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Comparative Study of Tray Dryer, Hot Air Oven and Tapered Fluidized Bed Dryer for Drying Wheat and Paddy

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ABSTRACT: The physicochemical analysis & drying properties of wheat and paddy were studied before and after drying under the tray dryer, hot air oven and tapered fluidized bed dryer. The grains were purchased from the local market in Hyderabad of Telangana state. The physical parameters of the grains such as length (mm), breadth (mm), l/b ratio, density (kg/m3), bulk density (kg/m3), porosity (%) and chemical properties such as moisture content (%), ash content (%), protein content (%), fat content (%), crude fibre (%), minerals (mg) were determined before and after drying. The grains were soaked in water for 5 minutes then drained and kept overnight in desiccators to obtain the farm level moisture in the grains. Drying is essentially a process of simultaneous heat and mass transfer process. The main purpose of drying is to extend the shelf-life of foods by reducing the water content present in the foods. In this work, drying of grains was carried out using tray dryer, hot air oven and tapered fluidized bed dryer at 60ºC at different intervals of time. The drying performance of tapered fluidized bed dryer has been studied by analysing moisture content of the sample during drying process. Finally, it can be suggested from the observed data that tapered fluidised bed dryer can be used for industrial drying purpose with a suitable scale-up factor. Results revealed that tapered fluidised bed dryer is better when compared to tray dryer and hot air oven method as it consumes less time and is having high drying rate with less nutrient losses making it very efficient. Farmers can use this drying method to dry the grains rather than in sun drying as it is very less time consuming and resulting in less nutrient losses in the grains.

KEY WORDS: Drying, Tray Dryer, Hot Air Oven, Tapered Fluidized Bed Dryer, Nutrients and Time.

I. INTRODUCTION

1.1 Wheat(Triticumaestivum) is the main cereal crop in India. Indian wheat is largely a soft/medium hard, medium protein, white bread wheat, which is somewhat similar to U.S. hard white wheat.World trade of wheat is greater than all the other crops combined. Demand of India's wheat in the world shows a rising trend. The country has exported 2,26,225.00 MT of wheat to the world for the worth of Rs. 424.94 crore / 60.55 USD Millions during the year of 2018-19.(APEDA.gov.in).

1.2 Paddy (Oryza sativa L.)is a self-pollinated crop botanically belongs to Gramineae family. A complete seed of rice is called paddy and contains one rice kernel. Outer layer of rice shell is called husk. The next layer is called rice bran and the innermost part is called rice kernel. There are two most important cultivated species of paddy namely Oryza sativa and Oryza glaberrium.

1.3 Dryingis a mass transfer process consisting of the removal of water or anyother solvent by application of heat to obtain dry solid product. Drying is theoldest method of preserving food by prohibiting the growth of enzymes andbacteria. The nutritional value of food is only minimally affected bydrying. Moisture content can be expressed in two ways, dry or wet basis. Theequations are given below:

Moisture percentage by wet basis = (Mass of water/Mass of sample) ×100

Moisture percentage by dry basis = (Mass of water/Mass of dry solid) ×100

Mass of sample = Mass of water + Mass of dry solid

1.3.1 Tray Dryeris the simplest form of dryer with a cabinet and a heater at the bottom that is of directedcirculation form, in which the air is heated

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and isdirected across the material in a controlled flow.The Tray Dryer is made up of three majorcomponents; energy (gas) supplier, the burnerand the drying chamber.

1.3.2 Hot Air Ovenis electrically operated equipment used to dryheat sterilize samples at temperature between 50°C to 300°C which requires exposure time up to 2 hours depending upon thetemperature employed. It is a closed thermally insulatedchamber with a door. The chamber is composed of layers thatdon't allow heat exchange between internal and externalsurroundings. The hot air oven is mainly made up of threeparts namely; drying chamber, blower and air heater.

1.3.3 Tapered Fluidized Bed Dryerby which fine solids are transformed into a fluid like state through contact with a gas or solidConical fluidized bed is very much useful for the fluidization of wide distribution of particles, since the cross-sectional area is enlarged along the bed height from the bottom to the top, therefore the velocity of the fluidizing medium is relatively high at the bottom, ensuring fluidization of the large particles and relatively low at the top, preventing entrapment of the small particles. Since the velocity of fluidizing medium at the bottom is fairly high, this gives rise to low particle concentration, thus resulting in low reaction rate and reduced rate of heat release. Therefore, the generation of high temperature zone near the distributor can be prevented. Due to the existence of a gas velocity gradient along the height of a conical bed, it has some favorable special hydrodynamic characteristics.

II. MATERIALS AND METHODS

2.1 Materials:

1. Sample Collection:

The raw materials, wheat and paddy were obtained from the local market in Hyderabad.

2. Experimental setup:

The laboratory scale batch type hot air oven, tray dryer and tapered fluidized bed dryer was used for the purpose of drying. The laboratory scale vernier caliper,screw gauge, muffle furnace, kjeltron, soxtron and atomic absorption spectroscopywere used for physico-chemical analysis.

2.2 Methodology:

1. Sample preparation:

Wheat and Paddy are obtained from a local market. The bulk was manually cleaned to remove foreign materials. The initial moisture content of wheat and paddy recorded as 16.11% and22.21%on wet basis respectively was determined by heating 10 g of the sample at a temperature of 105°C in hot air oven until three consecutive constant weights were recorded using an electronic balance measuring to an accuracy of 0.001 g. this was taken as the raw material for the study.

2. Methods of drying:

Hot air oven drying: Hot air oven drying of wheat and paddy has a common fixed bed method of drying. Hot air oven drying samples were dried at 60ºC using a hot air oven for a period of 3hrs at 30min interval and then the final moisture content obtained was determined by the gravimetric method till the weight reached a constant value.

Tray drying: The tray dryer was used for drying wheat and paddy. The product to be dried was spread on the trays in such a way that the hot air can circulate uniformly. The trays are arranged into the drying chamber after the set temperature is attained. The products are dried at 60ºC and the weight of the sample was recorded at an interval of 30minutes till the moisture content was obtained.

Tapered fluidized bed drying: A weighed amount of sample was charged into the tapered column and hot air at 60ºC was allowed to pass through the bed with different air flow rates till the bed was fluidized. For tests during each trial, process parameters (air inlet temperature, air flow rate and pressure) were kept constant.

Drying kinetics:

The moisture content and drying rate was calculated at each time interval.

$$\text{Moisture content (\%)} = \frac{\text{(Initial weight – Final)} \times 100}{\text{Initial weight}}$$

$$\text{Drying rate (g/min)} = \frac{\text{(Initial weight – Final weight)}}{\text{Time Interval}}$$

3. Methods Of Physico-Chemical Analysis:

Grain Size:

To characterize the grain used in this study, the length, breadth and diameter was considered as the size criterion. To determine the size,the grain was fixed between the jaws of the vernier callipers/ screw gauge and then the reading of the main scale, vernier/ head scale and least count were noted. The size of the grain was calculated by using the equation:

S= HSR + (PSR X LC) mm

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Where,
HSR= Head scale reading of the screw gauge
PSR= Pitch scale reading of the screw gauge
LC = Least count of the screw gauge (0.01mm)
The length and breadth ratio were also found for the suitable grains.
L/B ratio= (Length/ Breadth)

Bulk Density:

It is estimated as the ratio of mass to volume for each sample. It is determined by filling a measuring cylinder with the sample for a fixed volume.

Bulk density = weight/volume (gm/ml).

Density:

By definition, all matter has mass and occupies volume. The density ofa substance is the ratio of its mass to its volume. At constant temperature andpressure, the density (gm/ml) of a substance is constant.

$\rho = m/v$

Porosity:

Porosity indicates the extent of intracellular spaces or gaps in between thegrains. Porosity is expressed as

$$\text{Porosity} = \frac{\text{(Density - Bulk Density)}}{\text{Density}}$$

Determination of Ash Content:

About 5gms of sample was weighed accurately in to a porcelain crucible. This is transferred into a muffle furnace set at 550°C and left for about 3hrs. About this time, it had turned into white ash. The crucible and its content were cooled to room temperature in desiccators and weighed.The percentage of ash was calculated by the equation:

$$\text{Ash content (\%)} = \frac{\text{weight of ash x100}}{\text{Original weight of sample}}$$

Estimation of Protein Content:

The principle of this method involves the estimation of total nitrogen content in food and conversion of nitrogen to protein assuming that all nitrogen in food was present as protein and using a conversion factor based on the percentage of nitrogen in food.

Conversion factor F= (100/ (% of nitrogen))

Procedure:

1gm of sample was weighed and placed in digestion tube of instrument and 25ml of conc. sulphuric acid was added, 10gm of catalyst mixture was added. The temperature was adjusted to 370ºC and kept for digestion for 4-6 hours that was till the solution became blue in colour. The tube was removed from the digestion and then cooled the samples. 25ml of standard 0.1N boric acid solution or 0.1N sulphuric acid was placed in the titration receiver flask (250ml conical flask) and placed it in the distillation unit. The tube containing digested sample was attached to the distillation unit and the start button was pressed to affect the metered addition of 40% sodium hydroxide solution and to initiate the steam distillation when the receiver platform falls and the distillation stopped. The flask was removed and 5 drops of methyl red indicator solution was added and titrated with 0.1N HCl solution to yellow colour end point if boric acid was used or 0.1N NaOH if 0.1N sulphuric acid was used and indicator was phenolphthalein, carry out a blank determination.

$$\%\ \text{of Nitrogen} = \frac{\text{(titre value–blank)xN of HClx14x100}}{\text{(Weight of sample x1000)}}$$

Protein % = nitrogen% x conversion factor

Estimation of Fibre Content:

About 2-5gm of moisture and fat free sample were weighed into a 500ml beaker and 200ml of boiling 0.255N(1.25% w/v) sulphuric acid was added. The mixture was Boiled for 30 min keeping the volume constant by adding water at frequent intervals (glass rod inserted in the beaker helps in smooth boiling). At the end of this period the mixture was filtered through a muslin cloth and the residue was washed with hot water till free from acid. The material was then transferred to the same beaker and 200ml of boiling 0.313N(1.25% w/v) sodium hydroxide solution was added. After boiling for 30 min (keeping the volume constant as before), this mixture was filtered through a muslin cloth. The residue was washed with hot water till free from alkali, followed by washing with some alcohol and ether. Then it was transferred to a crucible, dried overnight at 80-100^0 C and weighed (We). The crucib1le was heated in muffle furnace at 600^0 C for 2-3 hrs, cooled and weighed again (Wa). The difference in the weights represents the weight of crude fibre.

$$\text{Crude fibre} = \frac{\text{[100-(moisture+fat)]x[weight of fibre]}}{\text{Weight of the sample}}$$

Where,

Weight of fibre = We-Wa

Estimation of Fat Content:

Fat content was determined using Soxhlet extraction method. This was based on the continuous extraction of the food with non-polar organic solvents such as petroleum ether (40-60) for about 3hrs. A known weight of food was placed in a porous thimble and the extracting solvent was

poured in a dried weighed distillation flask. The solvent then mixed with the food, dissolves out the fat and eventually siphons back into the original distillation flask. The process was repeated continuously for a period of 3hrs, after which it was assumed that all the fat has been extracted from the food and was now present in the solution in the distillation flask. Removal of solvent leaves the fat as a residue. The flask was weighed and the increase in the weight of flask was taken as the weight of fat present in original food.Here the dry sample 5-10gm was weighed accurately and placed in a thimble and plugged with cotton. Then thimble was placed in aSoxhlet's apparatus and extracted with anhydrous ether/petroleum ether for about 3hrs. The ether extracted was filtered into a weighed conical flask. The flask containing ether extract was washed 4-5 times with small quantities of ether and washings were also transferred. The ether was then removed by evaporation and the flask with the residue dried in an oven at 80-100ºC, then cooled in desiccators and weighed.

$$\text{Fat content (\%)} = \frac{\text{Weight of ether extract x100}}{\text{Weight of sample}}$$

Atomic Absorption Spectroscopy:

The samples were analyzed using atomic absorption spectrophotometer (AAS) model for determination of micro nutrients at different wave lengths. The method used was by direct aspiration of sample digest, using air acetylene flame. Atomic Absorption Spectrometry (AAS) is a technique for measuring quantities of chemical elements present in environmental samples by measuring the absorbed radiation by the chemical element of interest. This is done by reading the spectra produced when the sample is excited by radiation. The atoms absorb ultraviolet or visible light and make transitions to higher energy levels. Atomic absorption methods measure the amount of energy in the form of photons of light that are absorbed by the sample. A detector measures the wavelengths of light transmitted by the sample, and compares them to the wavelengths which originally passed through the sample. A signal processor then integrates the changes in wavelength absorbed, which appear in the readout as peaks of energy absorption at discrete wavelengths. To measure how much of a given element is present in a sample, one must first establish a basis for comparison using known quantities of that element to produce a calibration curve. To generate this curve, a specific wavelength is selected, and the detector is set to measure only the energy transmitted at that wavelength. As the concentration of the target atom in the sample increases, the absorption will also increase proportionally. A series of samples containing known concentrations of the compound of interest are analyzed and the corresponding absorbance which is the inverse percentage of light transmitted is recorded. The measured absorption at each concentration is then plotted, so that a straight line can then be drawn between the resulting points. From this line, the concentration of the substance under investigation is extrapolated from the substance's absorbance. The use of special light sources and the selection of specific wavelengths allow for the quantitative determination of individual components in a multi element mixture.

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III. RESULTS AND DISCUSSIONS

S.No	PHYSICAL PARAMETERS	WHEAT				PADDY			
		Before Drying	Tray Dryer	Hot Air Oven	Tapered Fluidised Bed Dryer	Before Drying	Tray Dryer	Hot Air Oven	Tapered Fluidised Bed Dryer
1	MOISTURE (%)	16.11	14.0	14.33	12.8	22.21	19.72	20.0	18.47
2	LENGTH (mm)	7.22	7.17	7.18	7.2	10.13	9.30	9.82	10.0
3	BREADTH or DIAMETER (mm)	3.25	3.11	2.83	3.0	1.41	1.32	1.35	1.37
4	L/B RATIO	2.22	2.3	2.53	2.4	7.18	7.04	7.27	7.29
5	DENSITY (g/ml)	0.81	0.82	1.2	0.9	1.43	1.43	1.5	1.47
6	BULK DENSITY (g/ml)	1.47	1.38	0.86	1.42	0.56	0.54	0.52	0.55
7	POROSITY (%)	35.69	39.95	37.39	38.21	60.13	62.24	66.80	63.24
8	ASH (%)	0.8	0.6	0.7	0.7	1.2	1.1	1.0	1.2
9	PROTEIN (%)	11.8	10.5	9.8	11.3	7.5	7.0	6.6	7.3
10	FAT (%)	1.5	1.0	0.7	1.2	1.0	0.7	0.7	0.8
11	FIBER (g)	1.2	1.12	1.10	1.15	0.6	0.55	0.55	0.58
12	CALCIUM (mg)	41	36	29	38	10	7	5	8
13	PHOSPHORUS (mg)	306	283	271	295	190	167	162	178
14	IRON (mg)	5.3	4.98	4.62	5.13	3.2	2.7	2.65	3.0

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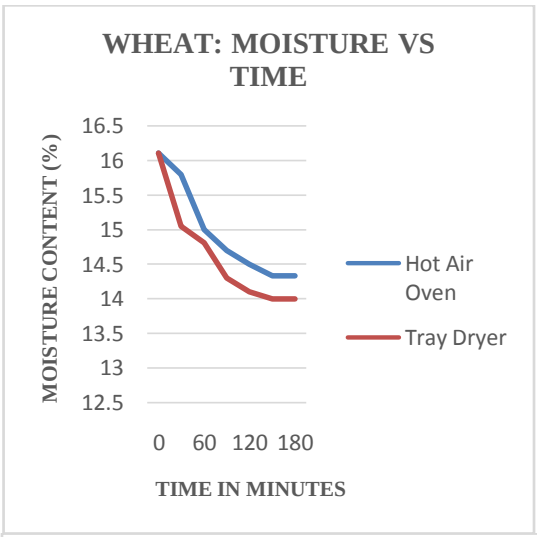
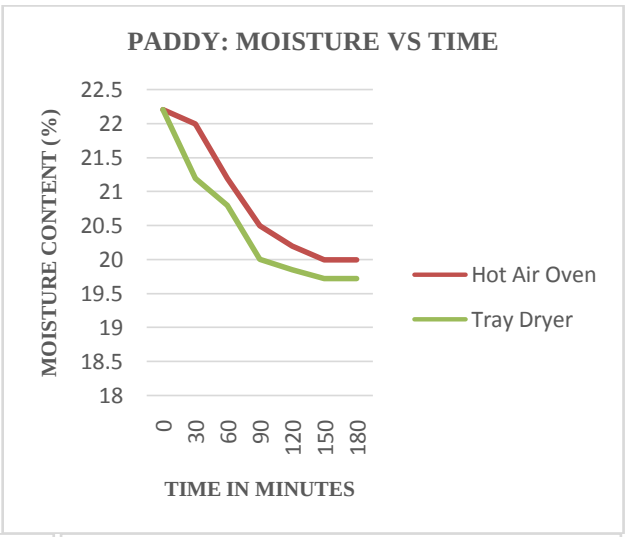
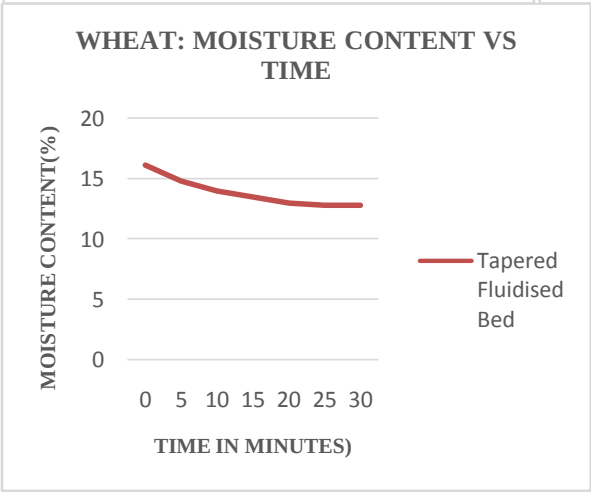
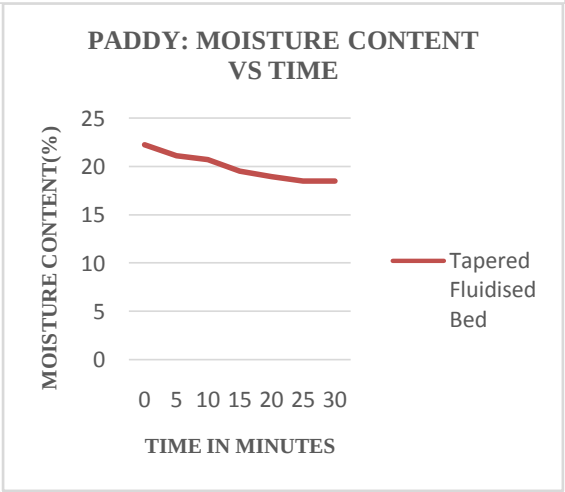
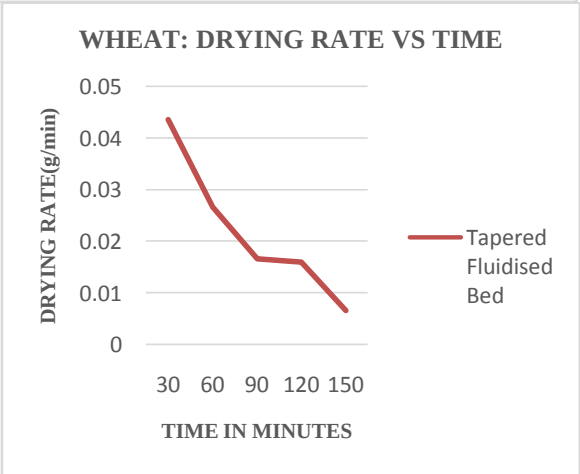
3.1 GRAPHS:

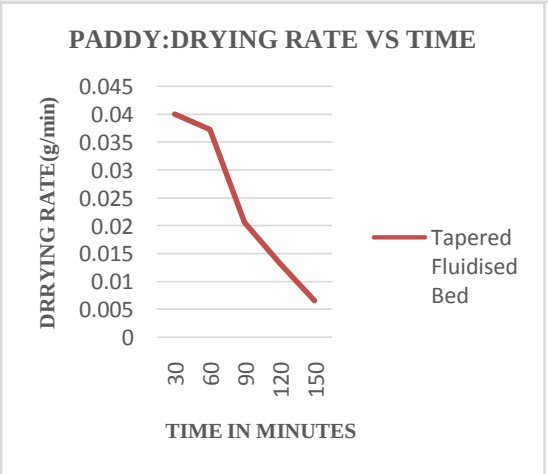












IV. CONCLUSION

The work done is mainly focused on finding the best dryer among the Tray dryer,Hot air oven and Tapered fluidized bed dryer for drying the grains. Based on the results obtained, tapered fluidized bed dryer is the best among the three dryers as it is taking less time, is having highest drying rate and less nutritional losses, tray dryer is the second best as it taking less time than hot air

oven for drying that is the drying rate is higher than hot air oven but lower than tapered fluidized bed dryer, the hot air oven is lagging as it is consuming a lot of time for the drying purpose and is the one with least drying rate. The grains used in this work are the most staple cereal grains in India that are wheat and paddy. The physical and chemical properties of these grains were found before and after drying and there was a slight difference in the properties after drying but, there were fewer losses in the tapered fluidized bed dryer when compared to the other two dryers. Tapered fluidized bed dryer can be scaled up so that the farmers can use this for drying the grains that are harvested instead of the other drying techniques so that there will be less losses to the harvest as well as to the farmer.

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