DESIGN AND FABRICATION OF A COLUMN FLASH DRYING UNIT FOR PROCESSING CASSAVA STARCH

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Abstract: A column flash drying unit for processing cassava starch was designed, constructed, assembled and test run to process 20 kg/h of dry starch. The column flash drying unit consist of the fan, the heater, the dryer column and the cyclone. Simprosys 2.1 software package was used to simulate the drying operation and mass/heat balances calculated to determine the dryer design variables. From the results generated, it was found that the fans power input and outlet velocity were 0.426 kW and 14.889 m/s, respectively. The heat duty evaluated for the heater was 8.281 kW. The drying chamber consists of a conical base with specially arranged blade ring at an angle of 9^o to the horizontal. The dryer chamber diameter and length were 0.184 and 1.657 m, and the cyclone diameter was evaluated as 0.305 m. The column flash drying unit was tested using 4 kg of freshly prepared cassava starch (with moisture content of 68.75%). 2.15 kg of dry cassava starch was recovered from the system in 10.8 minutes. The moisture content of the cassava starch was reduced from 68.75% to 8.50% wet basis at air velocity of 13.20 m/s and temperature of 105^oC. The thermal efficiency of the fabricated dryer was determined to be 60.21%.
Keywords: Column flash dryer, cassava starch, drying temperature, Simprosys

Introduction

Drying is a heat and mass transfer process. Heat is necessary to evaporate water. The latent heat of vaporization of water is about 2500 J/g (Strumillo *et al*., 2007), which means that drying process requires a significant amount of energy. Drying of various feedstock is needed for one or several of the following reasons: need for easy-to-handle free-flowing solids, preservation and storage, reduction in cost of transportation, achieving desired quality of product, etc. In many processes, improper drying may lead to irreversible damage to product quality and hence a non-salable product. (Pakwoski and Mujumdar, 1995).

Nigeria is the world's largest producer of cassava estimated at 34.8 million metric tons per annum (Maziya-Dixon and Olusegun, 2012). Drying wet cassava starch in Nigeria is generally still being carried out locally by direct drying in sunlight. The drying process is done by laying out the wet cassava starch on mats and floors, and then dried under direct sunlight (Ove and Sardo, 2001). The limitations with regards to the availability and cost of mechanical drying equipment are the major factors that makes the use of local drying method dominant (Sopanronnarit, 1999).

Locally dried cassava starch processing is not effective because it depends on the heat of the sun and is strongly influenced by weather conditions, resulting in increased drying time (during cold weather) and discouraging commercial production; local drying is known to expose the cassava starch to pest infestation and atmospheric contaminants.

The problems associated with local drying can be overcome if it a mechanical dryer for cassava starch processing is made available. In the column flash drying unit, heated drying air flows through a distributor consisting of angled blades in annular rings at the dryer bottom. The driving force for the particles to move over the distributed blades comes from the velocity head of the drying air.

There are different technology for the construction of flash drying systems which include The Selas technology, the Gentler Gens technology, SPX technology and the Royal Gouda technology. Of the three available technologies, the Royal Gouda technology forms the basis of this process column flash dryer design because the system is simple, efficient and has less complicated systems. Ajao and Adegun (2009) parameterized, developed and tested a mini cassava flour flash dryer. Generally, works on dryer development for drying of cassava starch are scanty in the open literature.

This work was aimed at using Simprosys (a process simulation software package specifically designed for drying and evaporation related processes) to carry out detailed design of the drying operation based on the physico-chemical properties of the wet cassava starch, so as to obtain some important design variables for use in fabrication of a cassava starch drying unit.

Materials and Methods

Simprosys 2.1 was used to simulate the drying operation based on the input variables as shown below (Mujumdar and Gong, 2010):

Design basis

The following were the physico-chemical properties of cassava starch used as input variables to determine parameters of interest necessary for the design of a column flash drying unit.

Feed moisture content = 68.75 % wet basis
Carbohydrate content of cassava starch = 28.90%
Protein content of cassava starch = 1.75%
Fat content of cassava starch = 3.0%
Fibre content of cassava starch = 0.09%
Ash content of cassava starch = 0.2%
Feed temperature = 24^oC.
Maximum drying temperature = 105^oC
Product moisture content = 8.5 % wet basis
Specific heat of the absolute dry cassava starch = 1.26 $kJ/kg{\cdot}^oC$ (Agunbiade and Ighodaro, 2010).
Mass flow rate (wet cassava starch) = 20 kg/hr
Drying air has the following initial laboratory conditions measured:
Initial pressure = 101.3 kPa
Initial temperature (dry-bulb) = 26^oC
Initial absolute humidity = 0.009 kg/kg
Mass flow rate wet basis = 400 kg/h

The above process variables were specified based on literature survey to obtain the design variables that will be used for fabrication.

Selection of technology

Based on the review of the various existing technologies for the construction of drying

Equipment, the Royal Gouda Technology was selected in this design project, because it is;

1. Suitable for pastry/dewatered solid materials
2. Has high drying efficiency providing low energy costs
3. Continuous processing with short processing time
4. Low operator overheads and minimum maintenance costs
5. Controlled residence time enabling high temperature drying
6. Controlled particle size
7. Very fine powder production
8. High-pressure, shock-resistant chamber for safe drying of flammable products

Material of construction

Stainless steel material was used for the construction of the dryer column and the cyclone units. Mild steel was used to construct the blower and the heater chamber to minimize cost of fabrication. Professional welder and a technician were given the working diagram for the drying unit for fabrication, based on the results generated from the process simulation software package (Simprosys 2.1).

Extraction of starch

Thirty kilogram (30 kg) of cassava was peeled, washed and wet milled. The starch was then extracted from the grated pulp by sieving while the fiber was retained. The fiber retained was washed repeatedly four (4) times with water on the screen. The starch extracted was allowed to sediment after which the water was decanted from the starch thereby leaving behind the starch cake ready for drying (Akintunde and Akintunde, 2012).

Test run of the equipment

Cassava starch was used to test the performance of the dryer; the moisture content of the cassava starch before and after the drying was determined to quantify the amount of moisture removed from the wet starch. The quality in terms of color, texture and quantity of the final product was observed after drying.

Moisture/dry matter (based on AOAC, 1995)

Petri dish was washed and dried to a constant weight in an Oven at 100°C. It was then removed and cooled in a dessicator and weighed (W_1). 2 grams of the cassava starch sample was placed in the weighed dish (W_2). The dish containing the sample was kept in an oven for about 3 hours at a temperature of 150°C, the sample were removed and cooled in the dessicator and weighed (W_3).

The % of moisture was calculated as: $\frac{W_2 - W_3}{W_2 - W_1} \times 100$

Results and Discussion

Plate 1 shows the process flow diagram of the drying unit, using Simprosys 2.1 simulation software package.

From Plate 1, atmospheric air enters the suction part of the blower and flows to the heater where it is heated. The heated air enters the drying chamber, as cassava starch is fed to the dryer chamber continuously, the hot air coming from the heater fluidizes the cassava starch, processing it and further transferring the processed particle to the cyclone, where air separates from the particle. The results obtained from the simulation are thus presented in Table 1 for each of the five (5) units present in the drying system.

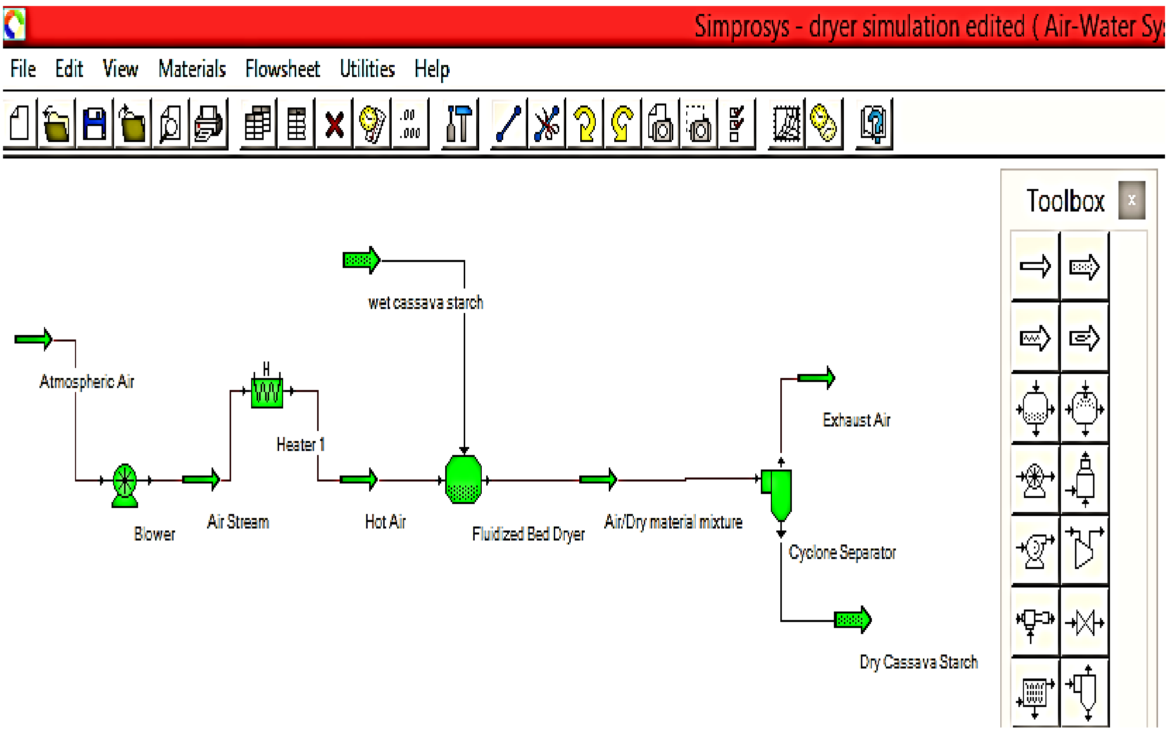

Plate 1: The drying unit process flow diagram

Table 1: Summary of simulation results

Unit	Parameters of interest	
BLOWER	- Power input = 0.426 kW - Outlet velocity of air = 14.889 m/s - Volumetric flow rate of air = 335.961 m^3/h	- Total discharge pressure = 3.131 kPa - Cross section = Rectangular - Outlet width = 80 mm - Outlet height = 80 mm
HEATING CHAMBER	- Heating duty = 8.381 kW - Diameter of chamber = 305 mm - Height of chamber = 401 mm	- Insulation was done with rock wool, of thickness 4 inches to minimize heat loss - Inlet and outlet cross sectional area : square = 6400 mm^2
FLUIDIZED BED DRYER	- Moisture evaporation rate = 9.621 kg/h - Cross section: circular - Diameter = 0.184 m - Length = 1.657 m	- Fluidization velocity = 13.20 m/s - Drying temperature = 105^{o}C - Bed Blade angle= 9^o
CYCLONE	- Number of cyclone = 1 - Cyclone diameter = 305 mm - Cone length = 0.465 m - Barrel plus cone length = 1075 mm - Inlet particle loading = 0.014 g/m^3	
SCREW CONVEYOR (direct coupled in-line drive)	- Pitch = 80 mm - Length = 300 mm - Screw diameter = 80 mm - Horsepower requirement=0.125 hp - Revolution per minute = 27 RPM	- Coupling shaft diameter = 50 mm - Troughs type = solid tube - End bearing = flange mounted ball bearing

Fabrication

The drying unit consists of five sub-units, which include the blower, the heating unit, the dryer column, the cyclone and the product collector.

A cone of base diameter 120 mm was constructed using stainless steel of thickness 1.5 mm, metal blades of width 30 mm and length 54 mm were arranged at an angle of 9^o to each other at the conical base of the cone and welded with stainless steel electrode of guage two to create the spiral movement of air required for the design. The conical base was designed adopting the Royal Gauda Technology. The Royal GMF-Gouda Spiral Flash Dryer features a highly efficient convection drying process. The heart of the system consists of a cylindrical processing chamber, in which the product follows a unique toroidal motion, which realizes an intensive mixing with air guaranteeing a homogeneous treatment and very fast processing. The wet product is dosed continuously through the ceiling of the processing chamber and drops onto fast circulating product already present in the chamber. All incoming process air is filtered. A radial fan supplies the air via the special blade ring arrangement in the dryer. The energy for drying is extracted from hot air, which is created with the help of a heater (direct heating of air with gas). Dried particles leave the rotating bed moving upwards in a spiral flow to the top of the processing chamber to be separated at the base of a cyclone or filter unit. The conical base was specially designed in such a way that the velocity of air at the tip of the cone was almost zero

To minimize cost of fabrication, the blower was constructed using mild steel of thickness 2 mm, an electric motor of capacity 1 hp was attached to the blower to supply the air flow needed in the design.

The heating unit was constructed with 4 mm mild steel plate that can withstand the quantity of heat generated by the heating coils, the heaters are arranged in the heating chambers, the heater chamber has a tangential opening at the inlet and outlet to increase the residence time of the air entering the system.

The dryer column was also constructed with stainless steel metal sheet of thickness 2 mm, it was constructed and insulated with rock wool to minimize the quantity of heat lost in the column also the cyclone unit was fabricated with stainless steel of thickness 2 mm, the cyclone unit separate the dried powdered particle from the hot exhaust air.

1– The interior view of the dryer basement, 2– the blower, 3– the heating chamber, T– temperature indicator, 4– the dryer basement, 5– the feeder, 6– dryer column, 7– the cyclone, 8– product collector

Plate II: The fabricated dryer for cassava starch processing

Principle of operation of the column flash dryer

Plate II shows the complete column flash dryer set up consisting of a blower (2) an air heating unit (3), the drying chamber (6), the feeder (5), the cyclone (7) and the dried product collector vessel (8). The heart of the system consists of a cylindrical processing chamber (6), in which the feed follows a unique toroidal motion, which realizes an intensive mixing with air guaranteeing a homogeneous treatment and very fast processing. The wet product is dosed continuously in the processing chamber by a screw conveyor feeder rotating at 27 revolutions per minute and drops onto fast circulating hot air. A blower supplies the air via the special angular blade ring arrangement in the dryer basement. The energy for drying is extracted from the hot air, when a process gas stream above atmospheric pressure is forced to pass through the opening of the blades of the drying chamber, the pressure head is converted in the blade array to a velocity head. The resultant velocity head keeps the cassava starch in suspension rotating toroidally. Dried particles leave the rotating bed moving upwards in a spiral flow to the top of the processing chamber to be separated by the cyclone. The dried particle is collected and the exhaust air ejected from the system at the top of the cyclone.

Results of Test Run

The dryer was test run with 4 kg of wet cassava starch with moisture content of 68.75%, the drying time recorded was 11 minutes and the mass of dried product was recorded to be 2.15 kg with moisture content of 8.5% wet basis, which indicate that 1.85 kg of moisture was evaporated from the wet cassava starch.

Conclusions

The following conclusions were deduced from this project work after the design, fabrication and a test run stages were completed.

1- A column flash dryer was designed using Simprosys 2.1 simulation software package and the Royal Gouda Technology was adopted in the construction of the dryer.

2- From the simulation, the quantity of heat required to heat air flowing at 400 kg/hr from initial ambient temperature of 26ºC to drying temperature of 105ºC is 8.381 kW, The length and diameter of the column was evaluated as 1.65 m and 0.260 m respectively, the velocity of air in the dryer column was also evaluated as 13.889 m/s, cyclone diameter and blower velocity were also evaluated as 0.305 m and 14.899 m/s respectively.

3- The dryer was fabricated based on the parameters of interest generated and was found to process 4 kg of cassava starch in 11 minutes during test run.

4- The moisture content of starch was investigated, and there was significant reduction in the moisture content, the value changes from 68.75 % to 8.5 % which falls within the standard required moisture content of 9.2±1.22 % for processed cassava starch powder in literature.

5- The theoretical thermal efficiency of the dryer was estimated as 75.9 % from Simprosys, while the experimental thermal efficiency of the fabricated dryer was evaluated as 60.21 %, the difference may be due to imperfection in the fabrication of the drying unit.

Recommendations

In this design, considerable efforts have been placed in developing a design for the column flash drying unit using Simprosys 2.1 simulation software package specially designed for drying and evaporation related processes, and the results used for fabrication. Thus, from the outcomes of this study, the following recommendations would help to improve the design of the fluidized bed dryer as well as it operation.

1. The control system for the fluidized bed drying unit can be automated to further enhance its performance
2. The drying unit can be improved by incorporating an air filter at the air exhaust point in the cyclone, and recycling the hot exhaust air back to the system to save energy and reduce cost.
3. The drying chamber can be constructed with a high temperature resistant fiber glass to be able to visualize the drying dynamics and principles in the drying chamber as drying of the product is taking place.
4. Temperature indicators should be incorporated at certain fluidized bed height, to study the effect of temperature and time on the rate of drying
5. Other starch materials having similar properties with the cassava starch can be dried with the fabricated fluidized bed dryer.

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