of the Constructed Solar Dryer

Next to the glass chamber we have the chimney shaped chamber here we have drying trays on which we place food items to dry .Hot air from glass chamber passes through this mesh collects the moisture content in the food. So by this technique we can remove moisture content in horticulture crops and can transform in to cooking powders and soups. In this we calculate the removal of moisture in dry basis and wet basis. To reduce the loses for the dryer an insulation material was made using 8 mm wooden plywood.

Thermal conductivity of wood = **0.15** w/mk

Convective heat transfer coefficient of the air = **25-400**w/m^{2}k

(Taken as **30** w/m^{2}k)

$$r = \frac{h}{k}$$

$$= \frac{0.15}{30} = 5\times10^{-3} \text{ m}$$

=5 mm

To decrease the losses the thickness of insulation must be greater than the Critical thickness of insulation. So, the thickness of the wood taken as the 8mm.

h= Convective heat transfer coefficient of the air

k= Thermal conductivity of wood

r=Critical thickness of insulation

The insulating wooden flanks are with different shapes and different sizes. The wooden flanks are cut from the following 130×130 cm wooden sheet. By using the scriber mark the required wooden flanks dimensions on the wooden sheet.

IV. HEAT EXCHANGER

Heat exchangers are devices allows transferring heat from high temperature fluid to low temperature fluid. Heat exchangers used in our daily lives are condensers, evaporators arranged in air conditioning units and refrigerators. Similarly we have boilers and condensers in heavy plants and Industries. And we also have heat exchangers in automobiles as radiators and oil coolers. Copper has many suitable properties for good thermal efficiency and suitable for heat exchangers. And copper is the best heat conductor as well as exchanger of degree of temperature. Desirable properties of copper next to conductivity is corrosion resistance, specific heat, tensile strength yield strength and easy of fabrication .Conductivity of copper is to be found as 399 W/(m k).The exhaust gases of diesel engine containing pollutants and contaminants but with high temperatures. Heat exchangers of compact kind have many benefits, among others massive heat transfer surface per unit volume of the core.

4.1 Copper Heat Exchangers

The copper tubes are organized at rock bottom of the trays. The copper tubes get heated because of the flow of exhaust gases from the engine. The natural air coming into through the duct passes through the copper tubes and therefore the temperature of the air will increase. Then the new air passes through the trays and removes the wet from the merchandise that is unbroken on the trays and {also the} cabin temperature also will increase considerably. Fin is analysed by design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions. The heat transfer performance of fin with same geometry having various extensions and without extensions is compared. Near about ranging 5% to 13% more heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions. A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it.

Figure 3 Copper Tubes as Heat exchangers

4.2 Arrangement of Heat Exchanger

The thermocouples are accustomed indicate the temperature of the air. The 3 thermocouples are organized at wherever temperatures are required. The primary thermometer is placed at the recess of the air, other placed at the entry of the recent air in to the chamber; third one is placed at the exit of the recent air at the vents. The thermometer ire's are connected to the digital measuring system for taking the temperatures as above.

Figure 4 Arrangement of Heat exchanger

V. DIESEL ENGINE

In internal-combustion engine combustion cycle, there's the energy balance of fuel combustion, thirty fifth of energy used because the work, two hundredth of the energy is lost because the engine agent, 100 percent is lost by radiation and thirty fifth is lost with the exhaust gas . Quality waste heat from the flue gas area unit warm temperature, and therefore the bigger potential price for warmth recovery. Heat lost with the exhaust gas of thirty fifth could be a potential that may be used for varies functions like for steam power plants, foodstuffs and agricultural product dryers, heating, or for alternative functions. There area unit 2 main criteria to utilize exhaust gas as a heating area unit exhaust gas temperature and exhaust gas mass rate. Internal-combustion engine exhaust gas temperature will reach two hundred ℃ looking on the ability and cargo variations. Exhaust gas mass rate related with the number of engine power, the degree of a cylinder, engine rpm, still because the fuel air quantitative relation.

VI. ARRANGEMENT OF CROP ON TRAYS

In the cabin we have arranged the wire mesh trays at a distance of 10cm each vertically. Three trays were used with average of 10 cm spacing arranged vertically one on top of the other, the tray size was $21 \times 50cm^2$.Movement of air around produce is further facilitated by drying on mesh trays rather than on solid platforms so aluminium net is stretched on wooden frames and supported by Kitchen wire On these trays we arranged the crop items in a quantity of 200 grams as a test in this equipment. Slices of crop with the thickness of 3mm placed on trays for the process of drying. And firstly we tried with the natural solar convention drying through cabin drying during the summer months i.e. May April. Next we conducted this natural drying with arrangement of copper tubes with diesel engine waste exhaust heat .Copper tubes are good conductors and exchangers of heat. For this reason we used copper tubes with normal and fins arrangement on tubes. And arrangement and drying pictures can be seen in below figure.

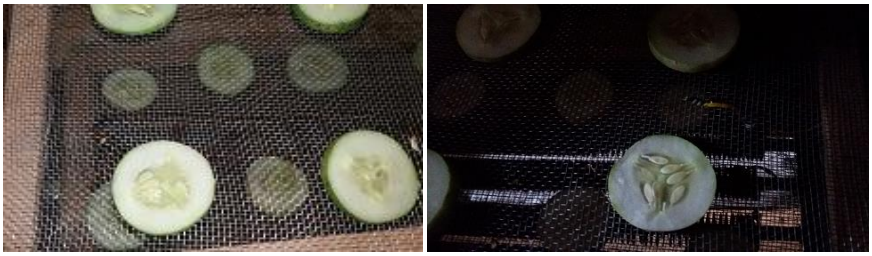


Figure 4 Arrangement of the crop before and after drying

Table 1 Design Conditions and assumptions

ITEM	CONDITION
Location	Kurnool(Latitude 15º 15'N)
Crop	Carrot, Cucumber, Tomatoes
During Period	April, May
Drying per batch normal tube(200grms)	0.2 kg sliced carrot
Initial moisture content(moisture content at harvest),M_i	87.5% w.b.
Final moisture content (moisture content for storage),M_f	18 % w.b.
Wind speed	2 m/s
Thickness of Sliced items	3mm
Vertical distance between two adjacent trays	10cm

SAMPLE CALCULATIONS

QUANTITY OF HEAT NEEDED TO EVAPORATE THE H_2O:

The quantity of heat required to evaporate the H_2O would be

$Q = m_w \times h_{fg}$ …… (4)

Where:

Q = the amount of energy required for the drying process, kJ
m_w = mass of water, kg
h_{fg} = latent heat of evaporation, kJ/kg H_2O

MOISTURE REMOVED CALCULATIONS:

Amount of moisture removed from a given quantity of cucumber slices to bring the moisture content to a safe storage level in a specified time.

The amount of moisture to be removed from the product, m_w, in kg was calculated using the following equation

$$m_w = m_p(M_i - M_f)/ (100- M_f)$$

Where:

m_p is the initial mass of product to be dried, kg;
M_i is the initial moisture content, % wet basis and
M_f is the final moisture content, % wet basis.

ADVANTAGES

- Dryer efficiency continuous at non sunny days.
- Reducing moisture content in crops will be easy by both solar and exhaust heat.
- Easy to install at Godowns and warehouses for preservation for long time.
- Safe from contamination and insects irrespective of time and climate.
- We can control temperature range depending on position of trays.
- Requires less space and more efficient.
- This protects food from natural calamities, UV rays so that preserves along with nutrition & colour.
- No much manpower is required.
- Quick drying time reduces chances to spoilage.
- Complete drying allows food for longer storage.
- Waste exhaust gas makes useful work for extracting moisture.

VII. RESULTS

Temperature variations and weight loss in the dryer (Natural Convection):

Table 2 Temperature Variations In Cucumber

Time(minutes)	Bottom tray	Top tray	Outside temperature
10:00	36	38.5	40
10:20	38	40	40
10:40	39.5	41.7	39
11:00	40.6	42.4	41
11:20	41	43	42
11:40	42	43.9	43
12:00	43	45.2	42
12:20	43.6	46.5	43
12:40	44	47.1	44
01:00	44.6	47.9	45

Graph 1 Time vs Temperature cucumber

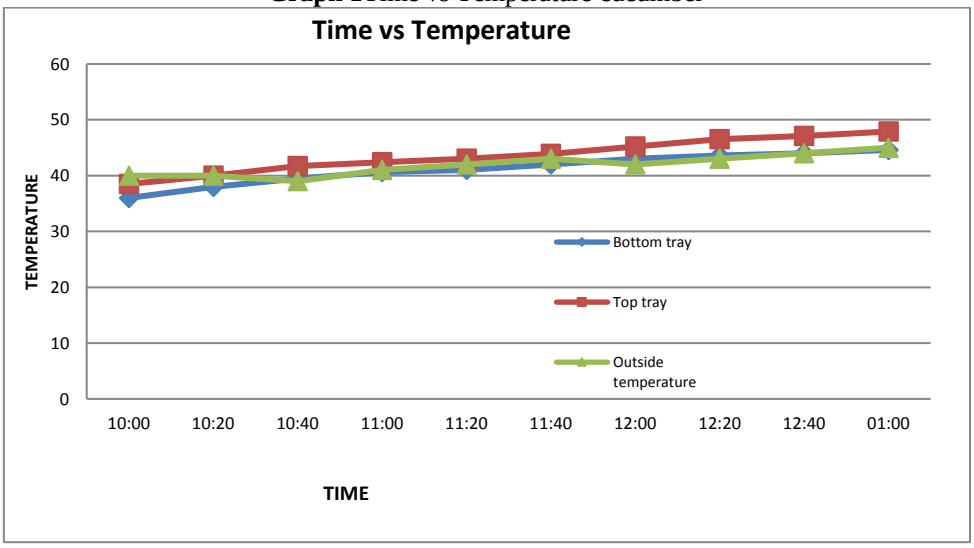


Table 3 Temperature Variations In Tomatoes

Time(minutes)	Bottom Tray	Top tray	Outside Temperature
10:00	35	39	41
10:20	37	41	41
10:40	39	42.2	40
11:00	41	43	42
11:20	42	43.5	43
11:40	43	44.7	43
12:00	44.2	45	44
12:20	45.4	47	46
12:40	46	47.9	46
1:00	46	48.4	45

Graph 2 Time vs Temperature Tomatoes

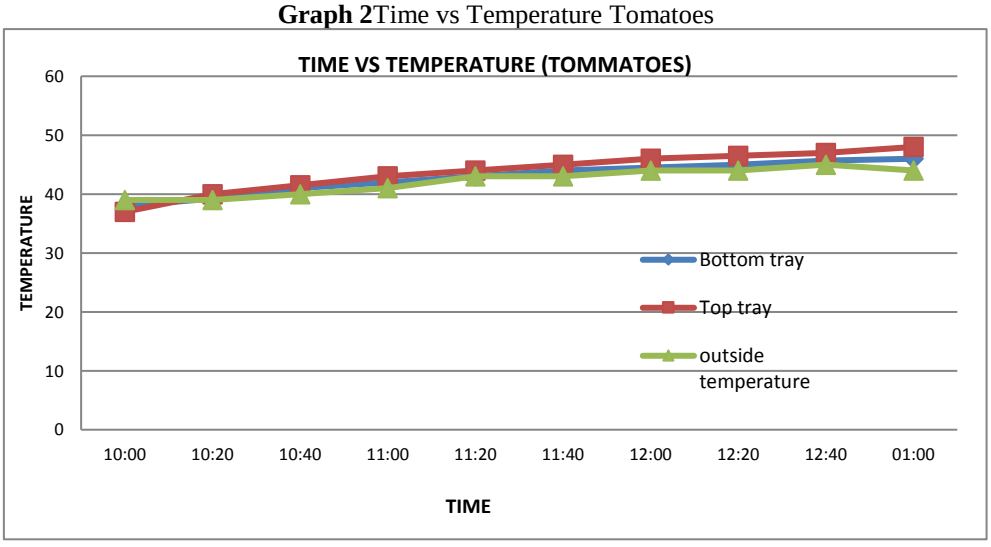


Table4 Temperature Variations in Carrot

Time	Bottom Tray	Top tray	Outside Temperature
10:00	38	37	39
10:20	39.2	40	39
10:40	41	41.5	40
11:00	42	43	41
11:20	43	44	43
11:40	44	45	43
12:00	44.5	46	44
12:20	45	46.5	44
12:40	45.7	47	45
01:00	46	48	44

Graph 3 Time Vs Temperaturein Carrot

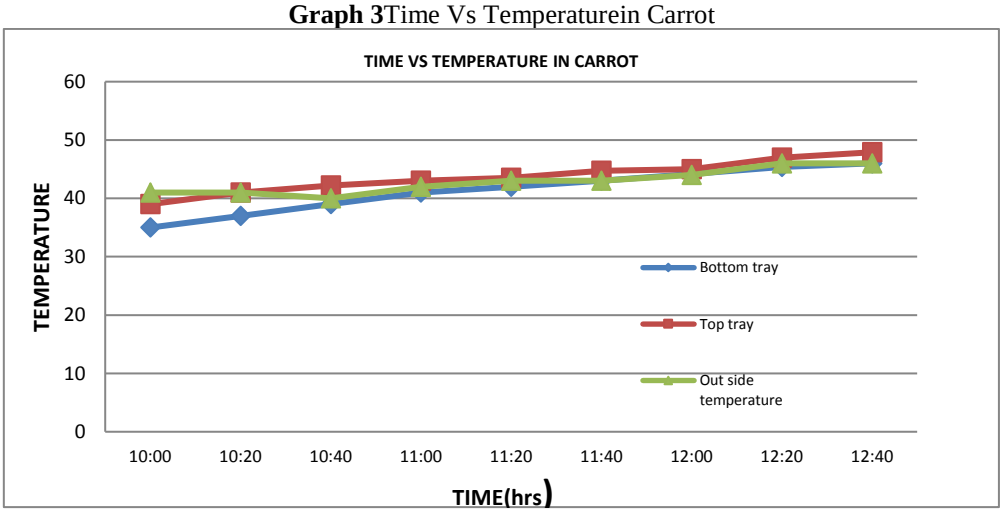


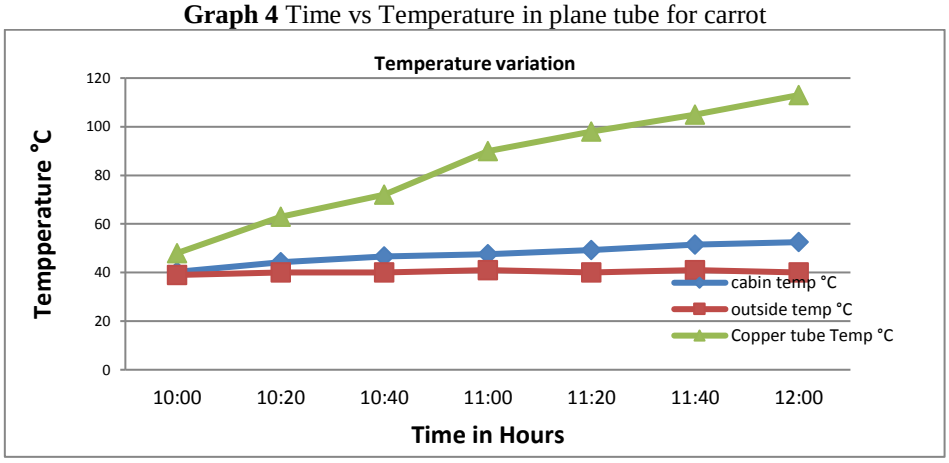
TABLE 5 Loss of Weight In Natural Convection Drying in Hours

TIME(hours)	WEIGHT LOSS IN Grams		
	CUCUMBER	CARROT	TOMATOES
10:00-11:00	169	180	170
11:00-12:00	150	161	145
12:00-1:00	110	145	104

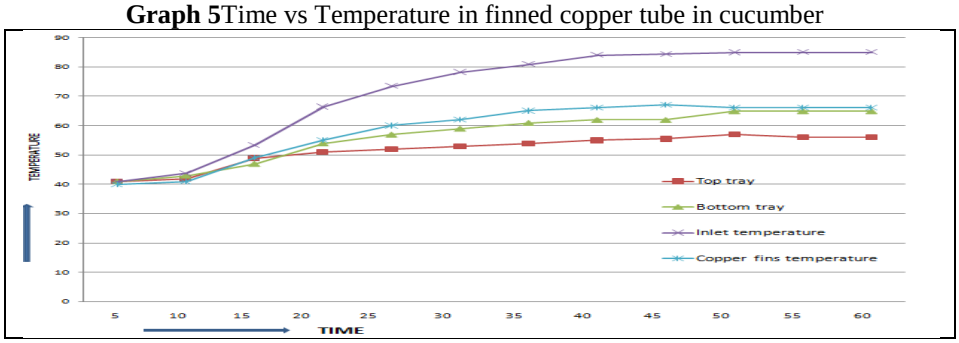
Here we observed that tomatoes crop have more moisture content than other crops .And here we can see that tomatoes can be preserved by removing its 50% of moisture but it took almost 3 hrs in sunny summer days of May. So this crop has lot of usage in every cooking items .And if we dry this crop we have chance to control fluctuations of prices as well as usage of this in various forms in dried powders as well as soups according to the requirement of household as well as in food courts. This will defiantly gain lot of confidents to farmers to grow this crop twice or thrice in a year. We also tried on potatoes and beetroot and we got less moisture removal in these crops. Here we came to know that this crops has less moisture content so initially the good amount of moisture was removed. After half of time its moisture percentage is reduced and only powder dried state is remained. From this result we came to know that we can also make dried chips from crops with more fats and powder contents.

Temperature variations and weight loss in the dryer (Exhaust gas copper heat exchanger tubes plane and with fins):

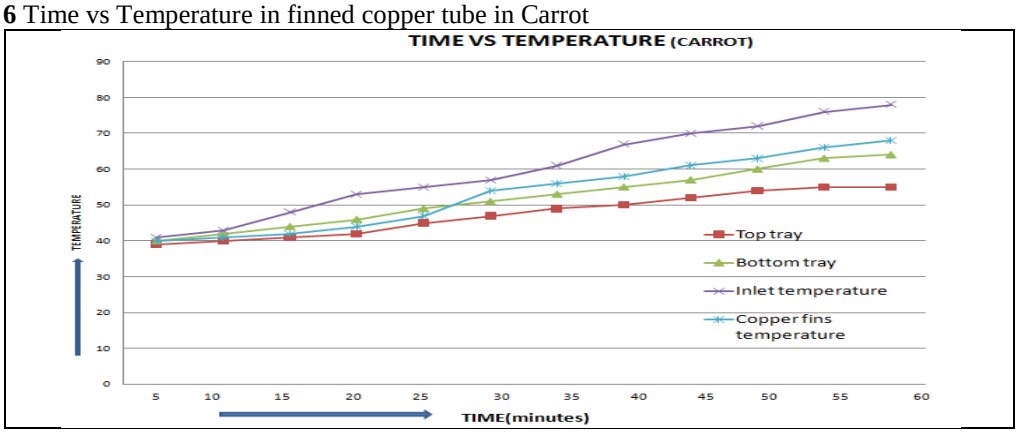
Graph 4 Time vs Temperature in plane tube for carrot



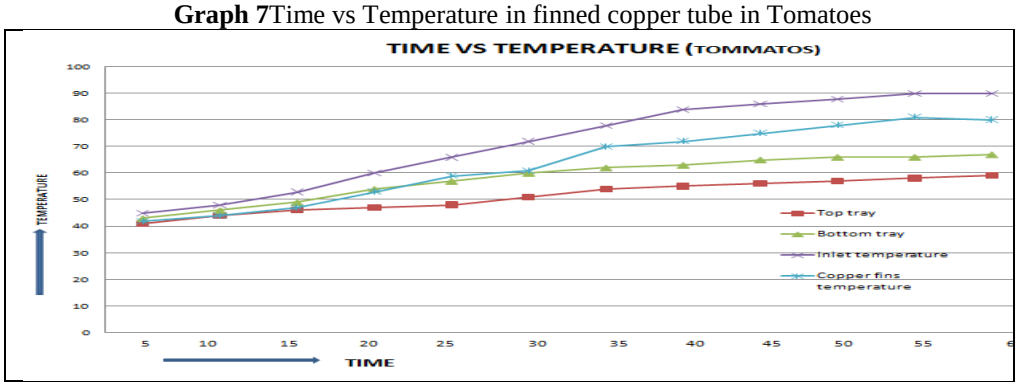
Graph 5 Time vs Temperature in finned copper tube in cucumber



Graph 6 Time vs Temperature in finned copper tube in Carrot



Graph 7 Time vs Temperature in finned copper tube in Tomatoes



We found that copper finned tube is more efficient than plane copper tube in exchanging heat from the exhaust gas of the diesel engine .so we continued with all three crops with finned copper tube.

Comparison Between Weights Lost And Moisture Content Removed natural Solar Convection And Exhaust Gas Copper Finned Tubes:

Weight Lost From Crop Through Exhaust Heat From Diesel Engine:

TABLE6 Loss of weight in natural convection drying

TIME(MINUTES)	WEIGHT LOSS IN grams		
	CUCUMBER	CARROT	TOMATOES
20MIN	192	194	191
40MIN	183	187	180
60MIN	169	180	167

Table 7 Loss of weight(grams) in exhaust gas drying

TIME(MINUTES)	WEIGHT LOSS IN (grams)		
	CUCUMBER	CARROT	TOMATOES
20MIN	186	187	182
40MIN	168	171	160
60MIN	146	150	134

Moisture Lost From Crop Through Exhaust Heat Gas From Diesel Engine:

TABLE8 Moisture removed in Cucumber

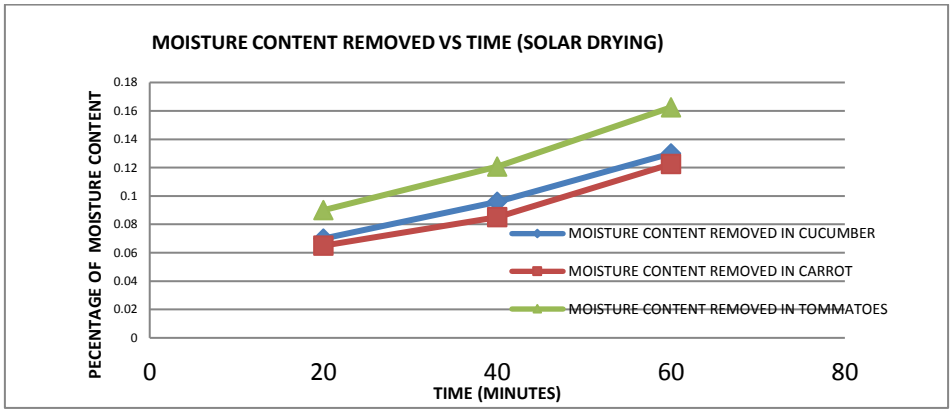
TIME IN MINUTES	Moisture removed in Solar Natural Convention Drying In Cabin		Moisture removed in Exhaust Gas Copper Tube Drying	
	Dry basis	Wet basis	Dry basis	Wet basis
20min	0.045	0.047	0.09	0.098
40min	0.057	0.061	0.01208	0.1375
60min	0.077	0.079	0.1625	0.1940

TABLE9 Moisture removed in carrot

TIME IN MINUTES	Moisture removed in Solar Natural Convention Drying In Cabin		Moisture removed in Exhaust Gas Copper Tube Drying	
	Dry basis	Wet basis	Dry basis	Wet basis
20min	0.03	0.031	0.065	0.069
40min	0.036	0.038	0.085	0.0935
60min	0.040	0.041	0.1228	0.14

TABLE10 Moisture removed in Tomatoes

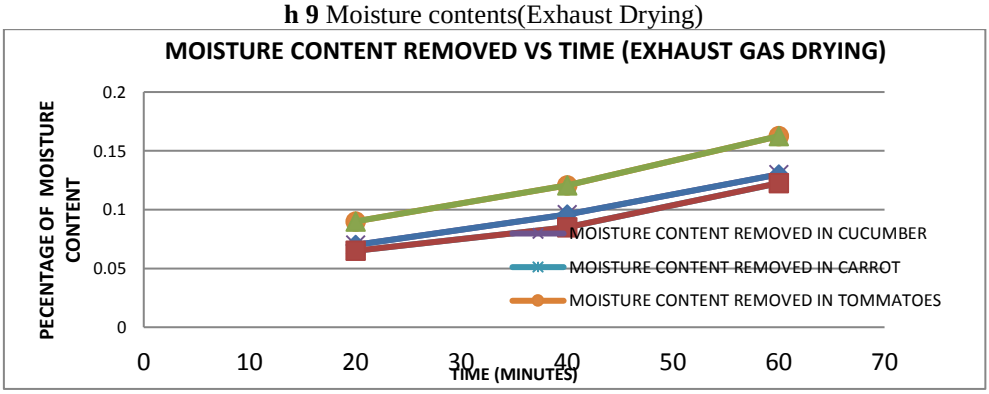
Graph8 Moisture contents(Solar Drying)



TIME IN MINUTES	Moisture removed in Solar Natural Convention Drying In Cabin		Moisture removed in Exhaust Gas Copper Tube Drying	
	Dry basis	Wet basis	Dry basis	Wet basis
20min	0.04	0.042	0.07	0.075
40min	0.047	0.049	0.096	0.107
60min	0.072	0.083	0.13	0.15

Grap

h 9 Moisture contents(Exhaust Drying)



VIII. CONCLUSION

Here project is concentrated on decreasing loses in horticultural. Associate experimental study of however this dryer fare compared to alternative dryers.. So by using these type dryers we can install at storages houses, warehouses and go downs can use generator exhaust to remove moisture for preservation until next crop.

[1] Internal-combustion engine or generator that emits the exhaust gases that has the temperature to dry the vegetables is employed.

[2] Accordance with the characteristics of the exhaust gas of diesel engines may be a compact device menstruation length and diameter of every 0.56m, 0.13 m, exploitation consecrate formed surfaces manufactured from copper material with a thickness of 0.6 mm. and also the copper tube with fin is with 1inch inner diameter and fin length is 3mm.

[3] Exploitation the exhaust gas during this drier for drying besides additional economical, it's additionally environmental and farmer friendly.

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