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Development of Batch Type Refractance Window (RW) Dryer for reduce drying time and cost

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ABSTRACT

The fourth generation, innovative technology refractance window (RW) dryer constructed to reduce drying time and cost of drying. The batch type refractance window dryer consists of hot water bath, electric heater, hot water pump, cold water bath, myler film or belt, SS roller pulleys, feed inlet hoper with motor, spreader roller, drying chamber hood, side view glass, air exhaust blower, main body, leg and lock type wheel, variable frequency drive, roller chain, Intel Pentium Processor, control panel, data logger with controller, temperature and humidity sensor, J-type thermocouple, contactor, DC drive, power adapter, MCB, scraper and product outlet tray with stand. The cost of batch type refractance window dryer machine was calculated ₹ 2,35,574. Hot water bath made of stainless steel with dimensions 1000 mm 480 mm 100 mm having 48 liters water capacity. Two coil type single phase 1.50 kW capacity electric heater was inserted into the hot water bath to heat the water. The recirculating type pump of 0.50 hp capacity to recirculate the hot water in the hot water. The dimensions of myler film or belt were 3800 mm 440 mm 0.25 mm. Cold water bath (SS) dimensions 500 mm 480 mm 100 mm having 24 liters water capacity. The data logger attached in the control panel of RW dryer to monitor hot water temperature, product temperature, relative humidity of the drying chamber, cold-water temperature and thickness of the material. Doctor blade or scraper 475 mm 100 mm 12 mm used to collect the dried product. The drying time and power consumption was observed 55 minutes and 1.50 kWh for drying carrot puree of 2 mm bed thickness and 85 °C hot water temperature. And the thermal efficiency and overall system efficiency of refractance window dryer was observed 78.78 % and 45.24 % respectively.

Keywords: Refractance window dryer, RW dryer, batch type RW dryer, Cost of RW dryer

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INTRODUCTION

Today's augmented race due to globalization and increasing consumer demand for better quality products in the drying process. It is used in food industries not only to increase shelf life but also to manufacture value added food products with certain characteristics. There are many methods for drying food materials, each have their own benefits and drawbacks for particular uses. A vast number of dryer designs reported in the literature are due to the differences in the physical attributes of the product, modes of heat input, operating temperatures and pressures, quality specifications on the dried product and so on (Sabarez 2016; Betoret *et al*. 2016). Various kinds of dryers are commercially being used but among them, 85 % of the dryers are convection type with either hot air or combustion gases as a heat transfer medium (Moses *et al*. 2014; Zarein *et al*. 2015; Al Hilphy *et al*. 2021; Mahanty *et al*. 2021). These conventional drying technologies (conduction and convection) lead to a decrease in the quality of the product in terms of nutritional, color, functional and sensory properties due to high drying temperatures and processing times (Moses *et al*. 2014; Verma *et al*. 2018; Verma *et al*. 2020; Mahanty *et al*. 2021). However, drying could also result in the loss of bioactive compounds and flavour. Drying systems are mainly classified into four categories based on the historical development they are the first, second, third, and fourth generation. Among all these dryer fourth-generation dryers is a greater emphasis on product quality, product temperature, drying time, and dryer efficiency (Verma *et al*. 2018; Verma *et al*. 2020; Al Hilphy *et al*. 2021; Mahanti *et al*. 2021). Refractance Window (RW) drying is a fourth generation drying technology and first developed by MCD Technologies Inc. (Tacoma, Washington, USA). It is a new and emerging technology (Ocoro-Zamora and Ayala- Aponte 2013). A RW dryer was mounted in a 60-liter thermo regulated bath, which was filled with distilled water. A sheet of plastic film (Mylar, polyethylene terephthalate), 2 mm thick, was placed over the bath in direct contact with the water, yielding a drying surface of 150 470 mm^2 (Hernández *et al*. 2019).

For the RW drying of mango pulp a laboratory-scale RW dryer, operating in batch (Zotarelli *et al*. 2015) consists of a container (0.8 m 0.4 m 0.05 m) with a plastic film covering its top and hot water circulating from a thermostatic bath. The plastic film is a 0.25 mm-thick Mylar film, which was set at the top of the reservoir, so that the bottom was in contact with the circulating water and the upper face served as support for the spread fruit pulp layer. Shrivastv *et al*. (2021) fabricated RW dryer to dry the strawberry puree. The overall dimension of the dryer was 200 70 157 cm. The main component of the experimental setup was a conveyor belt of mayler sheet (Food

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grade polyester film without use of plasticizer) of 250 μ, two electric heaters of 1.5 kW each, water circulating pump of 0.25 hp, screw feeder of variable feed rates, cooling chamber, stainless steel (SS306) roller to maintain the thickness of the product, scraper to remove a dried product from plastic sheet, hood with suction blowers and exhaust fans with a data logger. RW dryer consists of a water tank to hold about 20 liters of water. A PID temperature controller controlled the temperature of the water. The total effective area of drying was divided into two units, that is, one was a heating unit of 150 60 cm size, and another was the cooling unit of 48 60 cm size.

The RW dryer consists of a 5.5-liter stainless steel thermostatic bath filled with tap water. The water surface was covered with Mylar (an infrared-transparent plastic film of 0.26 mm thickness and area of 17 30 cm^2) on which samples were placed (Ochoa-Martínez *et al*. 2012). Ghanem (2010) fabricated RW dryer consists of water basin of 0.4 0.4 m and was insulated from its bottom and sides. A 2 kW heater, thermostat and an indicator circuit was used for controlling the water temperature in the basin. Jafari *et al.* (2015) manufactured refractance window (RW) dryer for drying of a diverse range of products including fruits, seafood, dairy ingredients, juices and nutraceuticals both in concentrated and dried forms. The main components of the dryer included a food-grade Mylar transparent polyester film, a water bath and a heating unit. Castoldi *et al.* (2015) used a batch-operated laboratory-scale RW dryer consists of a container (0.8 m 0.4 m 0.05 m) with hot water circulating from a thermostatic bath and of a plastic film covering its top. The 0.25 mm thick mylar film was attached to the top of the reservoir with its lower face in contact with the circulating hot water, while its upper face served as support for the spread fruit pulp (fruit pulp film) to be dried. A laboratory-scale batch type RW dryer was fabricated for drying of sapota pulp. It consists of 60-liter thermostatic water bath (3 kW, internal size: 460 380 425mm) filled with tap water. SS frame of 400 320 mm open area was prepared to fit the polyethylene terephthalate (PET) sheet of 80 mm thickness (Jalgaonkar *et al*. 2018). The aims of this research work were to construct the fourth generation, innovative refractance window (RW) dryer for drying of juices and pasty food materials.

Working Principle of Refractance Window Dryer

Principle 1-When water is heated

Infrared energy gets transmitted by convection into the water once it is placed over a source of heat. This heating energy is then radiated from water chiefly by evaporation (Figure 1).

Principle 2-When hot water is covered by an IR

If this hot water is covered by a membrane that is transparent to the IR heat radiation present in water, evaporation and its related heat losses will be blocked or refracted and thus conduction solely occurs. The membrane acts as if it's a mirror

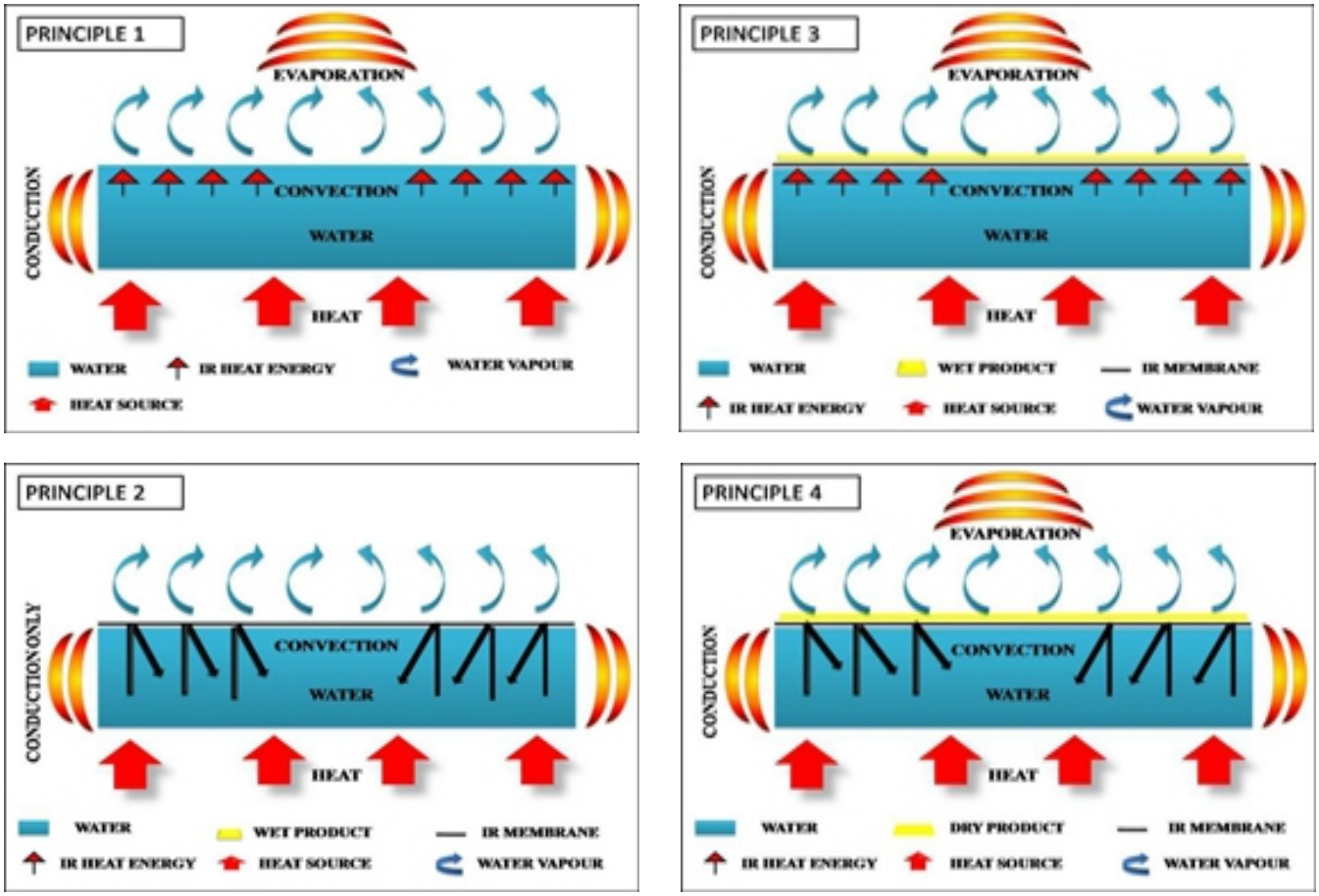

Fig. 1: Schematic diagram for principle of the RW dryer (Trivedi *et al*., 2017)

that reflects the infrared heat energy back in the water (Fig. 1).

Principle 3 – When wet product is applied uniformly on IR membrane

But when the surface of the membrane is laden with a moist product, the water in the product will create a "window" that acts as a passage for flow of IR energy through the material. Heat is directly transmitted into the remaining water present in the product (Fig.1).

Principle 4-When dried product is obtained

As time proceeds, the water in the product covered on the membrane gets evaporated and the "window" closes and infrared energy is "refracted" into the hot water and thus the material is no longer exposed to heat (Fig. 1).

MATERIAL AND METHODS

Construction of Refractance Window Dryer

The Batch Type Refractance Window (RW) dryer was constructed during the research work at College of Agricultural Engineering & Technology, Navsari Agricultural University, Dediapada, Gujarat during 2019-20 to 2021-22. The RW drying system consists (Fig. 2) hot water bath, electric heater, hot water pump, cold water bath, myler film or belt, SS roller pulleys, feed inlet hoper with motor, spreader roller, drying chamber hood, side view glass, air exhaust blower, main body, leg and lock type wheel, variable frequency drive, roller chain, Intel Pentium Processor, control panel, data logger with controller, temperature and humidity sensor, J-type thermocouple, contactor, DC drive, power adapter, MCB, scraper and product outlet tray with stand. The various parts for the construction of refractance window (RW) dryer were elaborated in details as under in subsequent headings.

Hot Water Bath

Hot water bath made of stainless steel with dimensions 1000 mm 480 mm 100 mm having 48 liters water capacity. It was filled with distilled water till water surface touches the films bottom surface. Myler film or belt was fixed with two stainless steel rollers pulley such that they float above the water surface. In this bath having two coil type electrical hater having capacity 1.50 kW to heat the water as per our set temperature. One hot recirculating pump was attached to hot water bath for recirculating the water to maintain the uniformity of temperature of bath. The temperature of hot water bath was measured by J-type thermocouple which attached with compatible temperature controller through data logger. The inlet of hot water bath was attached with level gauge which shows the level of water in the bath. If the level of water falls below the recommended level, then the additional water was filled in the bath through water inlet to maintain the water level.

Coil Type Heater

Two coil type single phase 1.50 kW capacity electric heater was placed under the hot water bath in two different places to heat the water as per set value of experiment.

Hot Water Pump

The recirculating type pump was used to recirculate the hot water in the hot water bath for maintaining the uniformity of temperature. The pump was attached with single phase, 240 V and 0.50 hp motor for operation. Operating temperature range up to 110 and speed 1440 rpm.

Cold Water Bath

Cold water bath made of stainless steel with dimensions 500 mm 480 mm 100 mm having 24 liters water capacity. It was filled with distilled water till water surface touches the film's bottom surface. The temperature of cold-water bath was measured by J-type thermocouple which attached with compatible temperature controller through data logger. The inlet of cold-water bath was attached with level gauge which shows the level of water in the bath. If the level of water falls below the recommended level then the additional water was filled in the bath through water inlet to maintain the water level.

Myler Film or Belt

The dimensions of myler film or belt were 3800 mm 440 mm 0.25 mm. This film of belt was supported over a two stainless steel roller end pulleys for moving the film during and later the drying process. It is a heart of RW dryer and made of food grade polyester without use of plasticizer. Puree which contains high moisture content was spread uniformly at one end of the film and the dried puree collects at the other end of the dryer. The transmissivity of mylar film depends upon the thickness of the film as thin film shows more transparency to infrared radiations but its mechanical strength reduces when thickness lowers. Hence, the optimum thickness was determined as 0.25 mm. The plastic sheet floats over heated water surface that carries thermal energy to the wet carrot puree material by combined conduction and infrared radiation. The sheet was supported by the buoyant force of the water.

Pulley

The two numbers SS304 stainless steel roller of diameter 128 mm and length 470 mm were used for conveying myler film or belt above the water surfaces. The distance between the two stainless steel rollers was fixed 1900 mm. The rollers were fixed with ball bearing with shaft which was supported by frame of the machine.

Feed Inlet Hopper

The feed hopper was made stainless steel materials. It has rectangular in cross section but have sides that slope at about a 60° angle. Slanted sides make it easier for the contained material to flow out. The dimensions of rectangular portion were 150 mm 100 mm 90 mm and for slanted portions were top width 100 mm, bottom width 35 mm and height 60 mm. The feed inlet hopper was fitted with the screw feeder for discharge the carrot puree materials above the myler film surface. The screw feeder was operated with feed motor.

Feed Motor

Feed motor was connected to screw feeder of hopper. The Lucas made Wiper Motor Type: GSW95 rated voltage 24 V and torque 120 Nm, number of speeds two *i.e.* 30 rpm and 45 rpm, frame size was 95 mm, operating temperature to 80 and precision moulded heavy duty single stage gear for transmitting power were used for the study.

Spreader Roller

Spreader roller having length 305 mm and diameter 66 mm made of stainless steel (SS304) was used for spreading the feed inlet puree materials. Carrot puree materials passes from feed hopper through screw feeder mechanism, then spreader roller spread puree materials over the film uniformly as per our set

carrot puree bed thicknesses. Thus, the role of spreader was very important for maintaining the uniform bed thickness of carrot puree.

Drying Chamber Hood

At the top of the film, a stainless-steel hood is provided to exhaust the vapour or moisture evaporated from the fresh carrot puree product. The pictorial representation of RW drying system along with the components is illustrated in Figure 3.5. The hood of drying chamber has rectangular and trapezoidal cross section. The rectangular surface area of front and back side both was equal 1050 mm 150 mm, right and left side both was 480 mm 75 mm, slanted rectangular front and back both was equal 1050 mm 285 mm and the rectangular surface area of top was 1050 mm 225 mm. The distance between free space of myler film and bottom width of hood was kept 75 mm. The drying chamber hood was fixed above the hot water bath. The SS304 plates of size 460 mm 100 mm 1 mm and 460 mm 25 mm 1 mm respectively were extended on both sides for proper support for movement of myler film smoothly.

View Glass

A rectangular view glass of size 900 mm 175 mm was fixed in the slanted stainless-steel sheet of drying chamber hood to observe the drying mechanism during drying process. The LED bulb of 10 W capacity was provided in the drying chamber to observe the clear visibility of the carrot puree product.

Exhaust Blower

The Mansi Enterprises make centrifugal exhaust blower, backward curve type, 240 V, single phase, closed impeller, speed 2880 rpm, power consumption 0.25 hp, suction capacity 25 kPa, continuous cycle, air flow 216 m^3/h was used to remove the moisture from drying chamber during the entire drying process. It was fitted on the top of drying chamber hood.

Main Body

The main body of the machine was made of mild steel (MS) sheet and supported by mild steel rectangular section pipe with leg and wheel. Distance between ground to main body frame or height of leg was 185 mm. The dimensions of mild steel main body frame were 1500 mm 480 mm 775 mm. It contains hot water bath, cold water bath, myler film and closed chamber. The dimension of closed chamber was 1500 mm 480 mm 645 mm. It was situated below the water bath. The closed chamber having central processing unit (CPU) connected to data logger in panel box, hot water pump with motor, water supply connection system between water bath to pump (PVC pipe, elbow, reducer, valve, etc.) and variable frequency drive (VFD).

Leg and Wheel

Leg of the machine was made of mild steel rectangular section pipe. The height of legs was 185 mm. The four leg was fixed with main body frame on all four side. Lock type heavy duty portable nylon wheels with metal casing of diameter 150 mm were fixed with legs. These legs were movable and could be move from one place to another place easily and they were fixed by locking the wheels as per our requirements.

Variable Frequency Drive (VFD)

AC voltage regulation 0-220 V, maximum power 4000 W, size: 85 mm 60 mm 40 mm, rotation hole 6 mm, maximum current capacity 25 A, motor: 0.5 hp, motor model: 71B-4, input speed 1450 rpm of variable frequency drive was used for power transmission. VFD also known with other names as variable speed drive, adjustable frequency drive, micro-drive and AC drive. There were few reasons behind choosing VFD as a controller, as follows: saving optimum energy, intelligent motor control and power of reducing peak power drawn. It provides a great range of adjustable operating speed and torque limit. VFD boosts smooth controlled acceleration and stopping of motors. It helps in eliminating mechanical drive components such as gearboxes.

Conveyor Chain

Double strand metric conveyor chain was used for conveying power from variable frequency drive (VFD) to SS roller pulley. The details specifications of conveyor chain were size number 05B-2, pitch 8 mm, roller width 3 mm, roller diameter 5 mm, pin diameter 2.31 mm, plate height 7.1 mm and transverse pitch 5.64 mm etc.

Intel Pentium Processor

The Intel Pentium processor for desktop PCs that are based on the Intel Net Burst® microarchitecture was used to collect and store the data through data logger. The Pentium D processor with Intel® Extended Memory 64 Technology (Intel® EM64T) enables the Pentium processor to execute operating systems. The Pentium D processor also includes the Execute Disable Bit capability. This feature combined with a supported operating system, allows memory to be marked as executable or non-executable. The 3.20 GHz processor, binary compatible with applications. Power management capabilities, system management mode, multiple low power states and 8-way cache associativity provides improved cache hit rate on load/store operations. The keyboard was fixed in the MS sheet of main body sheet. It was just below feed inlet hopper. The wireless mouse was used to operate the display monitor. The PLX–DAQ interphase software based excel spreadsheet was used for recording the data in the computer CPU.

Control Panel Box

Data logger

The data logger attached in the control panel of RW dryer was used to monitor hot water temperature, product temperature, relative humidity of the drying chamber, cold-water temperature and thickness of the material. These data signals are multiplexed and transferred through software installed on PC.

Compatible temperature controller

The compatible temperature controller and sensor were fixed in the control panel and connected through data logger. It measures the temperature of hot water bath, cold water bath, product temperature, drying chamber temperature with the help of J-type thermocouples. The temperature range of J type thermocouple was 210 to 760. The DS18B20 digital compatible temperature controller provides to measurements of temperature and has an alarm function with nonvolatile user programmable upper and lower trigger points. Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit

from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems. The operating temperature range was 0 to 350 ^{0}C and with 12 V DC.

Contactor

Operating principle of a contactor are the current passing through the contactor excites the electromagnet. The excited electromagnet produces a magnetic field, causing the contactor core to move the armature. A normally closed (NC) contact completes the circuit between the fixed contacts and the moving contacts. This permits the current to pass through these contacts to the load. When current is removed, the coil is de-energized and normally opens (NO) the circuit. The contacts of the contactors are known for their rapid open and close action. Contactor is one of the main electrical circuit parts, which can stand on its own power control device or a part of a starter. It was a black colour and fixed with connecting wire in the control panel box. The TC LC1-D173 model, AC3: 16 amp and AC1: 32 amp were used for our experiment.

Direct current (DC) drive

The DC motor drive is a type of amplifier or power modulator that integrate between the controller and a DC motor. It takes the low current and then converts it into a high current which is appropriate for the motor. DC drive converts an alternating current (AC) into direct current (DC) to run a DC motor. In DC motors, the speed is proportional to the armature voltage and inversely proportional to the field current. And also, the armature current is proportional to the motor torque. Therefore, by increasing or reducing the applied voltage, the speed of the motor is varied. The details specifications of used DC Drive were 0.25 hp for PMDC motor, input- 220 V AC, 10 %, 50-60 Hz, output for motor field voltage- 220 V DC fixed. Armature voltage- 0 to 180 V DC variable, for PMDC motor- 0 to 200 V DC variable, current capacity max 4 amp and current trip facility as per load.

Sensor controller

Sensors controllers were used to apply various forms of logic and functions to input signals from sensors and transmit relay or transistor signals. The specifications of sensor controllers were power supply for sensor 12 V DC 10 %, 200 mA maximum (with short-circuit protection), rated supply voltages 100 to 240 V AC 10%, power consumption 15 VA maximum.

Miniature circuit breakers (MCB)

The two MCB of rated voltage 240 V, 50 Hz frequency, 32 amp rated current, contact position indicating window (Clear ON-OFF indicator), three level indications for ON, OFF and TRIP (Under Fault), rated short circuit capacity 10000A (10kA) and trip free mechanism were fixed in the control panel box. One MC for main supply and other for electric heater were used in the control panel box.

Power adapter

A power supply is used to transform various types of power into a compatible format to be stored to electrical energy. The details specifications of i-CAT vision type power adapter were power supply 6 amp from cable connector, output voltage 24 V DC, input voltage 110-120 V, 60 Hz and SMPS design.

J-Type thermocouple

J-Type thermocouple was used to record the temperature in RW dryer at various pints. It is made of Constantan (Copper-Nickel). It consists of a positive leg which is iron and a negative leg which is approximately 45 % nickel 55% copper. When protected by compacted mineral insulation and appropriate outer sheath, the J-type is useable from 0 to 816 °C. It is not susceptible to aging in the 371 to 538 °C temperature range. The accuracy for standard: 2.20 or 0.75 % and special limits of error 1.10 or 0.40 %. The J-type thermocouple was best suited to oxidizing atmospheres.

Doctor Blade or Scraper

Acrylic is a transparent plastic material with outstanding strength, stiffness, and optical clarity. It has superior weathering properties compared to many other transparent plastics. The cuboid acrylic sheet size 475 mm 100 mm 12 mm was used as a doctor blade or scraper. After drying of carrot

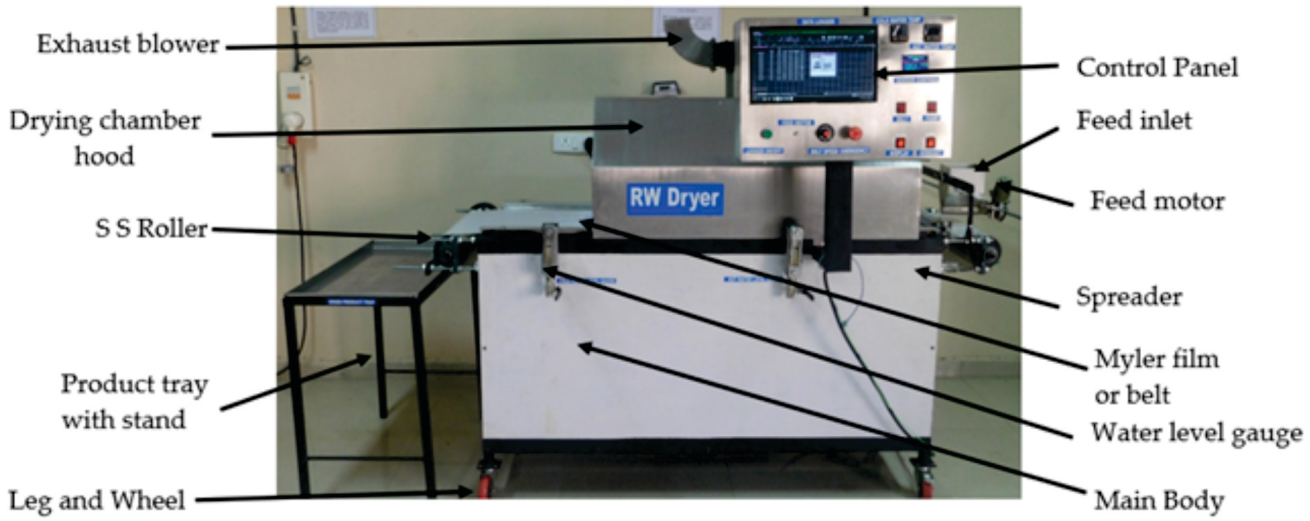

Fig. 2: Refractance window (RW) dryer machine

Table 1: Cost of material for fabrications of refractance window (RW) dryer machine

Sr. No.	Particular Description	Quantity /Unit	Rate (Rs/Unit)	Amount (Rs)
1.	Rectangular M.S. pipe 50 × 25 × 3 mm	58.50 kg	70 /kg	4095/-
2.	M.S. Sheet 2500 × 1250 × 1.2 mm	88.00 kg	63/kg	5544/-
3.	S.S. Sheet 2500 × 1250 × 1 mm	25.00 kg	200/kg	5000/-
4.	S.S. Pipe Ø80 mm × 2.11 mm	15.00 kg	205/kg	3075/-
5.	Recirculating hot water pump 0.50 hp motor	1 No.	10000/No.	10000/-
6.	Heater coil type 1.50 kw	2 Nos.	1500/No.	3000/-
7.	PVC Pipe Ø25.4 mm dia., 6000 mm long	1 No	360/No.	360/-
8.	PVC Pipe Ø12.7 mm dia., 6000 mm long	1 No	250/No.	250/-
9.	PVC Reducer coupling Ø12.7 mm dia.	2 Nos.	50/No.	100/-
10.	Valve Ø25.4 mm dia PVC valve	2 Nos.	280/No.	560/-
11.	Elbow Ø25.4 mm dia white U-PVC elbow	2 Nos.	220/No.	440/-
12.	Teflon tape 12 × 12 × 0.075 mm	1 No.	150/No.	150/-
13.	Scraper acrylic sheet 475 × 100 × 12 mm	1 No.	900/No.	900/-
14.	Exhaust air blower centrifugal, backward curve type, closed impeller, 2880 rpm, power consumption 0.25 hp, suction capacity 25 kPa, continuous cycle, air flow 216 m^3/h.	1 No.	10000/No.	10000/-
15.	Feed motor inbuilt gear box voltage 24 V and torque 120 Nm	1 No.	3500/No.	3500/
16.	Feed spreader S.S. roller Ø66 mm dia. × 305 mm length solid	1 No.	4000/No.	4000/-
17.	S.S. Roller with bearings Ø128 mm dia. × 470 mm length solid	2 Nos.	9000/No.	18000/-
18.	Variable drive maximum power 4000 W, size: 85 mm × 60 mm × 40 mm, 0.5 hp motor, input speed 1450 rpm.	1 No.	12500/No.	12500/-
19.	Roller chain double strand metric roller chain, chain size 05B-2	1 No.	1000/ No.	1000/-
20.	Myler Belt Size: 3800 mm × 440 mm × 0.25 mm , food grade polyester film without use of plasticizer	1 No.	2000/ No.	2000/-
21.	Wheels lock type heavy duty nylon wheels with metal casing, Ø150 mm	4 Nos.	400/ No.	1600/-
22.	Panel box S.S. size: 600 mm × 400 mm	1 No.	6000/ No.	6000/-
23.	Level gauge SS water level gauge operating temperature 0 to 100 °C	2 Nos.	1500/ No.	3000/-
24.	Water valves Ø 38 mm brass casing	2 Nos.	800/ No.	1600/-
25.	Compatible temperature controller and sensor, range 0 to 350 ^{0}C, 12 V DC	05 Nos.	9000/ No.	45000/-
26.	Data logger display from the logger. LED Screen, Programmable.	01 No.	12000/No.	12000/-
27.	ON/OFF switches toggle switches, 240 V, 15 A	10 Nos.	350/ No.	3500/-
28.	Push button switches , voltage rating: 24 V DC, current rating up to 14 mA	05 Nos.	600/ No.	3000/-
29.	Automatic temperature controller, ON-OFF/Auto-tune PID control. 10 A Relay / 12 V SSR control output. Supply voltage 90 to 270 V AC / DC (50 / 60 Hz). Power consumption 6 VA max @ 230V AC.	1 No.	4700/ No.	4700/-
30.	Panel Box: Fabricated panel box size 600 mm × 400 mm	1 No.	12000/No.	12000/-
31.	Humidity Sensor Range 0 to 100 %, 12 V DC, Programmable.	1 No.	12100/ No.	12100/-
32.	Data Logger to constantly log the sensors data. Programmable, Can log 10 sensors simultaneously, 12 V DC. High -performance, Low-power Atmel® AVR® 8 -bit Microcontroller. Operating Voltages: 2.7V - 5.5V for ATmega16L, 4.5V - 5.5V for ATmega16	1 No.	27000/ No.	27000/-
33.	Controller: To control data logger and log data in Windows, Microsoft excel.	1 No.	13500/ No.	13500/-
34.	Side view glass Side view glass size: 900 mm × 175 mm	1 No.	350/ No.	350/-
35.	S.S Tray 815 mm × 420 mm × 30 mm	1 No.	750/ No.	750/-
36.	Connection wires, nut, bolt, washers etc.	----	5000/-	5000/-
			Total	**2,35,574/-**

puree materials, the myler film or belt move forward direction to collect the dried product in outlet tray. The dried carrot puree products come contact with scraper then the all dried product scrapped off and collected in product tray automatically. The dried products were weight and packed in HDPE polythene bags of 100 micron for further analysis.

Product Tray with Stand

The outlet dried product tray size 815 mm 420 mm 30 mm was made of stainless steel. It was kept above the tray stand. The dimensions of tray stand was 820 mm 430 mm 735 mm. It was made of rectangular M.S. hollow pipe by cutting and welding. The dried product tray with stand were kept below the scraper in product outlet side.

Energy Meter

The single phase 2 wire electrical energy static kWh meter made by M/s Jaipur Electricals was used to record the power consumption in each experiments. The outer cover made of plastic in white colour. The dimensions were (L B H): 200 mm 200 mm 50 mm. Read and record data up to one point of decimal. Pulse rate 3200 impulse/kWh, rated current 5-20 amp and rated voltage 240 V, 50 Hz.

COST ESTIMATION FOR BATCH TYPE REFRACTANCE WINDOW DRYER MACHINE

The particular description of items, size and details specifications of material used in fabrication, quantity used, cost per unit or items, total cost per items of materials were given in Table 1. The total cost of refractance window dryer machine was calculated as Rs. 2,35,574.

Sample Preparation

Fresh carrots were procured from the local market of Dediapada, Narmada District, Gujarat. The procured carrots were washed with tap water to remove the dirt and soil residue. After that peeled the washed carrots and removed top and bottom inedible portion. The peeled carrots were cuts in small pieces into 1 1 1 cm cubes and then soaked in boiling water (temperature approx. 95 for 2 minutes to prevent browning reaction and then immediate washed in cold water (temperature approx. 10 for 5 minutes to cool the carrot. After water to be drained from the surface of cuts carrot, the puree products were prepared by mixer machine. The prepared carrot puree were used for drying by refractance window dryer. The carrot puree was spread above myler film of 2 mm bed thickness and temperature of hot water bath was kept 85 °C for RW drying process.

RESULTS AND DISCUSSION

The cost of developed batch type refractance window dryer machine was found Rs. 2,35,574. The performance of RW dryer was evaluated by drying of carrot puree of 2 mm bed thickness and hot water temperature of 85 °C. The drying time and power consumption was observed 55 minutes and 1.50 kWh for drying carrot puree. The thermal efficiency and overall system efficiency of refractance window dryer was observed 78.78 % and 45.24 % for carrot puree. Thus, the developed batch refractance window dryer can used for drying of paste, juice or concentrated solution of fruits and vegetables materials or products.

CONCLUSIONS

The batch refractance window (RW) dryer was constructed for drying of fruits and vegetables juices, paste and puree materials. Hot water bath dimensions were 1000 mm 480 mm 100 mm having 48 liters water capacity. Two coil type 1.50 kW capacity electric heater was placed under the hot water bath to heat the water. The recirculating type pump of 0.50 hp was used to recirculate the hot water in the hot water bath for maintaining the uniformity of temperature. The dimensions of myler film or belt were 3800 mm 440 mm 0.25 mm. The data logger attached in the control panel of RW dryer was used to monitor hot water temperature, product temperature, relative humidity of the drying chamber, cold-water temperature and thickness of the material. The cost of developed batch type refractance window dryer machine was calculated as Rs. 2,35,574. The drying time and power consumption was observed 55 minutes and 1.50 kWh for drying carrot puree. The thermal efficiency and overall system efficiency of refractance window dryer was observed 78.78 % and 45.24 % respectively for refractance window drying of carrot puree of 2 mm bed thickness and 85 °C hot water temperature.

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