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Effect of Environmental Condition and Drying Parameters on Paddy Processing

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Abstract — *Parboiling of the paddy is the hydrothermal retreatment process. It improves the paddy milling characteristics and head rice yield, without affecting chemical composition and nutritional value of the rice. The moisture content of the raw paddy is normally less than 33 %(db), and attend the high level of the moisture after parboiling up to 60%. The high moisture removal of paddy needs delicate drying operation. Rice kernel is sensitive to the thermal treatment. Proper drying of paddy achieves the sufficient mechanical strength for milling with low breakages of kernels. Whole rice and whiteness are most important qualities of the rice which gives more commercial value than the broken and partial yellow. The drying air temperature, relative humidity, drying air velocity, and variety of grain affect drying process .These parameters are studied and optimized for maximizing the head rice yield and whiteness.*

Keywords: Drying, Parboiled rice, head yield, ambient air drying, grain .

I. INTRODUCTION

Rice is the second largest produced cereal grain in the world. Asian farmers produce about 90% of the total rice produced in the world. Modern rice mills process 65% of paddy production and rest by huller/Sheller mills. In most of the south Asian nations Parboiled rice is consumed, but now it is gaining popularity in the western countries and Americans, because of its non sticky plum cooking as well as nutritional value.

The recovery of whole grain in traditional rice mill using huller for dehusking is around 52-54%,where-as in modern rice mills rubber roll Sheller for dehusking operation is around 62-64% in raw, and 66-68% in parboiled paddy. Yadollahinia et. al. [1]have said that about 80% of the people around the world consume rice. According to C.Igathinathane et.al. 2008 [2] in tropical countries, the paddy rice is usually harvested at 20% to 25 % (wb) moisture contents. Tirawanichakul et. al., 2004 [3] said, on such high level of moisture microorganism growth and respiration rate are high, therefore these paddies must be dried up to 12 - 14 % moisture content for long storage and high milling yield .

The drying process involves transfer of heat and mass between media and solid material, in which particles present in the dryer gains heat from media by convection, and vaporizing the water inside the particles. Parboiling of the paddy is the hydrothermal retreatment under taken to improve the paddy milling characteristics without affecting the basic content, chemical composition and nutritional value.

Larsen et. al. 2000 [4], stated that parboiled paddy gives more yield in milling. He also realized that it has more nutritional value, and beneficial to health. Despite the known phenomena of the kernels, hardening due to parboiling, the paddy processors experienced that the breakage of the kernels can be reduced if it is dried properly. Even after controlled drying process kernels are prone to fissure when exposed to high humidity environment . Chattopadhyay & Kunze, 1986 [5] found that fissuring occurs in raw rice due to moisture absorption. Kunje & hall [6], later attributed to tensile failure of the raw rice kernels, holds equally good for parboiled rice kernels. Marshall et. al. 1993 [7], reported that extensive parboiling is not necessary to obtain maximum head rice yields. They also indicated the influence of various processing conditions on the characteristics of the kernel.

The moisture content of the raw paddy is normally less than 33 %(db). It attends the high level of the moisture after parboiling up to 60% [2].This high moisture removal needed more delicate drying operation. According to Bhattacharya et.al. [8], drying method is important for milling quality of parboiling paddy. Since the rice kernel is delicate and sensitive to the thermal treatment during drying, the economic advantage of the parboiling cannot be fully achieved if drying is not performed properly. It can be said that parboiled paddy achieves sufficient mechanical strength for milling with almost no breakage if dried properly. Considering the appropriate ranges of the related parameters an attempt would be made to design the control objective towards automation of the dryer system of paddy.

II. LITERATURE REVIEW

A. Consideration of Parameters in Drying Process

Moisture removal of the agriculture product is depend on the drying temperature ,relative humidity of the air, velocity of the drying air and variety of the food grain [1]. This phenomenon is very complicated and may cause the irreversible change in the physical and chemical properties of the food materials, such as colour, cracking and viscosity. These changes lower the quality and reduction in the price.

German Elbert et. al. 2001 [9], stated that, for high moisture removal of paddy, drying process should be a multiple stages batch process with intermediate tempering operation to reduce the thermal stresses. Bhattacharya and Indudhara Swamy [8], have suggested the critical moisture content to initiate the tempering of the paddy to minimize the damage. C.Igathinathane,et. al. [10], stated that the thermal and moisture gradient is developed during tampering. Steffee and Singh reported that the tempering period is often based on the experience of the operators, and commonly it is ranging from 4 hrs to 24 hours.

Thin layer drying is the one of the important process for removal of high moisture from the porous media by evaporation. In this process excess heated air is passed through the thin layer of the paddy to remove the water content to reach the equilibrium moisture content (EMC). Cuto S. M. 2002 [11], stated the various isolated and combined parameters involved in grain drying. Under hot and humid climates, it is recommended to dry the paddy with low air flow rate (near ambient air) to minimize the energy consumption and moisture gradient in the grain bed for obtaining the high head yield in milling. Somchart soponronnarit et.al. stated that the head rice yield will decrease significantly if in the first stage high moisture paddy is dried rapidly below 18-19% moisture contents. Fast rate of drying to remove the excessive moisture leads to stress cracks, but prevent the rice from yellowing. Rice is subjected to lower milling yield if it is dried so quickly. Rice quality can be maintained by drying in several 20 -30 minute long passes through a dryer. In between the passes, rice should be stored in the temporary holding bins, this is called tempering, and allows moisture to equalize within kernels. (Rice quality workshop 2003, high tempering rice drying).

B. Effect Of Different Parameters On Drying Process

According to E.Barati, et. al. [12], effect of initial temperature of grain on the energy consumption is small. Aversa M., Curcio S. et.al., have studied theoretically the model using finite element method for determination of the influence of operating variables like air flow velocity, relative humidity, and air temperature on the performance of drying process. It is seen that the internal resistance to moisture movement of agricultural materials is much more than the surface mass transfer resistance that the air rate past the particles has no significant effect on the time of drying or on the drying coefficient. Handerson and fabis [13], found that air flow rate have no observable effect on thin layer drying of wheat when air flow is turbulent. They have also said that there is no significant effect on the drying rate of the wheat if air flow rate is varying from $10/cm^3/sec/\ cm^2$ to $68/cm^3/sec/\ cm^2$, but in case of the paddy it has some effect.

If the yield of the product quality in terms of the head rice yield and whiteness is to be preserved inlet air should not be of more than 120^0C [14], for superficial air velocity of 3.2 m/s, and bed depth of 0.1m.Looking in to the references it is summarized that the drying rate is depends on (1) Air temperature. (2) Air flow rate. (3) Relative humidity. (4) Exposure time. (5) Types and variety of grain. (6) Initial moisture contents (7) Grain bed depth. First four factors are playing more important role in drying process.

Bhattacharya et.al. 1967[8] have studied the effect of the temperature on drying process and shown that higher temperature is drying the parboiled paddy faster as compared to lower temperature. Simmonds et. al. 1953 [15], have done the study for wheat drying rate between 21^0C -77^0C, and showed that the drying rate is depend on the temperature variation.

Parboiling of rice consists soaking, steaming and drying of the rough rice. The well Known reason for the paddy parboiling is to get high rice yield, higher nutritional value and resistance to spoilage by insects and mould [19].

The method of drying is most important of parboiling process for maximizing the milling quality of the rice [8].Several methods are being used for drying the paddy. For parboiled paddy Louisiana state university dryer (LSU), and fluidized bed dryers are preferred by millers in India. The main reason of selection of these dryers is because of local whether condition and high amount of moisture contents of the paddy to be removed (55% to 13%). Considerable reduction in the breakage is found (Bhattacharya et. al. [8]), if moisture removal is done in multi stage with intermediate tempering period.

To study the effect of drying temperature, tempering time, and initial moisture level, German et. al. [9] conducted the experiments and found that these parameters are affecting the head rice yield and Browning Index (BI) of the rice .Based on the surface response technology, a polynomial model was obtained to predict over the wide range the effect of the drying conditions on quality variable. He further concluded that temperature has the negative influence on the head rice yield while tempering time affects positively. Similar effect of the temperature on the head rice yield was reported by Bhattacharya and Indudhara Swamy [8]. A decrease of head yield was observed for long tempering period at 80^0 C or above. This fact shows that the limit for both the drying and tempering periods.

It was observed that BI increases squarely with air temperature and tempering time where temperature is the influential factor .The tolerable limit of the yellowness is obtained using air temperature less than 70^0C. It was observed that the head rice increases as drying temperature decreases with fixed tempering time and initial tempering moisture .An increase in the tempering time produces also an increase in head rice yield, depending on the operating conditions the head rice yield changes between 68% to 74%.It can be further said that two stage drying with 16% initial moisture content leads to best rice yield within the range of permissible BI at 70^0C or below temperature.

Sutherland and Ghaly 1992 [16], did the experiment and found that head rice yield was 58-61% when the paddy was dried from 28.2 -20.5% Moisture content. Tumambing and Driscoll 1993 found that the drying rate was affected by drying air temperature and bed thickness under the conditions, drying air temperature 40-120^{0}C, Bed thickness 5-20 cm, air velocity varies from 1.5 -2.5 m/s.

Soponronnarit and Prachayawarakorn in 1994 [14] developed & work on the fluidized bed grain dryer. He suggested that moisture content of the paddy should not be less than 23% if the quality of head rice yield and whiteness is to be optimized. He further suggested the appropriate operating parameters such as air velocity (2.3 m/s), thickness of the bed (10 cm) and fraction of recycled air (0.8), is to be maintained to maximize the drying capacities and minimize the energy consumption.

Inspired with the results of Soponronnarit a private company "rice engineering supply co. Limited", collaborated and developed the prototype dryer with 1t/hr capacity approximately. The prototype comprising the dryer section, 7.5kw curved blade centrifugal fan, a diesel fuel oil burner, and a cyclone. The dimension of the drying bed was 1.7 m in length, 0.3m in width and 1.2m in height. During operation hot air (temperature was controlled by thermostat), is blown to the drying section through perforated steel sheet floor .The air and grain flow were perpendicular to each other. The small portion of the air leaving the drying chamber was allowed to go to atmosphere, while the major portion after cleaning mixed with ambient air to recycle. The mixture is reheated to achieve the desired temperature .The feed rate of the paddy varied from 1t/hr to 1.5t/hr. For reduction of moisture from 45-24% using air temperature of 100-120 ^{0}C, fraction of recycled air was 66% , air flow rate 0.05 kg /s-kg (dry matter),superficial air velocity of 3.2 m/s , bed depth of 0.1m and the total energy consumption was 2.32 mj/kg. The experimental results showed that the unit operating efficiently and yielded good quality rice in terms of head yield and whiteness. Fluidized bed dryer with the capacity of 2.5-5t/hr and 5-10t/hr compared with reference to ambient air drying. It is found that paddy quality in terms of head rice yield and whiteness are within the acceptable range. For higher moisture content of paddy it is further observed that fluidized bed dryer took low energy. It is further recommended that high moisture paddy should be dried up to 23% moisture level by fluidized bed dryer to maintain the paddy quality.

Somchart Soponronnarit et. al.[14] with the experiment in the lab managed the moisture of the paddy by three process in series (1) fluidized bed drying (2) tempering (3)ambient air ventilation . The moisture content of the paddy is reduced from 33-16.5% within 53 minutes approximately, by fluidized bed dryer with 1500C inlet air temperature. This inlet air temperature reduced the moisture contents up to 19.5% in 3 minutes. After that tempering was done for 30 minutes and finally paddy was cooled by ambient air of 30^{0}C and 55-60% Relative humidity (RH) with air velocity of 0.15 m/s for 20 minutes. The quality of the paddy in terms of head rice yield and whiteness was within acceptable range. Poosma et. al. 2002 [18], confirm the tempering period of 35 minutes experimentally and mathematically for two stages drying with fluidized bed dryer.

The first fluidized bed paddy dryer was commercialized in Thailand in 1995. Since then more than 200 commercial units with different capacities (5-20 t/hr) have been sold, and tested for basic properties such as factors affecting grain quality, moisture reduction rate, energy consumption etc for paddy and other food grain.

From the test results it can be said that the fluidized bed dryer is competitive with conventional hot air dryer and LSU dryer for high moisture content parboiled paddy. Its energy consumption is low, with acceptable drying conditions .Drying air temp 140 - 150^{0}c, fraction of air recycled about 0 .8, with the air velocity 2.0 -2.3 m/s, with variation of bed thickness 10 -15 cm for consumer acceptable quality. It is also seen that there is no significant difference in the quality of the food with reference to dried by ambient air or other conventional dryers.

Fluidized bed dryer is now fully commercialized and used in countries like Thailand ,Colombia ,French Guyana, Indonesia Malaysia, Mexico, Myanmar ,Philippines India and Taiwan. It is suitable for high moisture grains such as just harvested paddy, Parboiled rice, maize and soybean. Its drying rate is faster as compared to conventional grain dryer and drying unit size is very compact as compared to its capacity. This type of dryer takes low energy while quality of grain is maintained. It can be suggested that paddy should be dried quickly using fluidized bed dryer up to approximately 23% m.c.(db). Using multi stages drying, drying cost and quality of the grain product can be optimized. The advantages of multi stages drying are:- (a) Uniform moisture contents of the product that's why high temperature of the drying air can be employed. (b) Good heat and mass transfer that's why it can dry more grain. (c) Needs smaller drying chamber which reduce the cost of the dryer.

Saifullah M. H. Saif et. al. 2004 [19], have studied the effect of inlet air temperature for two different varieties of paddy (Lamont and Reco1), at 21^{0}C and 40^{0}C. The average moisture removal rate was different in both the cases. He stated that the drying temperature and duration of the environmental exposure are significant on the tensile strength of the rice. He also quoted that the tensile strength decreases with increase in temperature. Drying at room temperature is left the kernel with low residual stress as opposed to high temperature drying. C.Igathinathane, et. al. in their research paper "Development of an Accelerated Tempering process for drying Parboiled paddy" have shown the effect of temperature at different atmospheric pressure and concluded that drying of the paddy at different pressure is taking different drying time.

Petchart Jaiboon et .al. 2009[20], experimented on the waxy rice (RD 6) with initial moisture content 28.8 % (db) at 30^{0}C ambient temperature. The fluidized bed drying of waxy rice at 90 ,110 and 130^{0}C , superficial air velocity of 2.5m/s .The desired moisture level was 22-24%(db).The semi dried waxy rice than tempered for 30 -120 minutes in order to reduce the moisture stresses created during the drying. After tempering the sample was ventilated with ambient air (30^{0}C, 55-60 % RH) in the thin bed ventilator (3.5cm) with specified air velocity of 0.15m/s up to the moisture content reached 16% (db).

The ventilation time was (30-40 min.).This process to dry the waxy rice was evaluated in terms of head rice yield, thermal properties and color. With the experiment he concluded that the moisture removal rate was enhanced at higher drying temperature, and decrease in the moisture contents below 22-24% (db) causes rapid drop in head rice yield. The effect of higher drying temperature caused only a small drop in the head rice yield .These result are opposite to those reported in the case of low temperature drying [21] .In his study he found that waxy rice should not be dried lower than 22-23%(db) moisture content for batter head rice yield, otherwise the head rice yield would drop significantly. He found that the head rice yield is lower when the rice was dried at 110-130^{0}C and more when it is dried at 90^{0}C. The whiteness of the rice is independent of drying temperature and tempering duration.

III. Conclusion

Drying of paddy is nonlinear process and depends on drying air temperature, drying air flow rate, relative humidity, exposure time, types and variety of grain, initial moisture content and grain bed depth. First four factors are playing important role in drying process .After studying the various literature and experiments it is concluded that for high moisture removal, batch drying with multiple stages and intermediate tempering should be used. Fast rate of moisture removal in first stage leads to the thermal stress, which cause low head yield. There is little effect on whiteness of rice with tempering of 70^{0}C and below. Faster rate of paddy drying can be achieved with higher drying air temperature. Thin layer drying is batter process for removal of high level moisture from the food grain. To minimize the energy consumption drying air flow rate should be lower. To achieve more head rice yield , whiteness ,and optimum energy consumption in fluidized bed dryer, air flow rate 2.3m/s ,thickness of the bed (10 cm)and fraction of the recycled air should be 0 .8. Head rice yield decreases significantly if in the first stage high moisture paddy is dried rapidly below 18-19% moisture contents. The recommended air flow rate per unit mass for the paddy is 2.5m/s (crop dryer manufacturer association rev.feb .9, 1956). With the increase of humidity of air the drying rate decreases, but it has smaller effect as compare to temperature on drying rate. Quality of product in terms of the head rice yield and whiteness can be achieved if inlet drying air temperature is less than120^{0}C.

The higher food initial temperature provide the lower energy consumption in the drying process while warming up of food without evaporation in order to reduce energy consumption during drying .Anderson and pubis stated that turbulent air flow rate has no significant difference on the thin layer drying of the wheat, but it has some effect on the paddy. The recommended air flow rate per unit mass for the paddy is 2.5 m/s (crop dryer manufacturer association rev .feb.9, 1956). A Iguaz et.al.[22], experimented on medium rough rice at drying rate of 35^{0}C,25^{0}C,12^{0}C,& 5^{0}C , varying relative humidity from 30% -70% at two different drying air velocities 2.5 and 0.75 m/s. He found that at 2.5m/s air velocity on 35^{0}C and 5^{0}C, took 1.6 hr and 4.1 hrs to attend the moisture content of 0.05(dimensionless).

He further stated that the same moisture ratio was reached in 3.3 and 5.0 hrs at 2.5 and 0.75m/s air velocity respectively for the constant temperature of drying air at 12^{0}C.Thus rice dried 1.6 times faster at 2.5m/s than 0.75m/s. As for the effect of temperature is concern, rice dried 2.7 times faster at 35^{0}C than 5^{0}C for the same velocity (2.5m/s).Therefore the effect of temperature is more important than the effect of air velocity. However air temperature and air velocity both are considered to-gather the drying effect is higher .According to Jayas et. al. air velocity does not take an important role at higher temp drying .but at lower drying temperature such as 35^{0}C the difference in the time needed to reach the half moisture ratio with the different air velocity is low ,and as temperature decreases this difference increases . This indicates that the air velocity is important when drying is conducted at low temperature .with the increase of humidity of air the drying rate decreases, but it has smaller effect than the temperature on the drying rate.

Saifullah M. H. Saif et. al. [19] experimented on environmental exposure .He treated the sample after immediate drying for four different environmental conditions i.e. ,no exposure,65% ,86%, and 100% RH all at the ambient temperature of 21^{0}C and 40^{0}C.The effect of relative humidity(RH) exposure on the ultimate tensile strength (UTS) on two varieties of rice seed (lemount and Rico1) were observed . At higher RH exposure of 86%and 100%moisture, both UTS and tensile modulus of Elasticity (MOE) values tend to decrease over the period of exposure. He further stated that, during the experiment there were small gain in UTS by kernels till 2 hrs of exposure when exposed to high RH environment i.e.100%.However the strength value decreased slowly until about 9 hrs and than the rate started falling rapidly afterwards . A decrease in the UTS at higher than 65% RH exposure after drying because of moisture adsorption from environment that added to the stress thereby weakening the kernels.

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