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Design of waste fired-natural draft dryer

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■ **ABSTRACT :** India's contribution in the world production of fruits and vegetables during 2013-14 was 13.6 % and 14% , respectively (Anonymous, Indian Horticulture Database 2014). India wastes fruits and vegetables worth Rs. 13,300 crore every year. The excess moisture in the food is also contributes to its reduced storage life. To develop the dryer the design was prepared on the basis of volume of wet material to be handled. Weight of arecanut considered per batch was 15 kg. The drying efficiency of the dryer depends on different factors like, drying air temperature, relative humidity of the air and the airflow rate through the drying chamber. A dryer has different components like, drying chamber, heating unit and a chimney. While designing the dryer these components were taken in to consideration. On the basis of the above assumptions the different components of the dryer were designed.

■ **KEY WORDS :** Dryer, Arecanut

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India has been bestowed with wide range of climate and physic-geographical conditions and as such is most suitable for growing various kinds of horticultural crops such as fruits, vegetables, flowers, nuts, spices and plantation crops (coco nut, cashew nut and cocoa). Its horticulture production has increased significantly over the last two decades and as per the final estimates, by 2013-14, it has increased to about three times (2.87) since 1991-92 and to about twice (1.90) compared to the production in 2001- 02. This has placed India among the foremost countries in horticulture production, just behind China. As per Indian Horticulture Database 2014, during 2013-14, India's contribution in the world production of fruits and vegetables was 13.6 % and 14%, respectively. Total production of fruits during 2013-14 was about 89 million tons, while that of vegetables was 163 million tones. (Indian Horticulture Database 2014). India wastes fruits and vegetables worth Rs. 13,300 crore every year: Emerson study (ET Bureau, Nov. 28, 2013). The main cause of loss is country's lack of adequate cold storage facilities and refrigerated transport facilities. The other cause of losses is excess moisture content in the fruits and vegetables.

The excess moisture in the food is also contributes to its reduced storage life. There are various ways to enhance the storage life of the food. This includes fermentation, addition of heat, removal of heat, chemical treatments, etc. Out of these methods one which is adopted from the centuries is removal of moisture content through drying. The drying process drops down the moisture content to a safe level so that the water activity reduces and shelf-life enhances.

To reduce the losses and to enhance shelf-life, an accelerated moisture content removal is required. The drying methods employed for this purpose are heated air drying and sun drying.

The mechanical dryers during operation need constant electrical supply. In villages, un-interrupted power supply seldom available. This becomes prime hurdle in drying of perishable crops. It was therefore, an agro waste fired natural draft dryer was developed.

METHODOLOGY

To develop the dryer the design was prepared on the basis of volume of wet material to be handled. The design was undertaken on the basis of following assumptions. The crop to be dried was arecanut (Table A).

Table A : Assumptions for design of dryer

Sr. No.	Parameters	Assumptions
1.	Drying temperature of air, t_2	65 °C
2.	Temperature in drying	60 °C
3.	Temperature of exhaust, t_1	40 °C
4.	Specific heat of water, C_{pw}	1 kcal/kg°C
5.	Latent heat of vaporization of water	600 kcal/kg
6.	Initial moisture content of arecanut (d.b.)	71.1 per cent
7.	Final moisture content of arecanut (d.b.)	5.3 per cent
8.	Drying period of arecanut, θ	30 hour
9.	Initial temperature of arecanut, t_{ci}	27 °C
10.	Final temperature of arecanut, t_{cf}	55 °C
11.	Specific heat of arecanut, C_{pc}	0.28 kcal/kg°C
12.	Calorific value of saw dust, C_n	3000 kcal/kg.
13.	Weight of arecanuts, W	15 kg
14.	Thermal efficiency	25 per cent
15.	Heat exchanger efficiency, η_{ex}	35 per cent
16.	Combustion efficiency, η	65 per cent
17.	Density of Arecanut ρ_c	470 kg/m^3

Design of dryer:

A dryer has different components like drying chamber, heating unit and a chimney. Accordingly, while designing the dryer these components were taken in to consideration.

On the basis of the above assumptions the different components of the dryer were designed. The drying chambers design is as follows.

Design of drying chamber :

The drying chamber was designed based on the amount of arecanut to be dried, density of arecanut and the thickness of bed.

The floor area required for drying arecanut was calculated as under,

$$A_d = \frac{\text{Mass of arecanut, kg}}{\text{Density of arecanut, kg/m}^3 \times \text{Thickness of bed, m}} \quad (1)$$

The drying efficiency of the dryer is depending on different factors like drying air temperature, relative humidity of the air and the airflow rate through the drying chamber.

Airflow rate :

The rate of airflow required for drying can be calculated by a heat balance equation and with the help of psychometric chart. The heat loss is assumed 30% of the total heat provided. (Chakraverty, 2000).

$$Q_a = G \times V_1 \quad (2)$$

where,

Airflow rate, Q_a

Humid volume in air at ambient air temperature (27°C) and at 90% R.H. from psychometric chart, V_1 = 0.86 m^3/ kg.

Rate of air supply in G, kg/min

$$G = \frac{W_1[(X_{id} - X_{fd})\lambda + C_{pc}(t_{ci} - t_{cf}) + C_{pw}(t_{ci} - t_{cf})X_{id}}{(0.24 + 0.45H)(t_2 - t_1)\theta \times 0.70}$$

where,

W_1, Bone dry arecanut in kg = 5 kg

X_{id} Initial moisture content of arecanut, (d.b.) in fraction = 0.711

X_{fd}, Final moisture content of arecanut, (d.b.) in fraction = 0.053

λ, Latent heat of water vapour in kcal/kg = 600 kcal/kg

C_{pc}, Specific heat of arecanut in kcal/kg°C = 0.28 kcal/kg °C

X_{fd}, Final moisture content of arecanut, (d.b.) in fraction = 0.053

C_p, Specific heat of water in kcal/kg°C = 1.0 kcal/ kg °C

t_{ci}, Initial temp. of arecanut in °C = 27 °C

t_{cf}, Final temp. of arecanut in °C = 55 °C

H, Humidity at ambient air in kg/kg = 0.02 kg/kg

t_2, Drying temp. of air in °C = 65 °C

t_1, Temperature of exhaust air in °C= 40 °C

θ, Drying period of arecanut in hrs = 30hrs

Air requirement for drying, Q_a = 2.56 m^3/min

Fuel requirement:

It was assumed that the sawdust was used as a fuel in the heating unit of this dryer. The quantity of fuel required per hour was calculated with the help of a formula given below :

$$F = \frac{q_a}{\eta \times \eta_{ex} \times C_n} \quad \text{(Chakraverty, 2000)} \quad (3)$$

where,

F, Fuel rate, kg/hr.

q_a, Total heat required to heat the drying air, kcal/hr.

C_n, Calorific value of fuel, kcal/kg = 3000 kcal/kg

η, Combustion efficiency = 0.65

η_{ex}, Heat exchanger efficiency = 0.35

$$q_a = W_1 [X_{id} - X_{fd}) \lambda + C_{pc} (t_{ci} - t_{cf}) + C_{pw} (t_{ci} - t_{cf}) X_{id} \times \frac{1}{0.70}$$

= 1792.6 kcal/hr.

= 3.41 kg/hr

The dimensions of the heating unit were decided with the help of the quantity of fuel required while drying.

Chimney:

A chimney is required to convey the flue gases from heating unit to atmosphere passing through drying chamber's central duct.

The temperature difference between outside cold air and inside hot air of the drying chamber causes pressure difference in chimney (Basunia, 2001)

$$P = 0.000308 \times g \times (t_i - t_f) \times H \quad (4)$$

where,

P, Pressure difference between outside cold air and inside hot air, Pa

G, Acceleration due to gravity = 9.81 m/s^2

H, height of the chimney, m.

Actual draft was assumed to be 80% of the draft (P).

Actual draft (P_1) = 0.8 x P.

Velocity of exit air (c) = $(2 \times P_1 / \rho_e)^{0.5}$

Volume of exit air (v_e) = quantity of air in kg / ρ_e

Rate of exit air (q_e) = v_e / drying time

Cross sectional area of chimney (a_c) = q_e/ c

The inside temp of flue gases in chimney and outside temperature of gases are required for calculating pressure draft in the chimney with the help of a psychometric chart.

$$Q_a = \frac{K \times A(T_1 - T_2)}{x} \quad (5)$$

where,

Q, Heat loss, Watt

K, Thermal conductivity of material, W/m^{o}K

$T_{i,}$ Inside temperature of heating chamber or drying chamber, ^{o}K

$T_{o,}$ Outside temperature of heating chamber or drying chamber, ^{o}K

X, Thickness of material, m

A, Area of heating chamber or drying chamber, m^2

■ RESULTS AND DISCUSSION

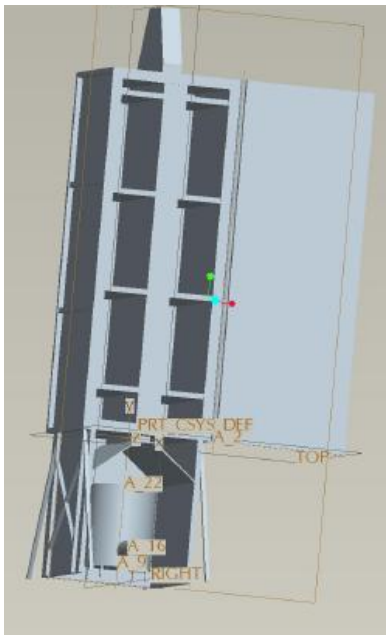
The dryer was designed with the help of above different formulae. The different components of the dryer were designed as follows.

Design of drying chamber :

The floor area required for drying arecanut was found as under,

$$A_d = \frac{15}{470 \times 0.035} \quad (1)$$

= 0.911 m^2



≈ 0.92 m^2 where

Mass of arecanut = 15 kg; Thickness of bed = 0.035m; Density of arecanut = 470 kg/m^3.

On the basis of the area of the drying chamber, the trays dimensions were finalized. Total ten trays having dimensions 0.46 x 0.20 m were designed. Trays were made of M.S. frame and wire mesh of 1"x1". The space between the trays was maintained as 230mm vertically. Accordingly the overall dimensions of the drying chamber was came as 1.130 m (h) x 0.510 m (w) x 0.490 m (Depth). This drying chamber was provided with a door having dimensions 1.130 m (h) x 0.510 m (w). A space of 0.60 m was provided beneath the drying chamber for placing the heating unit.

The drying efficiency of the dryer is depending on different factors like drying air temperature, relative humidity of the air and the airflow rate through the drying chamber.

Airflow rate :

With the help of eq. (2), the air requirement for drying, Q_a = 2.56 m^3/min

Fuel requirement:

$$q_a = W_1 [(X_{id} - X_{fd}) + C_{pc} (t_{ci} - t_{cf}) + C_{pw} (t_{ci} - t_{cf}) X_{id}] \times \frac{1}{0.70}$$

= 1792.6 kcal/hr.

= 3.41 kg/hr

Therefore, the overall dimensions of heating unit were 0.40m (h) x 0.25m (d). The heating unit's opening was kept as 0.070m diameter.

Chimney:

The inside temp of flue gases in chimney and outside temperature of gases are required for calculating pressure draft in the chimney with the help of a psychometric chart.

P = 0.045 kgf/cm^2

P = 0.044 Pa

From the pressure draft the height of chimney was calculated. Therefore from eq. 4 the height of chimney is as follows:

H = 1.12m

The actual draft was calculated as 80% of the calculated pressure draft.

P_1 = 0.80 x 0.044

P_1 = 0.032pa.

The velocity of exit air, C

$C = 2xP_1 / \rho_a$

= 0.064

C = 0.064 m/s

Volume of exit air, V_e

$V_e = 0.058 m^3$

Rate of exit air, q_e

$q_e = 1.94 \times 10^{-3}$ m^3/hr.

Cross sectional area of chimney, a_c

$a_c = 1.78 \times 10^{-3}$ m^2

with the help of formula (5) the heat loss was 663W.

As per the design considerations the dryer was fabricated with following specifications.

A drying chamber of 510x490x1130 mm was prepared with the help of eight M. S angles having 25x25x5 mm size. The walls of the drying chamber were prepared of an asbestos sheet. The asbestos sheet was preferred to minimize heat loss through walls. The drying chamber was provided with ten trays hiving dimensions 460x200 mm spaced vertically 230 mm apart. The trays were prepared using wires with mesh 17 X 17 mm. A chimney of size 1480x350x60mm was placed at the center of the drying chamber and the trays were placed on both the sides of the chimney five trays each side.

Conclusion:

The dryer having drying chamber of dimension 510x490x1130 mm with ten trays of size 460x200 mm each spaced vertically 230 mm apart and centrally provided with chimney of size 1480x350x60mm was designed.

REFERENCES

Baboo, B. (1981). A device for dehusking arecanut. *J. Agric. Engg. (ISAE)*, **19**(1) : 63–65.

Balasubramanian, M. and Panwar, J.S. (1986). Mechanical properties of arecanut (*Areca catechu* Linn) as related to dehusking. *J. Agric. Engg. (ISAE)*, **23**(1) : 82–88.

Chakraverty, A. (2000). *Selection, design, specifications and testing of grain dryers. Post Harvest Techmology of cereals*, pulses and oilseeds. (3rd Edn). Oxford and IBH Publishing Co. Pvt. Ltd.,New Delhi. pp. 94-99.

Condori, M., Echazu, R. and Saravia, L. (2001). Solar drying of sweet peper and garlic using green house drier. *Renewable Energy*, **22**: 447-460.

Drying kinetics of arecanut using solar cum biomass drying

system and performance of testing of a new natural convection solar dryer. Energy, 27: 579-590.

Gunaseelan, R., Shanthi, S., Sowmya, R. and Datta, M. (2007). Arecanut use among rural residents of Sriperambudur Taluk: A qualitative study. *Indian J. Dental Res.,* **18** (1): 11-14.

Kaleemullah, S. and Gunasekar, J.J. (2002). Moisture-dependent physical properties of arecanut kernels. *Biosystem Engg.,* **82** (3): 31-338.

Kiran, K., Govin, A.K., Bandi, M. and Shivasharanayya (2014). Design, development and testing of an arecanut Dehusking Agri-machine. *Internat. J. Engg. Res. & Applications,* **4**:7(2): 109-115.

Kulanthaisami, S., Subramanian, P., Venkatachalam, P. and Sampathrajan, A. (2007). Drying kinetics of arecanut using solar cum biomass drying system. *Madras Agric. J.*, **94** (7-12): 256-268.

Kulanthaisami, S., Subramanian, P., Mahendiran, R., Venkatachalam, P. and Sampathrajan, A. (2009). Drying Characteristics of coconut in Solar Tunnel Dryer. *Madras Agric. J.,* **96** (1-6): 265-269.

Negi, P.S. and Roy, S.K. (2001). Effect of drying conditions on quality of green leaves during long term storage. *Food Res. Internat.*, 34: 283-287.

■ WEBLOGRAPHY

Anonymous (2015). Indian Horticulture Database 2014. http://nhb.gov.in/area-pro/NHB_Database_2015.pdf