The International Journal Of Engineering And Science (IJES)
||Volume||2 ||Issue|| 9||Pages|| 88-94||2013||
ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805

Design and construction of a Vegetable Drier

AminuSaleh Mohammed
Hydraulic Equipment Development Institute, Kumbotso Kano

--**ABSTRACT**--
With the subsequent increase of food growing especiallyin rural areas, there is an accompanying need for preservation method. This has led to a substantial increase in the number of driers, yet expensive for local farmers to acquire.This paper condensed and comprehensive work done with the aim of reducing the cost of drying and also for practical demonstration of some of the theoretical knowledge acquired. It was discovered that the drier is efficient since the heat leakage was found to be very low.

KEYWORDS: *Drier efficiency, microbiological growth, heat leakage, coefficient of thermal conductivity and convection heat transfer*

Date of Submission: 28, August, 2013 Date of Acceptance: 30, September 2013

I. INTRODUCTION

The preservation of vegetable by drying is [1] believed to be one of the best post harvest operation thathas been practiced for a long time in Nigeria. This gives room for storage and future consumption or use.The success of any drying operation depends on removing enough moisture from food (vegetable) to achieve a water activity too low not to allow microbiological growth to take place. This in turn means that there must be sufficient transfer of heat to provide the latent of vaporizationneeded.Most people particularly farmers expose their crops to the sun by spreading them widely to dry before storage- Example of some of the vegetable are: Okro, tomatoes, pepper, carrot and spinach. Sun drying still remains the most widespread method of food preservation due to its simplicity and low cost. This is conveniently done in dry season because rainy season makes it difficult and domestic animals disturb the spreaded product hence making drying a difficult task especially in the rural area:

The method used for drying may be conviently classified as follows:

(i) Drying by healed air, the food (vegetable are placed in contact with a moving streamheated air. Heat is supplied to the product mainly by convection.
(ii) Drying by the application of energy from a radiating microwave or dielectric source.
(iii) Drying by direct contact with a heated surface heat is supplied to the product mainly by conduction
(iv) Freeze - drying; the moisture in fee food is froze and then sublimed to vapour,usually, by the application of heat under very low pressure conditions.

There are modem dryers that uses convectional fuel which are expensive for local farmers to acquire, operate and maintain, then, therefore a simple and mobile small scale drier which uses fuel available in the rural area will be of great help to our local farmer-
This project "Design and construction of a prototype vegetable drier" would use kerosine as fuel for the heat generation which can be obtained even in rural areas.

1.2 Literature Review

One of the longest established methods of food preservation is drying. It combines the benefits of micro-biological and physio-chemical stability with reduction in weight and transport costs and has other advantages in handling and storage. It is of wide application, covering fish and meats, fruit and vegetables and many part or wholly prepared food products. Example of preserved food included tea, coffee, granulated sugar, soft fruits, vine fruits, legumes, root vegetable, ready - meals, and herbs and spices.The success of any drying depends on removing enough moisture from the food to achieve a water activity too low to allow microbiological growth to take place. In order to achieve successful drying there must be sufficient input and transfer of heat to provide the latent heat of vaporization needed,As all moisture must be lost from exposed surfaces, normally to the air, it follows that the relative humidity of the air used for drying are critical factors, as will be the manner in which the food is supported during the drying operation, that is, the extent to which potential exposed surface are covered by contact with other food particles, trays or conveyors,

1.2.1 Drying Temperature

Most of the countries which dry fruits commercially have sunny climate that favours sun dry methods. Sun drying of fruit gives the required range of drying temperature and therefore it is still the method of drying fruits. The suitable drying temperature for fruit is 60°C - 80° C. Example Banana dries at (60°C - 7^C) until it is hard brittle. Avoid over heating to prevent darkening, vegetable are dried at (55°C - 60°C) until the legumes are brittle and crisp onion dries at *(5f C '* 70°C) until crisp.

1.2.2 Method Used for the Drying of Foodstuff

This may be conviently classified as follows:

(i) Drying by direct contact with a heated surface. Heat is supplied to the product mainly by conduction.

(ii) Freeze dry: the moisture in the food is frozen and then sublimed to vapour usually by the application of heat under very low - pressure condition.

(iii) Drying by heated air: The product is placed in contact with the heated air. Heat is supplied to the product mainly by convection.

(iv) Drying by application of energy a radiating microwave or electric source.

1.2.3 Types of Driers

There are various kind of dryer designed for drying grains grass, fruits and vegetables, Different types of dryers are constructed with fan to remove the moisture in vegetable for better storage.
Some of the drying operations and types of dryers are listed below:

1.2.4 Field Drying and Sun Drying

This is the system of drying where the combined effects of sun and wind provide the motive forces for effective evaporation. Effective successful 'field drying depends on local climate condition at point of harvest and therefore, is restricted to warm/hot parts of the world where wind and air humidity are satisfactory. Sun drying of harvest material is variable and only possible where the climate is suitable. Fruit and seeds are more frequently dried than vegetable, but some fruits regarded as vegetables are dried successfully in this way. For example peppers and the Sudanese slice tomato,

1.2.5 Air Drying

This may be batch wise or continuous and equipment include tunnels, trays or oven dryers, drum or roller dryers, pneumatic, trough rotary, cascade, tower, spiral, fluidized bed bin and but aband dryers, spray dryers, vacuum dryer etc, in most drying situations mechanical assistance isneeded over and above the-forceof nature, this being the convectional concept of air drying. For effective drying the partial pressure of water vapour is the air surrounding the material to be dried must be significantly lower than its saturated pressure at the operating temperature. This can be expressed as a relative humidity ratio and the lower the ratio the more effective the drying. As the ratio rises so fresh lower humidity air must be introduce into the system or the water vapour removed from it by some means. In generate hot air dryer are designed to allow a high airflow in the early stage but not so much as to move the material being dried, except where this is a requisite feature as for fluridised bed dryer. Typically an airflow rate of 180-300mm/min is used for vegetable piece, with dry' bulb air temperature of90°C to 100°C and wet bulb temperature 50°C.As moisture contents fall the airflow rate is reduced and drying temperature is decreased to 55°C or less until the moisture content is below 6,0%, Separate driers may be used to complete the final stage of drying,In fluoridised bed and air light or pneumatic driers, the airflow must be of sufficient velocity to lift the particles to be dries from a porous plate bed and cause them to behave as a liquid. This allows them to flow over a weir to exit the drier. Movement within the airstream provided excellentmixing and even drying. This can be used for powders; dried vegetables and for small whole vegetable such as peas. Again the moisture content and temperature of the air can be varied as can the airflow to suit the material being dried.

1.2.6 Vacuum Drying

These driers may be cabinet batch driers or continuous band driers with vacuum locks at infeed and outlet in either case heat transfer is by radiation and conduction. The advantage of vacuumdrying is that evaporation of water takes place more readily at low pressures.

1.2.7 Spray Drying

In spray drying system a spray of the material to be dried, which might for example be a pored vegetable suitable diluted and stabilized, is dispersed, as atomized spray into a counter current of hot dry air.The droplets dry in the airstream, falling to the bottom of unit as they do so, key elements are sufficient fan power and heating to achieve the required velocity and temperature, the atomizer, the drying chamber and the means of removing the dried product. The atomizer, the drying chamber may be one of the three basic types.

1.2.8 Freeze Drying

The sublimation of frozen moisture was originally a laboratory techniques for preserving highly sensitive products in micro-biological and mechanical works. As long as melting can be avoided, the moisture can be driven off without damaging the structure of solid material. Freeze drying methods are used for dehydrating food otherwise difficult of dry such as onion, coffee and certain sea foods.

The operation is carried out at the pressure below the triples point value usually about $50N/m^2$ and heat is produced either by radiation or conduction from hot platens which inter-leave the trays loaded with the product. The sublimed moisture condense on a fridge coil located at the fan end of the drying chamber.

1.2.9 Tray, Tunnel and Belt Driers

These drivers are similar in that they all use hot circulating air stream to provide the energy needed for drying and the product being dried moves at a high velocity compared to the circulating air velocity,

The figure shown below illustrates a tray drier. In the tray drier, the product to be dried is placed on the trays in the drying compartment. Air is heated by direct combustion with fuels or by steam or electric coils. Dampers are installed and regulated to control the amount of air entering and leaving the drier thereby controlling the humidity within the drier.

In tunnel driers, trays are loaded on to carts and the cart can be loaded into the drier tunnelon a quasicontinuous basic as shown below. The air stream in a tunnel drier could be arranged to flow in the same direction (parallel flow), opposite direction (counter flow) or at right angles (cross flow) with respect to the direction in which the carts move through the tunnel.

1.3 Drying Rates

The drying rates of a foodstuff alter during the drying cycle reflecting the changes which are occurring in the composition of the food " This is to be expected when one consider the complex, nature of foods. Water is an integral component of all organic materials. It is chemically and biochemically associated with the other foodstuff component. Moisture removal will also modify the cell structure thereby affecting the residual moisture content.

In the initial stage of drying of food, the rate of moisture migration from the interior of the particle to the surface is sufficiently high to cover the surface in moisture. This period of drying is known as the constant rate period. A critical moisture content will be reached when the moisture can no longer be drawn to the surface fast enough to maintain a completely wet surface. This can be attributed to physical and chemical changes occurring within the food. Once this critical moisture content has been reached, the rated of drying decreases. This second phase of the drying cycle is termed the falling rate period. Eventually the moisture content of the food will drop to a level where there is no driving force between the air and the surface, and drying will cease. The food is said to have reached its equilibrium moisture content.

In practical; terms, two important points should be made which benefit any drying extension work. The points are:-

i. For the initial drying of a commodity, the combination of high air velocity and moderatetemperature will optimize the use of energy for drying.
ii. In the latter stages of drying, low air flow combined with high air temperature will providemore rapid drying thana high air flow with a low temperature,

1.4 Drying Parameters

(i) The temperature of ambient air
(ii) The machine humidity of ambient air
(iii) The wind or air velocity
(iv) The initial moisture content of the product to be dried.
(v) The quantity of the product and depth of material to be dried,

1.5 Determination of Moisture Content

his may be made directly by drying the sample in an oven for a prescribed time and assuming that the resultant loss in weight is due to moisture

1.5.1 Equilibrium Moisture Content

This is the moisture content reached by a hygroscopic product after it'svapour pressure has come to equilibrium with that of the surrounding air.But during constant - rate drying period moisture is always present on the surface of the vegetable being dried. The water within this vegetable is able to diffuse to the surface at a rate faster than the rate at which it leaves the surface. This can be determined by heat transfer rate to material

(vegetable)

Mathematically, it is expressed as:

$$M = h_A \frac{T_R - T_S}{h_{fg}}$$

Where;

M = drying rate, kg/s

h = convection heat transfer coefficient, kw/m^2, °C

= Air stream temperature, °C

= Surface temperature

= Latent heat of vaporization evaluated at Ts, in KJ/kg

Specifically, the moisture content of vegetable determines its storability and can be expressed by a percentage by weight on a net basic grains of the moisture per l00g sample.

$$M.C = \frac{100wm}{Wm + wd}$$

where,

M = m,c net basis (%)

Wm = weight of moisture

Wd = weight of dried material

To convert from dry to wet basis

Mn = l00md

100 + wd

1.6 Material Selection

When constructing any machine in the engineering workshop such as the vegetable drier, it is very important to put into consideration the following factors when selecting the material. The factors are:-

i. The method by which it will be shaped,
ii. The durability of the material,
iii. The overall cost of both material and process
iv. The ability of the materials to withstand service condition.
v. The convenience of production when using the material
vi. The availability of the material
vii. Heat leakage and thermal conductivity of the material.

In construction of this drier all the above factors were considered, though may be difficult to have a material that posses al! the properties, but yet the wood was considered most suitable since the driers and the material combined the advantage of simplicity, portability, reduced cost, availability of material, low rate of heat leakage and low thermal conductivity over others in existence today,

Material	**W/mk**	**Cal/S cm^{0}C**	**Kcal/in°ks**
Aluminum	209	0.499	0.0499
Copper	385	0.921	0.0921
Iron	46	0.110	0.0110
Silver	414	0.99	0.099
Brick	0.65	1.55 xl0-^{3}	1.55 xl0-^{2}
Concrete	1.08	2.59xl0-^{3}	2.59xl0-^{2}
Cardboard	0.043	1.03x10^{-4}	1.03 xl0-^{5}
Glass	1.00	2.4 x 10-^{3}	2.4 x 10-^{2}
Pine wood	0.113	2.69 xl0-^{4}	2.69 x 10-^{5}
Air	0.025	6.0 x 10-^{5}	6.0 x 10-^{6}
Water	0.599	1.43 xl0-^{1}	1.43 x 10-^{6}

1.7 List of the Components Needed for the Construction

The table given below shows the various component and items used for the construction ofeach part. Priority was attached to the availability of the needed materials and the cost was also put into consideration with other factors:-

S/NO	Parts	Quantity	Material used
1.	Drier wall	3	ply wood
2.	Baffles	3	aluminimum sheet
3.	Door	1	plywood
4.	Tray holders	4	wood
5,	Nails	l"&2",l'/2kgeach.	standard
6.	Screws	10	standard
7.	Handle	1	standard
8,	Chimney chamber	1	wood
9.	Kerosine stove	1	standard
10,	Trays	2,35x3cm wire mesh	standard
11.	Hinges	2	standard
12.	Paints	2 tins	standard
13.	Insulator	4, 65cm & 65cm	standard

1.7.1 Construction Processes

S/N	Parts	Operation	Tools Used
1.	The wall of the drier.	The plywood was measuring planned and cut to size for different sides of the wall and other parts of the body that made up the driers. Glue was put to all the edges before nailing together in order to form the housing.	planner, ruler, scriber, nail, saw and hammer,
2.	The Baffles	The required dimension was marked out on the metal sheet and was cut into the number of the pieces needed. They werefolded to the required angle	Ruler, foldingmachine, scriber and trysquare.
3.	Tray holders	The wood was marked out to size and after which they were cut to the required length,	Saw, scriber and ruler
4.	Trays	The wire mesh and the wood were marked out and cut to size. The wood was nailed together to form a squarewhere the wire mesh was also nailed.	Hammer, scribed, assessor and saw.
5.	Bottom of the driers	The Galvanized sheet of metal marked out and cut to the size before covering the bottom by nailing them together with thenailing them together with the drier.	Steel rule, try square, cutting machine, service and hammer
6.	The door	The plywood was measured cut and planned to size of the required door, Hinges were used to fix it to"the drier wall.	Ruler, saw, planner and hammer.
7.	Insulators	They were placed between the inners surface ofthe wall and the sheet metal to minimize heat Leakage.	Ruler hammer and saw.
8.	Chimney area	A plywood was marked out and cut to the dimension of 40cm x 40cm at the base and 20cm x 20cm at the top. Two of the sides were raised to 60m and cover with aplywood of 30cm x 30cm to allow the free escape of the warm air.	Ruler, saw, trysquare and scriber.
9.	Stand	Plywood was marked out and cut into 4 pieces two of each were equal for the production of the rectangular box. Two sides were drilled to allow the entering of air.	Tape rule, saw, planner, hammer and drilling machine. Tape rule, saw, planner, hammer and drilling machine.

1.7.3 Assembly of the Drier

The entire parts of the drier were assembled manually. Either through nails or screws as the case might be. The drier is made up of a heating chamber and drying chamber with the measurement of 75cm & 70cm in length and width respectively for proper house forming. The material used for the construction is plywood which is internally insulated for maximum efficiency and to prevent heat lost. The openings at the top forming the chimney allow the free escape of the warm air an was by the side of the drier or safety purpose. At the bottom by the side of the door, drier is provided with 5cm opening to allow intake of air to move up the heat from the bottom to the top of the drier.

II. CALCULATIONS

Calculating the rate of heart transfer per unit area of the drier.

Using the formular $\frac{Q}{A} = \frac{(t}{\frac{l_1}{k_1} + l}$

Where:

Q	=	Rate of heat transfer
A	=	Area in m^2
t	=	Temperature (^0C)
K	=	Coefficient of thermal conductivity
l	=	Length (thickness) of the material

Let = Rate of heat transfer per unit area.

For 15 minutes heating (testing)

Data

Internal temperature of the drier ( ) = 59^0C.

Outside surface temperature of the drier wall = 28^0C

$$\frac{Q}{A} = \frac{(t_1 - t_4)}{\frac{l_1}{k_1} + \frac{l_2}{k_2} + \frac{l_3}{k_3}}$$

Data

=	59^0C	Q	=	?
=	28^0C	A	=	Unit area
=	1×10^{-3}			
=	$12 \times 10^{-3}m$			
=	$11 \times 10^{-3}m$			
=	209w/mk			
=	0.043w/mk			
=	0.113w/mk			

Computing (Solution)

$$\frac{Q}{A} = \frac{(59-28)}{\frac{1 x 10^{-3}}{209} + \frac{12 x 10^{-3}}{0.043} + \frac{11 x 10^{-3}}{0.113}}$$

$$= \frac{31}{4.78 x 10 + 0.279 + 0.097}$$

$$\therefore Q = 82.445w$$

To calculate the interfaces temperature we apply fourier's equation

$$\frac{Q}{A} = k_1 \frac{(t_1 - t_2)}{l_1}$$

i. $82.445 = \frac{2}{}$

$$\frac{82.445 \times 10^{-3}}{209} = 59 - t_2$$

$$t_2 = 59 - \frac{(82.445 \times 10^{-3})}{209}$$

$$t_2 = 59 - 3.94 x 10^{-4}$$

$$t_2 = 58.9^{o}C$$

ii. $\frac{Q}{A} = k$

$$82.445 = \frac{0.043(58.9 - t_3)}{12 \times 10^{-3}}$$

$$t_3 = 58.9 - \frac{82.445 \times 12 \times 10^{-3}}{0.043}$$

$$t_3 = 58.9 - 21.99$$

$$t_3 = 36.19^{0}C$$

From the above calculation it can be seen that the drier is efficient since the heat leakage is very low. Thus, the materials used for the construction are effective,

III. CONCLUSION

From the result of the calculation made in chapter three, the performance of the drier can be said to be satisfactory. Instead of drying for 2-4 or weeks traditionally, this drier will be able to dry vegetable for 9-36 hours without smoke, moisture inside and desirable market quantities. It also has the advantage of maintaining the original colour of the vegetable, it is hygienic and no dust.However, since this project is a prototype, it could be developed into bigger efficient vegetable drier. There can be diverse ways in which the project can be improved upon depending on where and the quantity of the vegetable to be dried.bg

REFERENCES

[1]. D.Arthey& C, Dennis, Vegetable processing (1978)

[2]. J. Clari Batty and Steve L. Folkman, Food engineering fundamentals (1983)

[3]. Internal labourorganisation, solar drying practical methods of food preservation (1986)

[4]. P. L. Sardeson and D. D Deshmuch, Appliedphysis for polytechnic (1990).