ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 9, Issue 12, December 2022

Experimental Study on Drying Behaviour of Paddy Grains through Open Sun Drying

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Abstract*— In this Present work, experimental studies have been carried out with paddy grains through traditional Open Sun Drying (OSD) to investigate the better drying efficiency with better quality product along with economic feasibility for the effective application of a low cost drying method in rural areas. Here, the effect of drying time and drying temperature on moisture content (wet basis) removal of paddy grains through traditional Sun drying where four different batch sizes viz. (1, 2, 4 and 8) kg have been taken for experimental study during harvesting period of paddy grains on Agartala climate where temperatures are recorded as (21, 20 and 18) degree centigrade with relative humidity as (82, 80 and 79) percent on 15th, 30th December 2021 and 15 January 2022 respectively. Four samples are collected keeping 3 hours interval from four different corners of 0.5 square meter floor area for each experiment. Temperature of products, temperature around the products, solar temperature and moisture evaporation rate are the main important parameters in OSD. It is observed from results that 8 kg has showed comparatively more economical drying among four batch sizes. Drying temperature of 20 degree centigrade with relative humidity 80 percent is found suitable for drying. The best result for these experiments is obtained as 12.1 percent moisture content (wet basis) for a drying period of 18 hours with 8 kg batch size at 20 degree centigrade with relative humidity 80 percent.

I. INTRODUCTION

Open Sun drying (OSD) is a very simple and common way of drying various agricultural products in rural areas. Besides few drawbacks, OSD is broadly followed due to economic feasibility and easiness of drying. Paddy (Oryza sativa L.) is the major cereal crop cultivated in South East Asia region contributing to 90% of production in the world [1]. Rice, obtained after processing of paddy, is the primary source of staple food for more than half of the world`s population. India is in second position in terms of production of white rice. Paddy/ rice are mainly a high energy calorie food. The major part of rice consist of carbohydrate in the form of starch, which is about (72-75) % of the total grain composition [2]. The protein content of rice is about 7% [2]. Before preserve for long term all the agricultural products need a proper drying for minimizing fungal affects, food damage and transportation costs along with increased colour, flavour and nutritious value of the products where the drying process should be easy, low cost, naturally available and frequent to minimize the cost of final product. Sodha et al. (1985) have prepared analytical model of open Sun drying and cabinet drying on various fruits where observed that analytical models are helpful for predicting the hourly variation of product temperature and moisture content of drying processes [3]. Goyal and Tiwari (1998) have studied heat and mass transfer for wheat and gram drying where observations are recorded for relative humidity, temperature of crop and air and for moisture evaporated [4]. Anwar and Tiwari [2001] have evaluated convective heat transfer coefficient in various crop drying using open Sun drying where heat transfer coefficients for crops like chilli, onion, potato etc. are found out [5]. Mursalim et al. (2002) have experimented on drying of cashew nut in shell using solar dryer and got results as dry air up to78.70C maximum on average ambient temperature 27.20C, drying rate of 0.59% m.c/hr, efficient of 64% with M1 quality grade in Indonesia [6]. Jain and Tiwari (2003) have done experiments to find out the thermal aspects of open Sun drying of various crops where found that Sun drying is widely practiced for its easiness and observed that heat transfer analysis is mainly dependent on moisture transfer rate which is also enhanced during drying process [7]. Togrul Inci Turk (2003) has found the convective heat transfer coefficient of various crops under open Sun drying where observed that values of convective heat transfer coefficient varied from crop to crop with a range of (0.25 to 3.3) W/m2 0C [8]. Kashani Nejad, M., et al. (2003) have worked on the effect of various drying methods on quality of pistachio nuts where moisture content, lipid quality, sensory attributes and percent split shell of pistachio nuts are studied and found Sun drying and bin drying are resulted in higher split shell percent on pistachio nuts than over other drying methods [9]. Ebru Kavak Akpinar (2005) has done investigations for heat transfer coefficients of various agricultural products under open Sun drying conditions and experimental errors in terms of percent uncertainty is also calculated [10]. Inci Turk Togrul (2005) has determined the convective heat transfer coefficients of apricots in open Sun drying condition at different initial moisture contents and at ambient temperature and found to increase exponentially with increase in moisture

ISSN (Online) 2456-1290

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content [11]. Mahanta et al. (2010) have done experiments on fluidized bed drying where observed that bed temperature and heat transfer coefficient increases with increase in bed inventory and particle size where inventory was taken as a mixture of particles with sands [12]. Dhanuskodi et al. (2014) have worked on solar biomass hybrid dryer for 40 kg of cashew drying having initial moisture of 9% where drying time and drying efficiency are compared with open Sun drying results and found hybrid drying mode operation is twice faster than the Sun drying [13].The summary of reviewing many literatures is come out as post-harvest moist agricultural products should be dried properly in order to avoid fungal affects for long duration storage, to maximise the final product quality and to minimise the losses. But, drying process should be economical, easy operational and socially feasible for the farmers. Besides few limitations, Sun drying process is the most common method of agricultural product drying in developing countries and that is why an attempt has been taken through this present work to investigate the drying rates of paddy grain and raw cashew nuts using open Sun drying.

II. MATERIALS AND METHODS

Traditional Sun drying of paddy grains are the drying of harvested moist paddy grains under the direct Sunlight. Among various processes of Sun drying, in this experiment `mat drying` process is followed where 0.5 square meter of mat is used under direct Sunlight and heat and the various sizes of harvested moist paddy grains are placed on the mat for 18 hours.Basically, in the very beginning harvested paddy grains are collected from paddy field and initially the batch sizes are measured by a general weighing machine whereas digital weighing machine with an input of 230 V, 50 Hz and 85 mA which can measure a minimum of 10 gm. to maximum of 310 gm. is used for the experimental sample measurement where four samples from each experiment at initial level as well as 3 hours interval are collected and measured.Four crucible containers, which can withstand high temperature of 105^0C for 16 hoursof muffle furnacehaving programmable digital PID control digital timer function, 20 Amp,are used for total drying for moisture content of samples collected from Sun drying after regular interval of 3 hours. The weight of samples at mentioned intervals during experiment and after getting the same samples from muffle furnace after total moisture drying are recorded. From these readings and using formula for moisture content (wet basis), the moisture content (wet basis) is found out at the mentioned time intervals for each experiment. The atmospheric relative humidity and weather temperature are measured by a psychrometer and thermometer respectively.

Fig.1. Open sun drying of paddy

Fig.2. Digital weighing machine and crucible

Fig.3. Muffle furnace

A. Process parameters

The process parameters like atmospheric temperature, relative humidity and natural air flow rate have a vital role in open Sun drying process.Increase in atmospheric temperature increases the rate of drying and vice versa. But this approach to increase the rate of drying cannot be used always because paddy grains are harmed by high temperature. Atmospheric air humidity should be as low as possible for faster drying rate because the humidity of air decreases the rate of drying increases. With the increase in air flow rate, the drying rate is also increased but natural air flow rate should not be too fast or too slow in order to get efficient drying.

B. Drying mechanism

Drying is an operation in which water particles or moisture contents are removed from a wet solid.Moisture content M is the percentage of moisture by weight of the bone-dried solid. The equilibrium moisture content is that to which material can be dried under given conditions of air temperature and humidity. The process of drying usually takes place in three stages namely warming-up period, constant-rate period and falling-rate period.

C. Determination of moisture

The equation for moisture content measurement on wet basis [14] may be followed as

$$M_t = \frac{W_o - W_d}{W_o} \qquad (1)$$

Where M_t is standard moisture content (w.b. %), $W_o$is initial weight of dried product (gm.), $W_d$is final weight of dried product in (gm.).

III. RESULTS AND DISCUSSION

Drying is actually dehydration which implies removal of water along with a chemical change. For the present experiments, conduction and convection are the main heat transfer processes that are mainly responsible for the completion of the drying process whereas the effects of

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

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outside drying medium like atmospheric temperature and humidity, natural air velocity and paddy grain shape are responsible to influence the drying rate. In this present work, harvested paddy grains` moisture content (wet basis) removal rate enhancement with the variation of atmospheric temperature along with variation of relative humidity (RH) and effect of duration of drying time on moisture content (wet basis) removal are studied and presented in the following sub-sections.

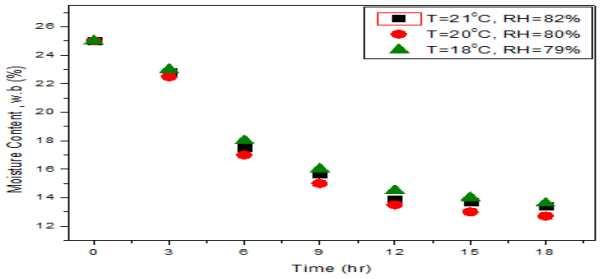

Fig.4. MC verses Time curve for batch size 1 kg

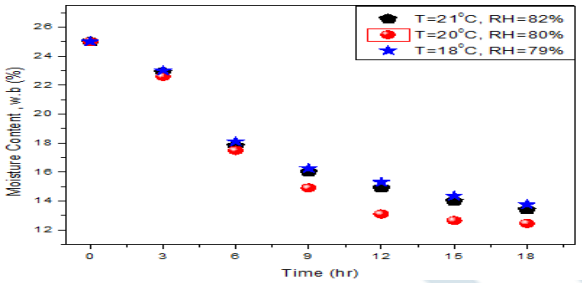

Fig.5. MC verses Time curve for batch size 2 kg

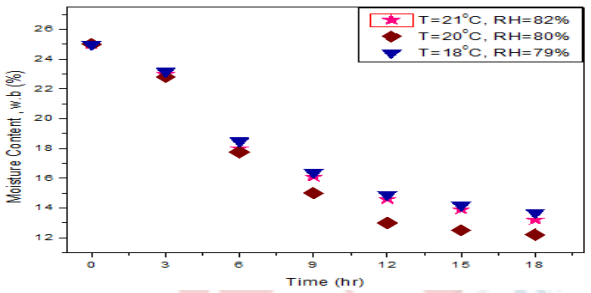

Fig.6. MC verses Time curve for batch size 4 kg

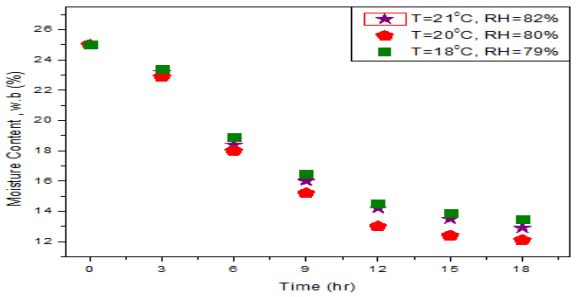

Fig.7. MC verses Time curve for batch size 8 kg

A. Effect of temperature and RH

Moisture content (wet basis) verses Time (hour) graphs for 1 kg, 2 kg, 4 kg and 8 kg batch sizes of paddy at three different temperatures and relative humidity (RH) are shown in figure numbers 5, 6, 7 and 8 respectively.

TABLE I. MC_{wb} (%) status of paddy grains for various input parameters during sun drying

Time (hr.)	MC_{wb}(%) (Batch=1kg)			MC_{wb}(%) (Batch=2kg)		
	T=21°C RH=82%	*T=20°C RH=80%*	*T=18°C RH=79%*	*T=21°C RH=82%*	*T=20°C RH=80%*	*T=18°C RH=79%*
0	25	25	25	25	25	25
3	22.8	22.5	23	22.91	22.6	23
6	17.5	17	18	17.8	17.5	18.1
9	15.7	15	16	16	14.9	16.25
12	13.9	13.5	14.5	14.9	13.1	15.3
15	13.7	13	14	14	12.65	14.35
18	13.4	12.7	13.6	13.4	12.45	13.75

EMC is found to drop by 0.55% for every 10.5^{0}C temperature rise for the same percentage of RH. In each temperature and RH range, 18 hour drying has showed the satisfactory results for paddy storage which is closer to 12% MC_{wb} [2, 3]. But 8 kg batch size has showed better drying results among four batch sizes which imply increase in batch size will give the economical drying. Drying temperature of 20^{0}C with relative humidity 80% is found suitable for drying. The best result for these experiments is obtained as 12.1% MC (wet basis) for 8 kg batch size at 20^{0}C with relative humidity 80%.

TABLE II. MC_{wb} (%) status of paddy grains for various input parameters during sun drying

Time (hr.)	MC_{wb}(%) (Batch= 4 kg)			MC_{wb}(%) (Batch= 8 kg)		
	T=21°C RH=82%	*T=20°C RH=80%*	*T=18°C RH=79%*	*T=21°C RH=82%*	*T=20°C RH=80%*	*T=18°C RH=79%*
0	25	25	25	25	25	25
3	23	22.8	23.2	23.2	22.9	23.4
6	18	17.75	18.5	18.4	18	18.9
9	16.1	15	16.4	16	15.2	16.5
12	14.6	13	14.9	14.2	13	14.5
15	13.9	12.5	14.2	13.5	12.4	13.9
18	13.2	12.2	13.7	12.9	12.1	13.5

B. Effect of drying time

The figures 9, 10, 11 and 12 has showed the comparison between MC_{wb}(%) level with three different temperatures levels at three RH ranges for four batch sizes at 6 hour, 12 hour and 18 hour time duration to find out the best suited operating parameters for the experiments and to achieve the desire MC_{wb} level of 12% [2,3]. All these four graphs have showed that 18 hours drying duration has lowered the MC_{wb} level in a preferable range for the given parameters. But the best results are observed for 8 kg paddies when Sun dried for 18 hours at 20^{0}C and at 80% RH which is 12.1% MC_{wb} and at this MC_{wb} the paddies can be store for a period of (6-8) months [2,3].

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 9, Issue 12, December 2022

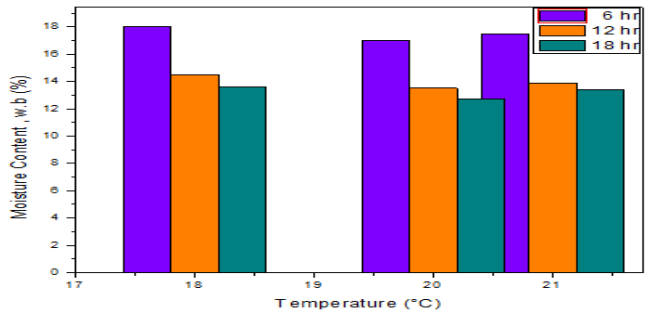

Fig.8. MC verses Temperature curve for 1 kg

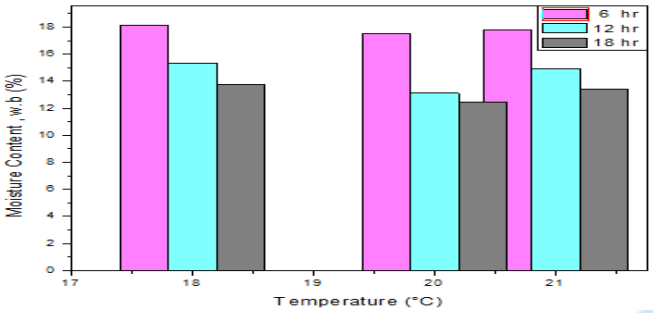

Fig.9. MC verses Temperature curve for 2 kg

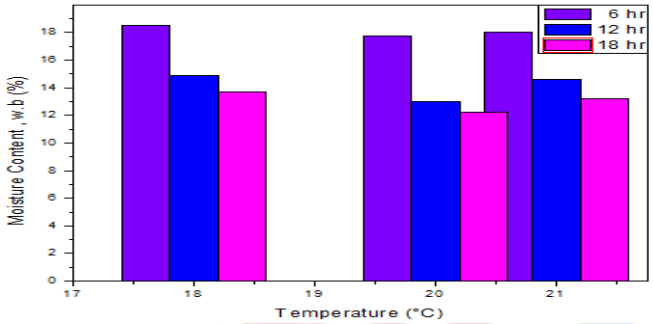

Fig.10. MC verses Temperature curve for 4 kg

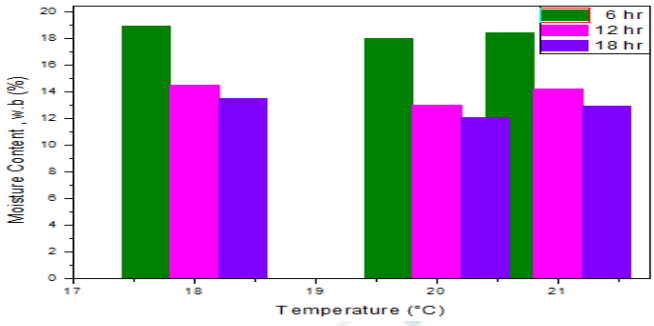

Fig.11. MC verses Temperature curve for 8 kg

IV. CONCLUSION

Experimental results showed that removal rate of moisture content (MC_{wb}) of four different batch sizes of paddy depends on both temperature and RH level of atmosphere at the time of drying operation. EMC for paddies is found to drop by 0.55% for every 10.5^{0}C temperature rise for the same percentage of RH. It is observed from results that 8 kg has showed comparatively more economical drying among four batch sizes. Drying temperature of 20^{0}C with relative humidity80% is found suitable for Sun drying for given parameters. The best result for these experiments is obtained as 12.1% moisture content (wet basis) for 8 kg batch size at 20^{0}C with relative humidity 80%. During drying, using lower batch size is found less economical. Around last week of December is suggested for paddy grain post-harvest Sun drying due to comparatively higher temperature level and lower RH level of atmospheric air. Besides some limitations like totally dependent on climate conditions, huge time consuming, the Sun drying has economic feasibility along with ease of operation. The present experimental outcomes designate highest drying efficiency.

V. ACKNOWLEDGMENT

The authors are very much thankful to TIT Agartala and NIT Mizoram for laboratory and technical support during research work and also graceful to all who have inspired for the work.

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