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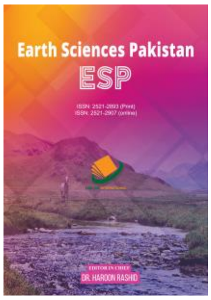

DESIGN, FABRICATION AND EVALUATION OF ROTARY HOT-AIR DRYER FOR THE VALUE ADDITION OF FRUIT WASTE

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ABSTRACT

Citrus waste is solid residue that remains after fresh fruits are squeezed for their juices. Pakistan is among the top ten citrus producing countries in the world. Pakistan is contributing 2.16 million tons per annum in fruit waste generation. Fresh food waste is often used locally to feed animals as milk enhancer. When fresh fruit are squeezed, a solid residue is produced which is commonly known as citrus waste. Fresh citrus waste has a natural acidity, but it is still a perishable product due to its high moisture content and soluble sugar. Dehydration method is usually applied for the removal of moisture content up to less than 10 % to increases the shelf life for easy handling and transportation. The present study enables the design of a rotary-hot air dryer having an internal rotating body. The drying efficiency increased with the increase in the internal temperature and the air flow rate in the rotary drum, while the drying efficiency decreases with increasing the drum speed. The drying process provided the optimal results with respect to drying time and Vitamin C concentration. The present designed hot-air dryer provides fundamentals for fruit pulp industry who can easily adopt this technology. This dryer can be installed within pulp industry and waste can be processed at source point. The dehydration process increases the shelf life of citrus fruit waste and it will be available throughout the year around the country. The dehydrated material can enhance the milk quantity of animal.

KEYWORDS

Rotary hot-air dryer, Citrus fruit waste, Drying time, Vitamin C concentration.

1. INTRODUCTION

Drying is an energy intensive process that results in the removal of moisture from a body by evaporation. Different drying methods are used to drying food waste. Drying time, the rate of heat and mass transfer depends mainly on the transport mechanism in the boundary layer. The hot air drying is the most commonly used method holds an important position among drying methods. This method seriously leads to serious quality loss such as reduction in the taste, color and nutritional content of the dry product. It also leads to a change in the water absorbance capacity and shifting the solutes from the internal part of drying material to the surface because of high temperature. The drying method is based on passing hot air through the material situated on the rotary drum. A rotary hot air dryer was chosen for the design due to the fact that there are many advantages possessed by this type of design for this particular process. The main advantages of rotary hot-air dryer are following:

1. It resists microbial growth as well as do not let harm the nutritional value of pulp by a moderate heating.
2. It will dry the pulp from 85% moisture to 10% moisture content.
3. It increases the shelf life of fruit waste
4. Shuffle the material which decreases drying time and improve end product quality.

It was found that intensive particle circulation rates resulted in high heat and mass transfer rates and uniform moisture content [1]. Dried pulp of Citrus is a by-product obtained after extraction of the juice from citrus fruits and drying of the remaining. Citrus pulp has abundance of energy, fiber, ascorbic acid and calcium, but deficient in protein and phosphorus with respect to digestion, the grain, citrus pulp and hay given together were mutually commendatory, as they form a satisfactory measure. Conventional hot-air drying of sample normally involves thermal and/or chemical pretreatment and drying at temperature maintained between 50 and 70 C. Due to long drying time usually consisting of 4 to 6 hours and overheating of surface during hot-air drying, the problems of darkening in colour, loss in flavour and decrease in rehydration ability occur. Although the influence of hot air drying on food quality is well recognized the understanding of processes caused by dewatering and adversely affecting material properties is limited. This is because evaporation of water at elevated temperature causes chemical, physical and biological changes in food, which can proceed simultaneously or in sequence, some can be advanced while others are just initiated [2].

1.1 Sensitivity of Vitamin C during drying

In a study, stated that degradation of ascorbic acid depends on several factors, which include oxygen, metal ion catalysis, light, temperature and moisture content [3]. The absence of air during drying may inhibit oxidation, and therefore, color and nutrient content of products can be largely preserved the solubility of vitamin C in water and heat sensitivity of it compared to most other nutrients may cause problems during the preservation of foods. Oxidation of food ingredients such as vitamins, pigments and aroma compounds is one of the most important causes of quality loss during food processing and is the main deteriorative reaction in microbiologically safe foods like dry and frozen products.

1.2 Kinetic model for vitamin C

The kinetic model representative of vitamin C degradation during air drying is obtained using a dynamic test approach an empirical first-order kinetic model is used for degradation kinetics of vitamin C.

$$-dC/dt = kC \quad (1)$$

Where C is the concentration of vitamin C (normalized with respect to initial concentration). Temperature dependency of the first-order rate constant, k, could be described as an Arrhenius relationship given at below equation:

$$k = k0 \exp(-Ea/RT)^{1/4} \quad (2)$$

Where k0 and Ea have moisture functionality,

$$\ln k0 = P_1 + P_2M + P_3M^2 \quad (3)$$

$$k0 = P_1 + P_2M + P_3M^2 \quad (4)$$

$$Ea = P_4 + P_5M + P_6M^2 + P_7M3 \quad (5)$$

Where M is the moisture content in g/g dry solid [4].

1.3 Vitamin C concentration in citrus

Vitamin C content of canned orange juice averages 40 mg per 100 g of juice. Reconstituted juice from orange concentrate contains about 11% more than single-strength canned juice. Thus, both canned orange juice and juice reconstituted from concentrate would provide more than 100% of the U. S. RDA, serving (124 and 140% respectively). For compliance with the regulations vitamin C content of the product must not fall more than 20% below the labeled value. A quick method of testing orange juice products for label compliance is needed. In the Official Method of the Association of Official Agricultural Chemists, vitamin C is titrated with the redox dye, 2,6, -dichloroindophenol. Introduced by and modified by others, the method recommends 3 aliquots of each sample be titrated with reproducibility of better than 99% [5].

1.4 Calcium concentration in citrus fruit

The calcium concentration in orange is given by the following table.

Table 1: Concentration of calcium in orange

Calcium in 100g	Per cup, sections (180g)	Per orange (131g)
40mg (4% DV)	72mg (7% DV)	52mg (5% DV)

Conventional hot-air drying of sample normally involves thermal and/or chemical pretreatment and drying at temperature maintained between 50 and 70 C. Due to long drying time usually consisting of 4 to 6 hours and overheating of surface during hot-air drying, the problems of darkening in colour, loss in flavour and decrease in rehydration ability occur. Although the influence of hot air drying on food quality is well recognized the understanding of processes caused by dewatering and adversely affecting material properties is limited. This is because evaporation of water at elevated temperature causes chemical, physical and biological changes in food, which can proceed simultaneously or in sequence, some can be advanced while others are just initiated [6].

2. OBJECTIVES

The aims and objectives of the project are following:

1. Design and fabricate of hot air dryer for dehydration of fruit waste.
2. Performance evaluation of developed rotary hot air dryer to obtain optimum drying conditions of fruit waste in terms of minimum drying time and maximum Vitamin C concentration.

Hot-air drying is a method which is used to reduce the moisture content of the product so as to retard adverse biological (such as growth of spoilage micro- organisms, germination, insect attack, etc.), chemical, and enzymatic processes [7].

3. MATERIALS AND METHODS

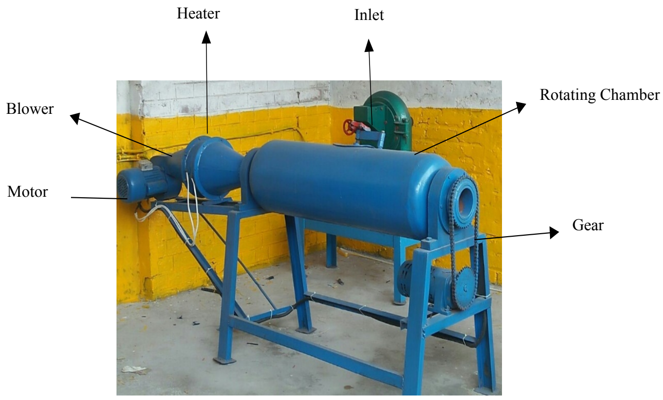
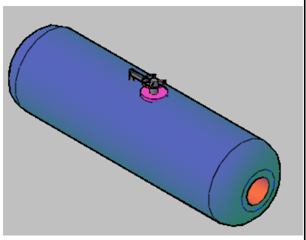
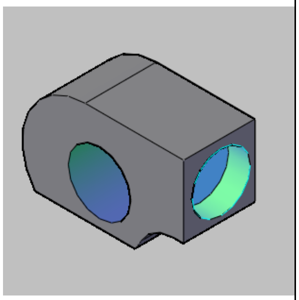
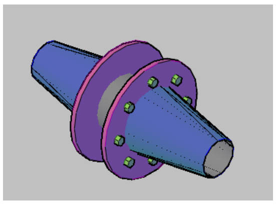
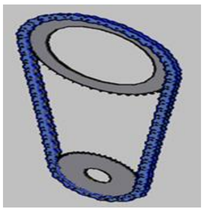


Figure 1: Pictorial view of Rotary Hot-Air Dryer

Figure 1 represents an experimental setup for testing the drying of citrus waste. It consisted of a rotary hot-air dryer, a waste feeding device, blower, heater, gear along motor and a control panel to control temperature and drum speed.

Table 2: Shows the material procured and designated for the fabrication of Rotary Hot-Air Dryer

Serial No.	Parts	Functions	Pictorial view of different parts	Specifications		No. of Pieces
1	Rotating chamber	To hold and shuffle the material.	 **Figure 2:** Rotating chamber	Rotary chamber (Capacity 5 Liter)	Mild Steel	01

2	Blower	To sucks air at room temperature and moves toward the heater from where is passes through the drying chamber which is in rotating condition. The inlet air flow can be controlled by damper plate	 **Figure 3:** Blower	Blower 1hp (2800 rpm)	Mild steel	01
3	Heater	Hot air crosses the drying chamber and transfers the heat to the product to be dried	 **Figure 3:** Heater	Heater capacity (1000 Watt)	Spring winded	01
4	Gear	Rotates the drum in clockwise direction in order to move the pulp inside the cylinder.	 **Figure 4:** Gear	Large gear (12cm Diameter) and small gear (8cm Diameter)	Cast iron	01

3.1 Determination of Moisture Content

The dried citrus waste collected and was checked for the moisture content and the drying efficiency was calculated. The moisture content (WC) in thee dried citrus waste was calculated by Equation.1

WC (%) = $= \frac{W_1 - W_2}{W_1}$ x100 ---------- 1

Where W_1 is the weight of dried citrus waste from the dryer and W_2 is the weight of citrus waste [8].

3.2 Determination of Vitamin C (Ascorbic Acid)

In order to determine the Vitamin C content of the waste, Titration will be used. The ascorbic acid present in fruit waste was determined using 2,6 dichlorophenol indophenol (DCPIP) by standardizing 0.1% standard 2,6 dichlorophenol indophenol (DCPIP) dye solution against 0.1% ascorbic acid solution according to the method (985.33) described by AOAC (2000). Waste sample was prepared by grinding then weigh approximately 10g sample in 250 mL conical flask. Add in metaphosphoric acid-acetic acid solution and makeup to a volume of 200 ml. Homogenize the sample by using a magnetic stirrer. Then, filter in 250 mL conical flask with a funnel and filter paper. If the sample colors too dark, add 1 tablespoon of charcoal to absorb the color and filter throw a funnel with filter paper. Remove 10 ml of sample and fill in 100 mL conical flask. Make 3 replicates.

Titrate the filtrate with dye until pink color (remain at least 5 sec). From equation 2

Ascorbic Acid (mg /100g) = $X \times A \times \frac{V}{Y} \times \frac{100}{W}$ -------- 2

Where,

X = mL of indophenol used to titrate the sample
A = mL of indophenol used to titrate the ascorbic acid standard (equivalent to mg of ascorbic acid contained
V = total volume (mL) of sample used
Y = total volume (mL) of sample used in titration to pink color (10 mL)
W = weight of sample (g) [9]

3.3 Determination of density of fruit waste

Density of food waste was calculated by using a measuring flask and weighing balance. Measure the weight of empty flask as "W_1" and put the citrus fruit waste in the flask and again take the reading ''W_2". The filled volume of the flask was taken as "V". Put all the given values in the equation and calculated the density of citrus fruit waste. From equation 3. Density of citrus fruit waste in (kg/m3), ρ = (W_2-W_1)/V --------- 3 [10].

3.4 Drying Performance Evaluation

The waste will be fed into the rotating drum by feeding inlet. The rotating drum will be turned on and the fan will bring air from outside and convey to the heading duct from where the air will pass through the heater. By passing through the heater, it will get warmed. This warmed air afterwards will move towards the waste inside the rotating drum. After getting in contact with the waste and air will take it moisture and will be moved forward to the exhausting part and will be exhausted outside.

Following factors will be kept in view for experiment being carried out

1. Temperature (°C)
2. Air flow rate (m/sec)
3. Drum speed (rpm)

Feeding rate was fixed constant at 30 % of the total volume of the drum. Drying time (minutes) to obtain final moisture content at less than 10% and Vitamin C (Ascorbic Acid) in mg/100g were selected as dependent variables. Statistic 8.1 software was used to study the effect of temperature, air flow rate and drum speed on drying time and Vitamin concentration. Only Vitamin C was analyzed to assess the overall quality of dried fruit waste because Vitamin C is the sensitive nutrient if it is preserve, it means all other nutrients will also be preserved.

3.5 Statistical Analysis

Statistical analysis was applied on the following parameters in order to check the significance of results obtained by the experimentation.
Independent variables that were involved in analysis:
1) Temperature, T
2) Drum speed, V
3) Air flow rate, Q
These were the independent variables which observed at three different values for each parameter for temperature (60°C, 70°C, 80°C) , Drum speed, V (40rpm,50rpm,60rpm) and Air flow rate, Q (1,2,3) and dependent variable Vitamin C (ascorbic acid)

4. RESULTS AND DISCUSSIONS

Results shows that effect of temperature on drying time and Vitamin C concentration is highly significant followed by air flow rate and drum speed. Showed that as temperature increases from 60°C to 80°C, Vitamin C and drying time decreases rapidly. On the other hand, drum speed has inverse effect on drying time as drum speed increases from 40 rpm to 60 rpm, drying time increases from 150 minutes to 170 minutes which indicated that material inside the drum not shuffle properly. Air flow rate also has significant effect on drying time as air flow rate increases drying time decreases. Drum speed and air flow rate has non-significant effect on Vitamin concentration.

4.1 Measurements and Mathematical Calculations

1. Length of rotating chamber = 1 meter
2. Diameter of rotating chamber = 0.3 m
3. Area of rotating chamber = $A = 0.3$ m^2
4. Volume of rotating chamber =V=$\frac{\pi}{4}d^2L$

Volume of rotating chamber = V= $\frac{3.14}{4}(0.3m)^2(1m)$

Volume of rotating chamber = V = 0.07 m^3

5. Weight of rotating chamber = 40 kg
6. Weight of waste carried by the rotating chamber = W = 10 kg (When rotating chamber is completely filled)
7. Density of rotating chamber = p =$\frac{40\ kg}{0.07\ m3}$

Density of rotating chamber = p = 571 kgm^{-3}

8. Density of waste = p = $\frac{3\ kg}{0.07\ m3}$ (when the chamber is filled 1/3rd of total volume)

Density of waste = p = 43 kgm^{-3}

9. Weight of waste carried by the rotating chamber =W =3 kg (when the chamber is filled with 1/3rd of total volume)
10. Total weight = W_t = Weight of rotating chamber + Weight of waste

Total weight = W_t = 40 kg+3 kg (when the chamber is filled 1/3rd of the total volume)

Total weight = W_t = 43 kg

11. Horsepower of gear motor = 0.5 hp

While 1 hp = 760 watt

Power supplied by gear motor = P = 760×0.5

Power supplied by gear motor = P = 380 watt

380 watt power is required to rotate a drum holding a weight of 50 kg.

12 . Speed of blower/fan = 2800 rpm

4.2 Graphical Representation

After statistical analysis, a graphical representation obtained of the relationship between temperature and Vitamin C in the following figure.6

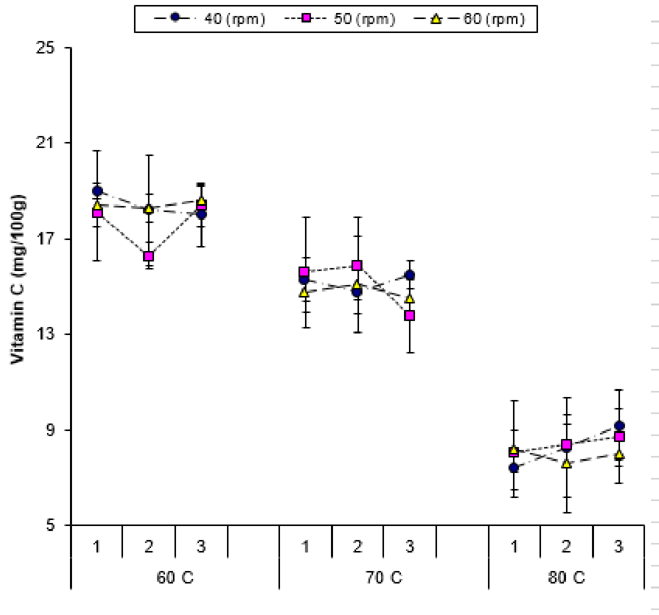


Figure 6: Effect of temperature, Air flow rate and drum speed on Vitamin C concentration

After statistical analysis, it was examined that temperature has a significant effect on vitamin C. Air flow rate has non-significant effect on vitamin C concentration. A graphical representation of the relationship between temperature and drying time is shown in figure.7

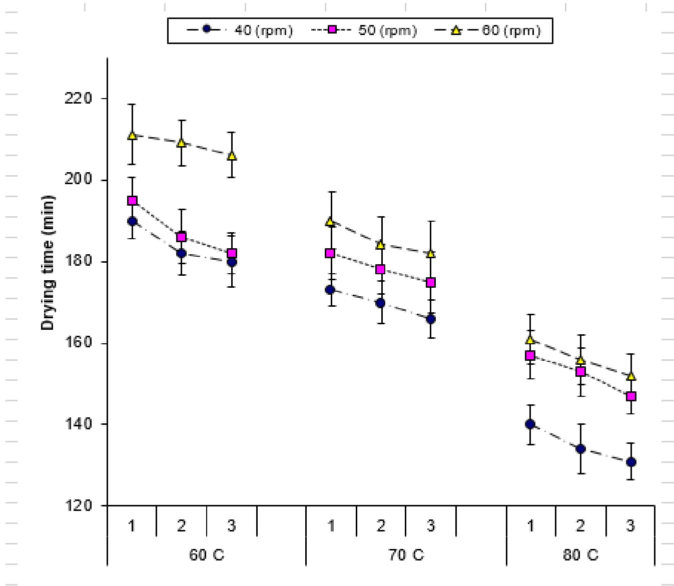


Figure 7: Effect of temperature, Air flow rate and drum speed on drying time

After statistical analysis, it is concluded that air flow has significant effect on drying time as flow rate increases, drying time decreases.

5. CONCLUSION

In this study a rotary hot-air dryer was designed and evaluated to dehydrate citrus fruit waste. This study concluded that the optimum drying conditions for citrus fruit waste was at 60°C temperature, 1m/sec air flow rate and 40 rpm of drum speed. The drying process took 200-220 minutes to reach to moisture content below 10%. This dryer has the ability to dehydrate not only fruit waste but also grains and pulses. The waste obtained after juice extraction by the food processing industry can be consumed at the same time and it can be converted into useable material such as animal feed to enhance the milk quality and dairy product.

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