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An ASABE Meeting Presentation
DOI: https://doi.org/10.13031/aim.202200815
Paper Number: 2200815

Effect of high-power microwave drying on moisture removal, fissuring and milling yield of rough rice

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Written for presentation at the
2022 ASABE Annual International Meeting
Sponsored by ASABE
Houston, Texas
July 17–20, 2022

ABSTRACT.

Drying rough rice (RR) by employing a microwave (MW) dryer is one of the promising technologies for high throughput drying of high moisture rice. The milling quality of RR in MW drying is important for stakeholders to adopt the drying method. Hence, drying experiments were conducted with an industrial MW dryer operating at 915 MHz. The power levels and heating durations employed were 16, 18, and 20 kW and 1, 2, and 3 min, respectively for a single pass drying. The RR's moisture content, surface temperature, fissuring and head rice yield (HRY) were determined. The maximum measured surface temperature of RR at severe (20 kW for 3 min) and least severe (16 kW and 1 min) treatment conditions were 91.86°C and 62.56°C, respectively. The initial moisture content of RR was 21%. The severe MW drying conditions of 20 kW for 3 min, 18 kW for 3 min and 16 kW for 3 min decreased the moisture content by 9.69, 8.91, and 7.80 percentage points, respectively, from their respective initial moisture content. Maximum fissuring percentages of 90.70% and 93.67% were observed at 18 kW for 3 min drying after one day and after seven days, respectively. Interestingly, the HRY at short MW drying conditions i.e. for one minute at all the MW power levels were higher than that of the gently dried condition (25°C, 56% RH). In conclusion, the high power and short duration MW drying of RR showed huge potential for drying of RR. MW drying has the promise of reducing drying duration and hence resolve issues related to bottlenecks of low drying throughputs that are associated with conventional methods.

Keywords.

high-power microwave drying, Rice drying, moisture content, head rice yield, rice fissuring

Introduction

Rice is a major crop throughout the world. It is harvested at field moisture contents ranging from 20 to 25% w.b. Moisture content of such harvested rough rice need to be reduced to safe storage moisture content of about 12.5% w.b. as soon as possible through drying. The quantum of crop, weather conditions prevailing in rice cultivated areas such as heavy rains, cyclones and floods create an emphasis on high capacity and quick rough rice dryers. In this context, drying rough rice (RR) by employing a microwave (MW) dryer is one of the promising technologies. Further, head rice yield (HRY) is influenced by various factors, among those drying is a major factor. Hence, there is a need for high throughput drying method without compromising on HRY. Studies on taking the assistance of microwave dryer has been carried out previously by the various researchers. In their studies, the MW power levels used were maximum of 10 kW and the heating times were long. As there are various advantages of drying rough rice with microwaves, the work is in progress to take the full advantages of microwaves for industrial rough rice drying. Further, key in this process is the scaling up the drying process employing high power levels of microwaves, thus enhancing the throughput. Hence, keeping in view of the above the present work was taken up with the objectives of (i) initial drying of rough rice in a continuous industrial microwave dryer, and (ii) to evaluate the milling quality of rough rice.

Materials and methods

Raw material procurement

Long grain Hybrid rough rice (RT 7321) harvested at Pocahontas, Arkansas, USA was collected during harvest at filed moisture content. The collected rough rice samples were cleaned and stored at the harvested moisture content in a walk-in refrigerator maintained at 4°C. The rough rice in tote boxes were drawn from the cold chamber 24 h before the experiment.

Drying with industrial microwave (MW) dryer

The samples from each treatment conditions were drawn for determining initial moisture content of rough rice. The initial MW drying experiments were carried out in Industrial MW Dryer (Model No. AMT2448.05, Industrial Microwave Systems, AMTEK, USA) operating at a 915 MHz. The MW dryer consists of 75 kW generator and 48-inch length drying oven along with the console. It is provided with a 54 cm wide continuous belt. The control panel has all the controls for operating the dryer like choosing the MW power level and belt speed. Hopper at the feeding end was adjusted to feed the rough rice at a bed depth of 2 cm and bed width of 42 cm (16.5”). The rough rice of known moisture content was fed on the moving conveyor belt at the feed end in such a way that the RR bed length of 1.22 m (48 inch) pass through the oven only for the treatment duration. The treatment conditions: MW power levels of 16, 18, and 20 kW and treatment durations of 60 s, 120 s and 180 s were chosen based on the trial and error. Rough rice was dried under these conditions (3 MW power levels and 3 durations, 3 replications totaling 27 treatment runs). Rough rice moves from feed end to the exit end via MW dryer. During this continuous travel, the MW at a particular power levels causes the heating of RR and subsequent loss of moisture from the grain.

Before the rice falls from the conveyor belt, the surface temperature of the RR was taken with a IR Camera (Model: FLIR E 60, FLIR Systems AB, Sweden). Then the RR on entire portion of the 1.22 m length which underwent MW drying for the designated treatment time. Then the sample for moisture content was drawn which give the moisture loss of RR after drying at each MW drying condition. The required sample was drawn by mixing the treated RR in a tote box and sealed in a double plastic bag.

Gentle air drying

The rough rice samples collected from each MW drying treatment were dried to milling moisture content of 12.5% w.b. following ASAE method D245.5. In this method, the collected samples were spread in a separate perforated tray at about 2 cm depth and the trays were kept in EMC Chamber (Model No. AA-600-PF, R.S.P. Industries Inc., Brooklyn, New York.) maintained at 25°C and 56% RH. Gentle air drying gently dried rough rice at these conditions to the milling moisture content of 12.5% w.b. Triplicated experiments were conducted at each MW power level and at each duration.

Moisture content of rough rice

Moisture content of rough rice was determined following AACC method 44-15.02. During the moisture content measurement, about 15 g of rice was taken into a drying pan. After taking the weights of the drying pan and sample, sample and drying pans were kept in a Convection hot air oven (Model No. 1370FM, Sheldon Manufacturing Inc., 300N, 26 TH Cornelius, OR-97113, USA) set at 130°C for 24 h. After 24 h, the sample were removed and cooled to room temperature in a desiccator, weight was taken and moisture was calculated. Average value of triplicated samples was reported for all the treatments.

Surface Temperature of rough rice

Surface temperature of rough rice immediately after coming from MW was measured with the help of IR Camera (Model: FLIR E 60, FLIR Systems AB, Sweden). From the thermal image the surface temperature of the rough rice at three different points were noted down.

Fissuring of rough rice

Fissuring of rough rice after one day from the MW drying treatment and after seven days was measured by taking the X-ray Image of 50 kernels at a time with the help of X-ray Imaging System (Model: UltraFocus, Faxitron Bioptics LLC, AZ, USA). The seven days after MW drying treatment was assumed to be the time required for complete development of fissures in the kernels, hence X-ray imaging after seven days. For these two 50 kernels lots of RR were counted from each sample and used in the imaging. The number fissured kernels from each image was manually counted and percentage of fissures were calculated.

Head rice yield (HRY)

For HRY determination, 150 g of RR at milling moisture content of 12.5% w.b. was taken. The husk was removed with the help of Rice Huller (Model: THU-35A, Satake Engineering Co., Ltd., Higashihiroshima, Japan). The rice huller was pre-adjusted to suit for this long grain. Later, the dehulled rice was milled in a McGill #2 laboratory Miller (McGill #2 Rice Mill, RAPSCO, Brookshire, TX). The time for milling was determined initially developing degree of milling curve (Milling duration vs surface lipid content). The milled rice was carefully removed from the mill, husk and unmatured broken grain was aspirated with the help of aspirator. Then, head rice and rice fractions were separated with the help of shaker table and finally manually. From the mass of head rice obtained, the head rice yield was calculated as the ratio of mass of head rice to the mass of rough rice multiplied by 100.

Results and discussions

Moisture content of rough rice during MW drying

Moisture content of rough rice just before feeding to the MW Dryer and immediately after coming from MW were measured. The initial average moisture content of RR was about 21% (wet basis). The severe MW drying conditions of 20 kW for 3 min, 18 kW for 3 min and 16 kW for 3 min reduced the moisture content of about 9.69%, 8.91%, and 7.80%, respectively from their respective initial moisture content. The least moisture reduction of 1.45% from its initial moisture content was resulted at least severe MW treatment of 16 kW for 1 min.

Surface temperature of rough rice

Surface temperature of rough rice immediately after coming out from MW Dryer was measured with the help of an IR Camera. The measured surface temperature of RR varied from minimum of 62.6°C at least severe drying condition (16 kW and 1 min) to 91.9°C at severe drying condition (20 kW for 3 min). At all other MW drying conditions, the surface temperature was recorded between the minimum and maximum values. At the given MW power level, with the increased treatment duration the surface temperature of rough rice increased.

Fissuring of rough rice

Fissuring of rough rice was measured by analyzing X-ray images after one day and after seven days from the MW drying without fully drying to milling moisture content. Maximum fissuring percentages of 90.70% and 93.67% were observed at 18 kW for 3 min drying after one day and after seven days, respectively. In contrary, the severe treatment condition of 20 kW for 3 min drying resulted in fissuring percentages of 86.22% and 85.33% after one day and after seven days, respectively. Fissuring percentage of harvested moisture content and Gentle air-dried rice kernels were less than 2.0% only.

Head rice yield

HRY at short MW drying conditions i.e., MW drying treatment for one minute at all the MW power levels were higher than that of the Gentle air-dried condition.

Similarly, the HRY at short MW drying conditions i.e., MW drying treatment for one minute at all the MW power levels were higher than that of the Gentle air-dried condition. The minimum HRY was observed at 18 kW for 3 min MW drying followed by 16 kW 3 min (Figure 1).

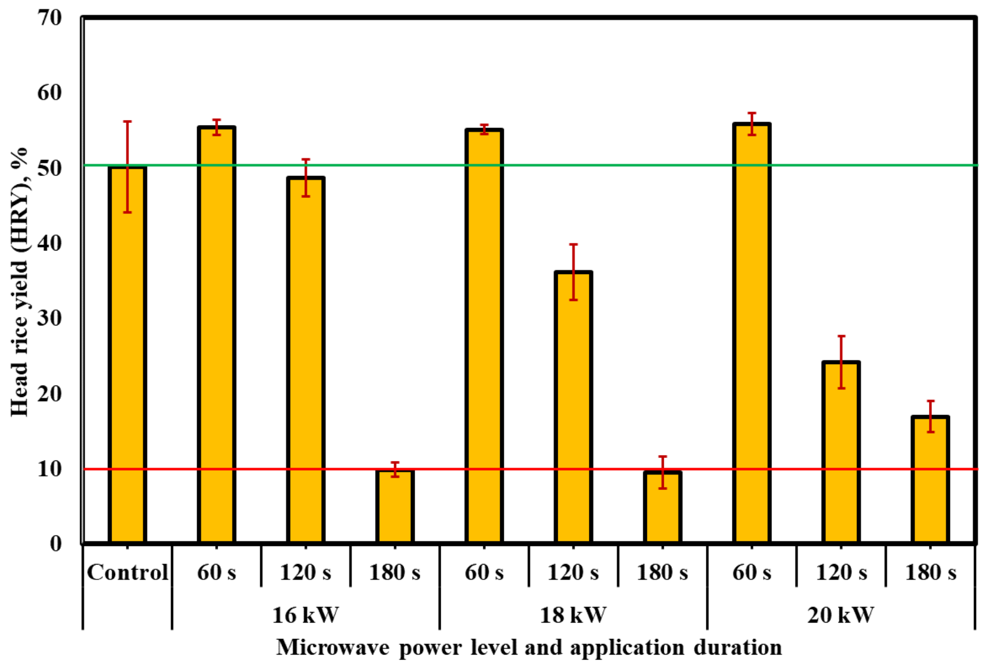

Figure 1. Head rice yield for various drying treatments.

Conclusions

Drying experiments were conducted with an industrial MW dryer operating at 915 MHz. The moisture content before and after MW drying, rough rice's surface temperature profile immediately after MW drying, fissuring percentage on day 1 and on day 7 after MW drying, and head rice yield (HRY) of rice were measured. The severe MW drying conditions of 20 kW for 3 min, 18 kW for 3 min and 16 kW for 3 min decreased the moisture content of about 9.69%, 8.91%, and 7.80%, respectively from their respective initial moisture content. This is way beyond the moisture to be removed from the field harvested moisture content. The rough rice surface temperatures ranged from minimum of 62.6°C (at 16 kW and 1 min) to 91.9°C (at 20 kW for 3 min). Maximum fissuring percentages of 90.70% and 93.67% were observed at 18 kW for 3 min drying after one day and after seven days, respectively. Interestingly, the HRY at short MW drying conditions i.e., for one minute at all the MW power levels were higher than that of the gentle air-dried condition. And, the HRY at short MW drying conditions i.e., MW drying treatment for one minute at all the MW power levels were higher than that of the gentle air-dried condition. It may be concluded that the least severe MW Drying conditions are producing the positive impact. Further, concluded that the negative impact on milling quality of rice is not linear as some of the positive impact is seen at the severe treatment condition of 20 kW for 3 min. Hence, besides realizing the advantages of MW drying at higher power levels for shorter duration, further investigations are required to explore the impact of the higher MW power levels.

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