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COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE:
Development of New Techniques for Improved Shelf life of Rough and Brown Rice and Stabilization of Rice Bran

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OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

Objectives:

Our previous results showed that infrared (IR) radiation heating has a great promise to improve the drying efficiency and milling quality and achieve effective disinfection of rough rice and effective stabilization for rice bran. However, further study is needed to investigate the effects of IR heating and tempering treatments on storage stability of rough rice and brown rice, determine optimum IR heating and tempering conditions to achieve effective stabilization of rice bran, and evaluate the effect of IR heating and tempering treatment on the quality of rice bran oil. To achieve the goal, the following specific objectives were chosen:

1. Investigate impact of IR heating and tempering treatments on storage stability of rough rice and brown rice.

2. Optimize the IR-heating and tempering conditions to achieve an effective stabilization for rice bran.

3. Evaluate the quality and shelf life of rice bran oil at optimized IR heating and tempering treatment conditions.

Experimental Procedures

<u>Investigate impact of IR heating and tempering treatments on storage stability of rough rice and brown rice</u>

Samples and IR treatment

Freshly harvested medium grain rice, M206, obtained from Farmers' Rice Cooperative (West Sacramento, CA) was used for conducting this research. The initial moisture content (MC) of rough rice sample was 20.10±0.21% (w.b.)at harvest. The MC is on wet basis and was determined by the air oven method (130°C for 24 h) (ASAE, 1995). The rice sample was split into three equal portions. The first portion of samples was heated using IR device developed in the Food Processing Laboratory in the Department of Biological and Agricultural Engineering, University of California, Davis (Fig.1). The detailed descriptions for IR unit were mentioned in our previous publications (Pan et al., 2008 and 2011; Khir et al., 2011 and 2012). The samples of a single layer with loading rate of 2 kg/m^2 were heated using IR under radiation intensity of 5000 W/m^2 to temperature of 60ºC. The temperature of heated rice was measured using a type-T thermocouple (time constant of 0.15s, Omega Engineering Inc. Stamford, Conn) immediately after the heated rice was collected into preheated container with the targeted rice temperature of 60ºC (Pan et al., 2008). The mass losses during IR heating and the initial MC were used to calculate the moisture loss during the heating period. The moisture loss was calculated as the difference between the initial MC and the MC after IR heating and is reported as percentage points. After IR heating, the tempering treatment was conducted by keeping rice samples in closed containers placed in an incubator set at temperature of 60 ºC for 4h. After the tempering treatment, samples were allowed to cool naturally to the room conditions (temperature of 22±1°C and relative humidity of 43±2%). The temperatures of the sample were close to room after 30 min of cooling. The mass changes caused by tempering and cooling treatment were recorded at the end of cooling and used to calculate the moisture loss based on the MCs after the corresponding IR treatment. After the tempering treatments, the samples were dried with ambient air to final moisture content of 13.80±0.12%. The second portion of samples were dried from their initial MC to MC of 13.91±0.24% using the current drying practice applied in the rice industry which uses 43°C air drying for 20 min followed by a 4 h tempering at room temperature for each drying pass. The third portion of samples were dried from the original moisture contents to 13.89±0.21% by one single pass without tempering using ambient air with temperature of 22±1°C. The drying characteristics of infrared drying (IRD), hot air drying (HAD), and ambient drying (AAD) methods were determined. The dried samples using (IRD), (HAD) and (AAD) methods were divided into two portions. One was used as rough rice and the other one was dehusked to produce brown rice. The rough rice and brown rice samples were stored at accelerated storage conditions (temperature of 35ºC and relative humidity of 65±3.0%) for four months. Milling quality and degradation in lipids were evaluated over the storage time. Three replicates were conducted for each condition.

Fig. 1. Infrared treatment of rough rice.

Storage stability of rough rice and brown rice

The degradation of lipids in rough and brown can impart off flavors by undergoing lipid hydrolysis and subsequent oxidation during storage. Therefore, free fatty acid levels and peroxide values are normally used as indicators of storage stability for rough and brown rice. (Dautant et al., 2007; Piggott et al., 1991; Shin et al., 1986; Sowbhagya & Bhattacharya, 1976; Yasumatsu et al., 1966; Yoshida et al., 2011). Consequently free fatty acid (FFA) and peroxide value (PV) were used as indicators to detect any notable degradation of lipids in rough rice and brown rice during storage. The FFA and PV were measured according to the AOCS Official Method Ca 5a-40 and AOCS Official Method Cd 8-53.

Evaluation of milling quality

The rice samples dried using IRD, HAD and AAD (4000g each) were dehulled and milled using Yamamoto Husker (FC-2K) and Yamamto Rice Mill (VP-222N, Yamamoto Co. Ltd., Japan). The samples were milled three times to achieve well-milled rice as defined by the Federal Grain Inspection Service (FGIS). The setting of throughput and whitening were 1 and 4 during the first two milling passes and 1 and 5 during the third milling pass. Total rice yield (TRY), head rice yield (HRY) and whiteness index (WI) were used to evaluate the effects of different drying methods on milling quality. The HRY was determined with Graincheck (Foss North America, Eden Prairie, MN). The WI was determined by the whiteness tester (C-300, Kett Electronic Laboratory, Tokyo, Japan). A high index number indicates whiter milled rice. All reported milling quality indicators are averages of three replicates.

<u>Determine optimum IR-heating and tempering conditions to achieve an effective stabilization for rice bran.</u>

Ambient air dried rough rice sample with MC of 13.80±0.12% (wb) was dehusked and milled to produce rice bran. The MC of rice bran was 11.1± 0.1%, determined by oven method (105ºC for 3 h) (AOAC, 1995b). The rice bran samples of 250 g with loading rate of 2.7 kg/ m^2 were heated using the IR device as a thin layer of 3mm (Fig. 2). They were heated to reach to corresponding temperatures of 60, 80 and 100 ºC. After IR heating, the tempering treatment was conducted by keeping rice bran samples in closed containers placed in an incubator set at temperature equal to heated sample temperatures (60, 80 and 100 ºC) for four hours. After the tempering treatment, samples were allowed to cool naturally to the room conditions (temperature of 23±1°C and relative humidity of 42±4%). For each treatment, three replicates were performed. The treated samples were stored at 25 ºC and relative humidity of 46±3% for 29 days. The concentration of total FFA in rice bran oil, expressed as oleic acid percentage, was evaluated according to alcoholic alkali titration method. After extraction and evaporation of hexane, 3.0 ml of ethanol with 0.5% w/v phenolphthalein was added to the extracted oil. The mixture was stirred sufficiently and then titrated by 20 mM aqueous NaOH. During the titration, the mixture was vigorously shaken until the first permanent pink color appeared. The total FFAs percentage was calculated by the following equation.

$$FFA\% = \frac{V_{NaOH} \cdot N_{NaOH} \cdot 282.5}{10 \cdot m_{oil}} \times 100\%$$

where, FFA% is FFA percentage in rice bran oil (g/ 100 g rice bran oil), V_{NaOH} is amount of titrant (ml), N_{NaOH} is normality of titrant (mmol/ml), 282.5 is molecular weight of oleic acid and m_{oil} is weight of rice bran oil (g).

The FFA concentration of rice bran after each treatment and over the storage period were quantified and compared to those of untreated samples. Based on the changes in FFA concentration over storage time, the kinetic of FFAs formation was investigated for treated samples and compared with those untreated according the following approach:

Triglycerides $\xrightarrow[\text{k (include } k_1 \text{ and } k_2)]{\text{Lipase enzyme}}$ Free fatty acids

$$r_{FFA} = \frac{dC}{dt} = \frac{k_1 C}{k_2 C - 1}$$

$$\frac{\ln(A+1)}{t} = \frac{k_2 C_0 A}{t} - k_1$$

$$A = \frac{C - C_o}{C_o}$$

where C is total FFAs concentration, t is time (day), k_1 and k_2 are kinetic parameters of FFAs formation. $C=C_o$ at $t = t_0$

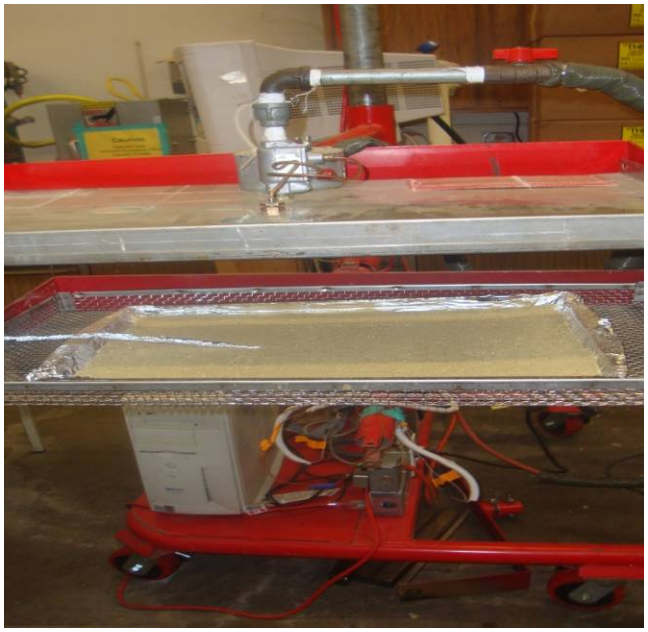


Fig. 2. Infrared treatment of rice bran.

Evaluate the effect of IR heating and tempering treatment on the quality of rice bran oil

Rice bran oil extraction was conducted using hexane method. The treated samples were mixed with hexane and shaken for 1h at 20 ℃ using a mechanical shaker followed by centrifugation (Eppendorf 5810 R, Germany) (Fig.3) for 6 min at 3500 rpm (Fig. 3). Rotatory evaporator (R. Büchi, Switzerland) was applied to evaporate the hexane and the oil was collected for chemical analysis (Fig. 4). The chemical characteristics, including free fatty acids (FFA) and peroxide value (PV) were determined using the standard procedures by AOCS (Cd 8b-90). The color of rice bran oil (RBO) was determined using Minolta Chroma Meter (CR-200 reflectance colorimeter, Minolta, Japan) (Fig. 5).

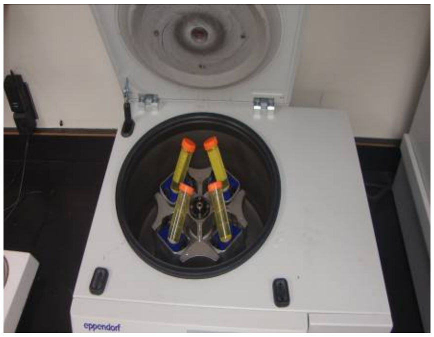


Fig. 3. Centrifuging process.

Fig. 4. Rotatory evaporator.

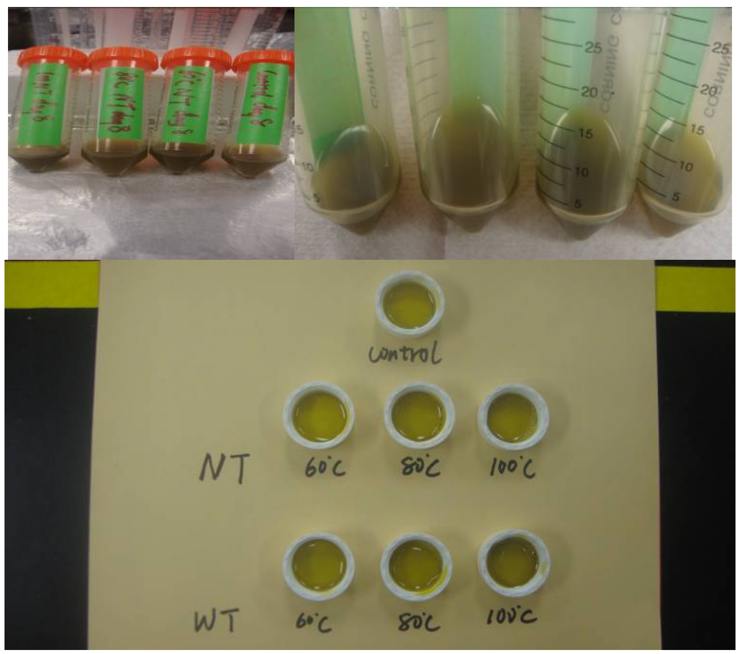


Fig. 5. Extracted oil from treated and untreated rice bran.
(NT-no tempering, WT-with tempering)

SUMMARY OF 2012 RESEARCH (major accomplishments), BY OBJECTIVE:

Investigate the impact of IR heating and tempering treatments on storage stability of rough rice and brown rice.

After rough rice samples with initial moisture content of 20.10 % were heated using IR, they reach to temperature of 60 ºC after 58s. The corresponding moisture removal during IR heating only was 2.1 % points. After tempering and natural cooling additional 1.2 % point of moisture was removed. This means that about 23.24 % of total moisture was removed during less than one minute and more moisture about 13.26 % of total moisture was removed during natural cooling without consuming energy (Fig. 6). For hot air drying (HAD) ambient air drying (AAD), it took 13 h (three drying passes) and 18 h to dry the rough rice from initial MC of 20.10% to MC of 13.91 % and 13.89 % for HAD and AAD, respectively (Figs 7 and 8). These results confirm our previous findings that high heating and drying rate of rough rice can be achieved under infrared heating.

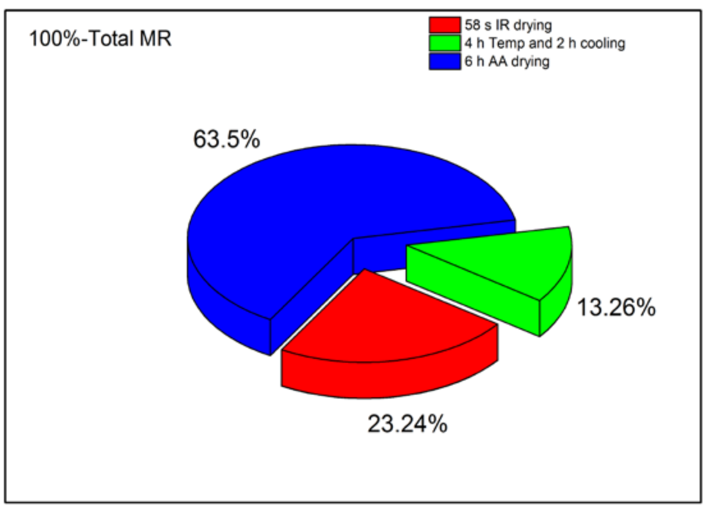


Fig. 6. Percentage of moisture removal under infrared heating.

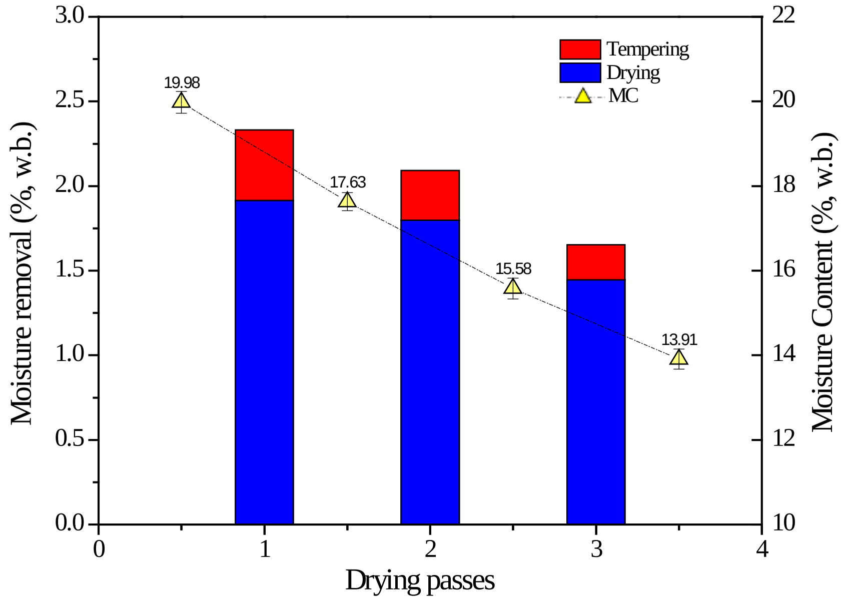


Fig. 7. Moisture removal during hot air drying.

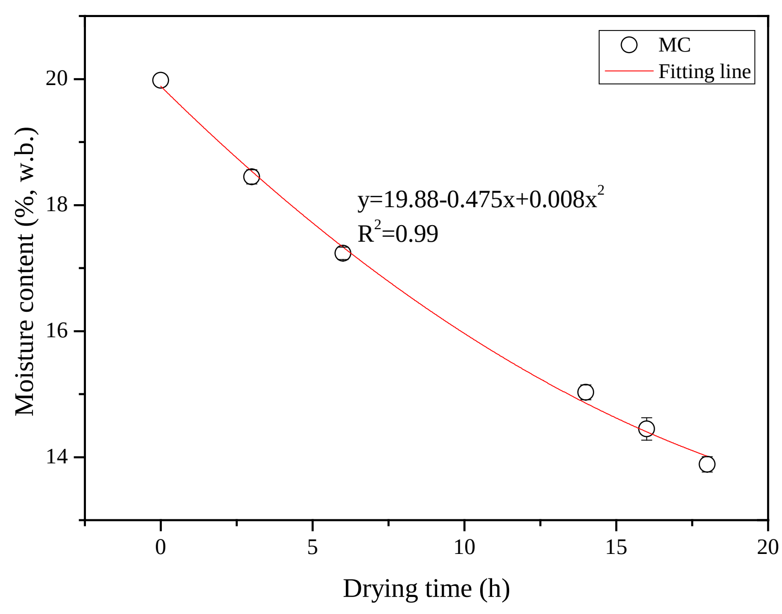
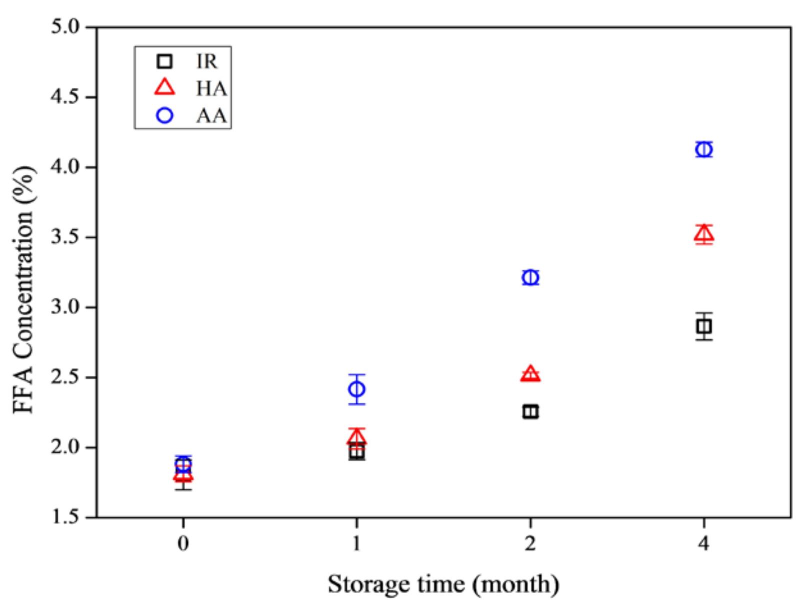


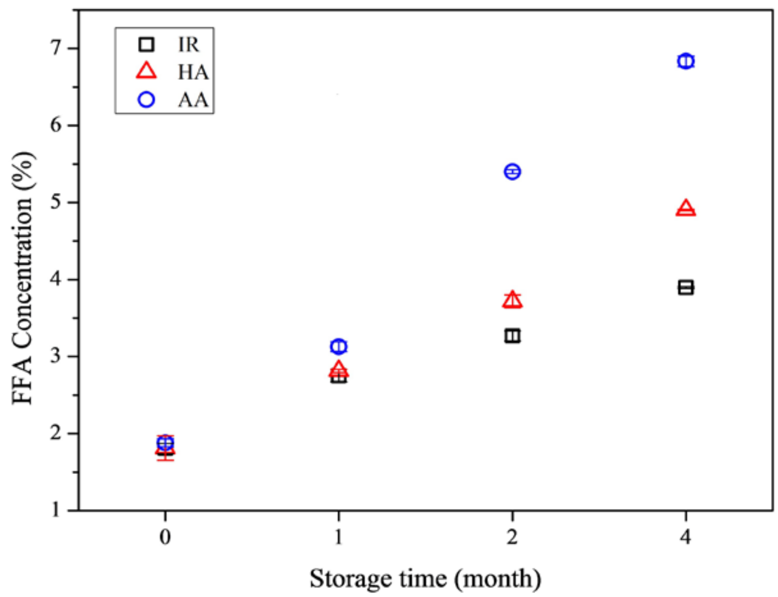
Fig. 8. Moisture removal during ambient air drying.

Storage stability

Concentration of free fatty acid (FFA) over storage time of rough rice and brown rice is shown in Fig. 9. The average of FFA concentration increased from 1.8±0.2% to 2.7±0.1%, 3.2±0.1% and 4.2±0.1% on month four of storage for rough rice dried using IRD, HAD and AAD, respectively (Fig. 9a). The corresponding values of brown rice were 3.4±0.3%, 4.9±0.3% and 6.8±0.1% (Fig. 9b). The results showed that rough rice was more stable than brown rice. For both rough rice and brown rice, FFA level rose gradually during storage period from month zero to month one and there was no significant difference ($P<0.05$) in FAA concentration for rough and brown rice dried using IRD, HAD and AAD. However, after four months of storage IRD significantly ($P<0.05$) reduced FFA in brown rice compered to HAD and AAD. This means that infrared heating resulted in an effective inactivation of the lipase and consequent improvement in the long-term storage stability of rough and brown rice was achieved under an accelerated storage condition. For peroxide, the average of peroxide values increased from 6.05±0.25, 5.72±0.29 and 5.94±0.15 mill equivalent/1000g on month zero of storage to 8.38±0.08, 8.46±0.10 and 8.16±0.15 mill equivalent/1000g on month one of storage for rough rice dried using IRD, HAD and AAD, respectively (Fig. 10a). The corresponding values of brown rice were 12.60±0.01%, 12.80±0.05% and 12.61±0.02% (Fig. 10b). There was no significant difference among peroxide values for rough rice dried with IRD, HAD and AAD. A similar trend was observed for brown rice. After month four of storage the peroxide value decreased to 3.89±0.38, 4.44±0.27 and 4.87±0.32 for rough rice and 5.86±0.20, 6.09±0.18 and 5.91±0.22 for brown rice. The increased trend of peroxide during the first period of storage may be due to the partial oxidation of oxidized compounded such as ketones by elevated temperature of storage (Farag, 1992). It is important to notice that the peroxide value of brown rice was much lower than that of 20.00 mill equivalent/1000g defined as an indicator of unstable state (AOCS (2004).

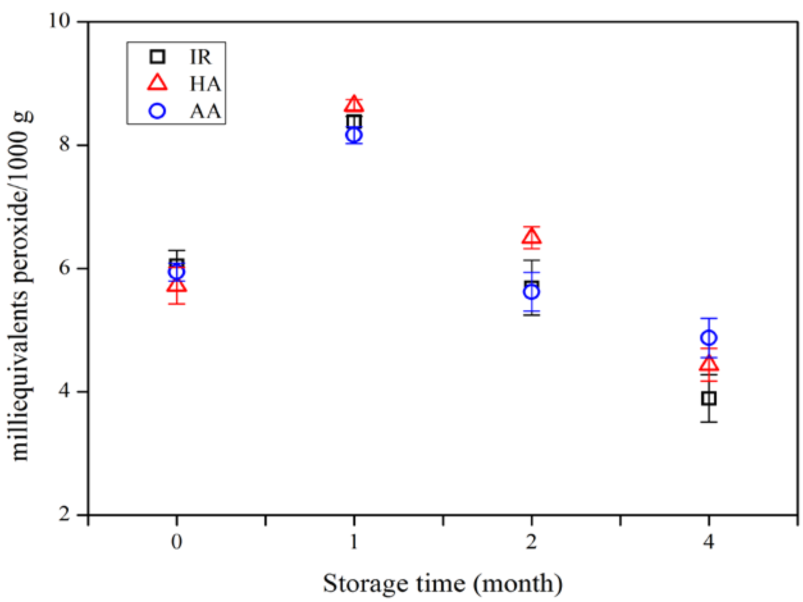


(a)

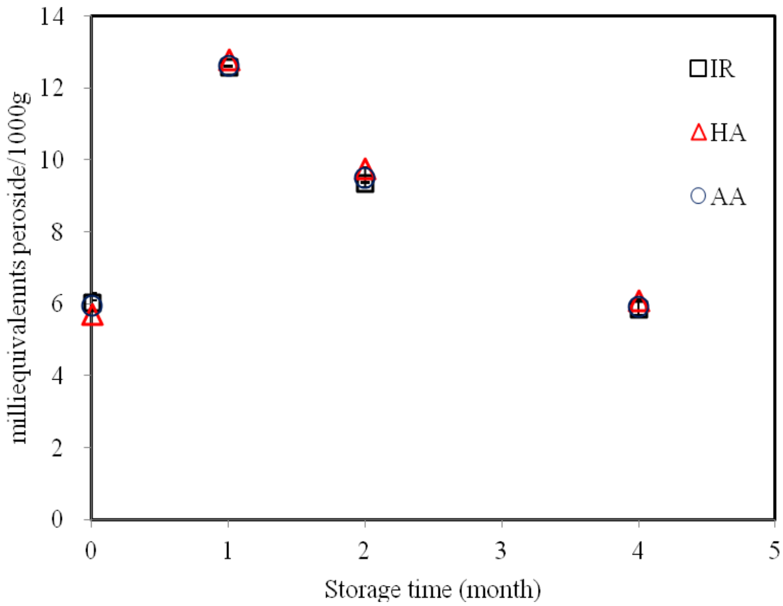


(b)

Fig. 9. Concentration of free fatty acid (FFA) over storage time of (a) rough rice, (b) brown rice. (IRD-infrared drying, HAD-hot air drying, AAD-hot air drying)



(a)



(b)

Fig. 10. Concentration of peroxide over storage time of (a) rough rice, (b) brown rice. (IRD-infrared drying, HAD-hot air drying, AAD-hot air drying)

Milling quality

The milling quality results at different storage times for rice dried with different methods are shown in Figures 11 and 12. The results revealed that the infrared dried rice (IRD) and tempering followed by natural cooling had similar and higher TRY and HRY compared to those dried with AHD and AAD. For all tested drying methods, the TRY values significantly ($P<.05$) increased after one month of storage, however, for storage times more than one month the maximum variation (less than 1%) among the different drying methods was found to be not significant at $p<0.5$. On average, the TRY values increased from 67.06±3.10, 67.76±2.80 and 66.60±2.60 percent at zero month of storage to 68.23±2.50, 67.95±1.60% and 67.82±2.10% percent at month two of storage for rice dried with IRD, AHD and AAD, respectively (Fig. 11). The corresponding TRY values at month four of storage were 69.10±1.50 %, 68.70±2.20% and 68.90±2.20% percent. Similarly, for all tested drying methods, the HRY values significantly ($P<.05$) increased after one month of storage. Additionally, the HRY values of rice dried with IRD were significantly ($P<.05$) higher than those of rice dried with AHD and AAD. On average, the HRY values were 58.81±1.60, 56.58±2.40 and 56.84±2.1 percent at month one of storage (Fig. 12). The corresponding HRY values at month four of storage were 60.50±2.20%, 68.31±1.90% and 59.10±2.10% percent. The results showed that the WI values of milled were above 38.50 units under different drying methods. However, after storage time of month two and four, there was a decreased trend in WI values (Fig. 13). This may be due to the elevated temperature of accelerated storage conditions. For samples dried using AAD the decrease in WI may be due to enzyme activity. The obtained results clearly demonstrated that good milling quality can be achieved by heating the rice to about 60 ºC using IR followed by tempering and natural cooling. These results are in agreement with earlier reports (Pan et al., 2008 and 2011; Khir et al., 2011 and 2012).

The obtained resulted clearly revealed that high drying rate and good milling quality can be achieved by heating the rice to about 60 ºC using IR followed by tempering and natural cooling. Moreover, the results obtained from this research demonstrated that the improvement of brown rice stability during storage can be achieved by heating rough rice using IR to temperature 60 ºC followed by tempering and natural cooling. Stability of rice brown would lead to an increase in storage capacity, a reduction in energy use and an increase its consumption.

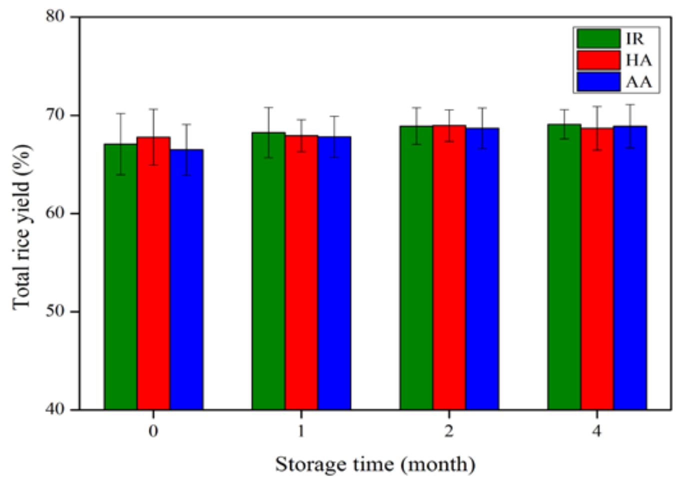


Fig. 11. Total rice yields over storage time of rough rice dried with different methods. (IR-Infrared, HA-Hot air, AA-Ambient air)

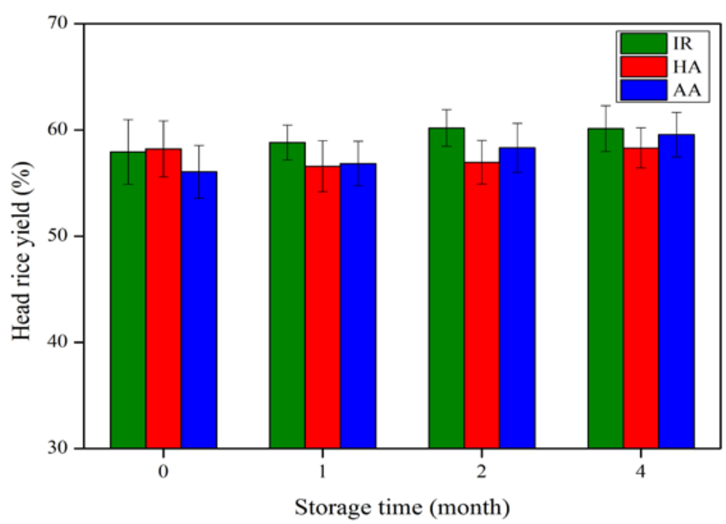


Fig. 12. Head rice yields over storage time of rough rice dried with different methods. (IR-Infrared, HA-Hot air, AA-Ambient air)

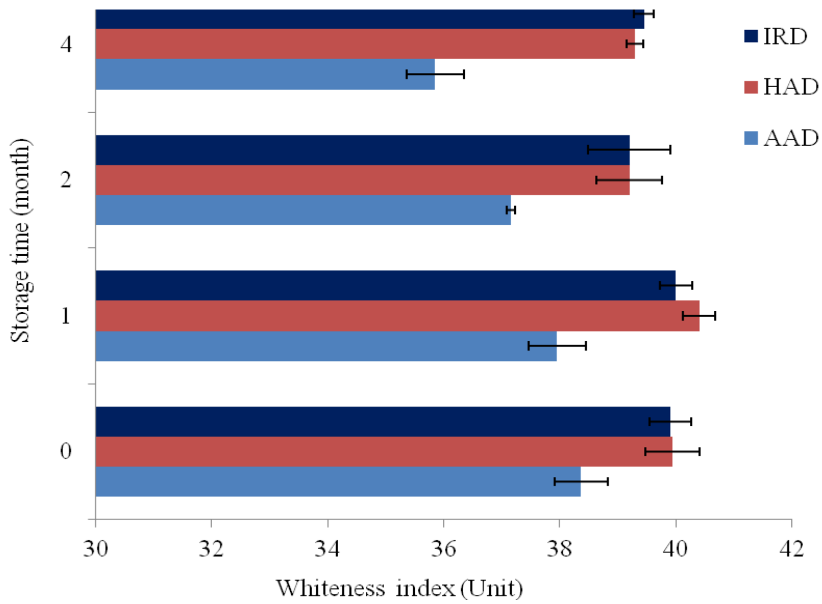


Fig. 13. Whiteness index (WI) over storage time of rice dried with different methods.
(IR-Infrared, HA-Hot air, AA-Ambient air)

Determine optimum IR-heating and tempering conditions to achieve an effective stabilization for rice bran.

The results showed that high heating and effective lipase inactivation of rice bran can be achieved with a short IR heating time followed by tempering treatment. It took only about 42, 73 and 103 s to achieved about 60 °C, 80 °C and 100 °C rice bran temperature, respectively (Fig. 14). IR heating of rice bran to temperatures about 100°C has shown promising potentials to completely inactivate lipase enzyme. It was observed that the concentration of FFAs could be remained under 4% for more than four weeks. The kinetic parameters (k_1 and k_2) for the FFAs formation in the stored rice bran were determined by plotting (ln (A+1))t versus At^{-1} (Fig. 15). Fig. 16 shows that there is good agreement between the experimental and kinetics data, and that the kinetic model explained fairly well the formation of FFAs. The kinetics model can successfully describe and predict the FFAs formation in the course of rice bran storage which can be used to prepare proper processing plan for rice bran.

Based on obtained results, infrared heating has a potential to be used as an efficiently alternative method to conventional heating methods to achieve a high heating rate and effective stabilization of rice bran. IR heating of rice bran to temperature of 100 °C followed by tempering treatment for 4 h has shown promising potentials to completely inactivate lipase enzyme and reduce the FFA concentration under 4% for a storage time of more than four weeks. Therefore, IR heating could potentially be used to inactivate the lipase enzyme and improve the utilization of rice bran. However, the effect of IR heating on rice bran oil quality needs to be evaluated, which is discussed in the next section. This may lead to apply a new approach for processing and utilize the rice bran to obtain edible oil prior to its deterioration.

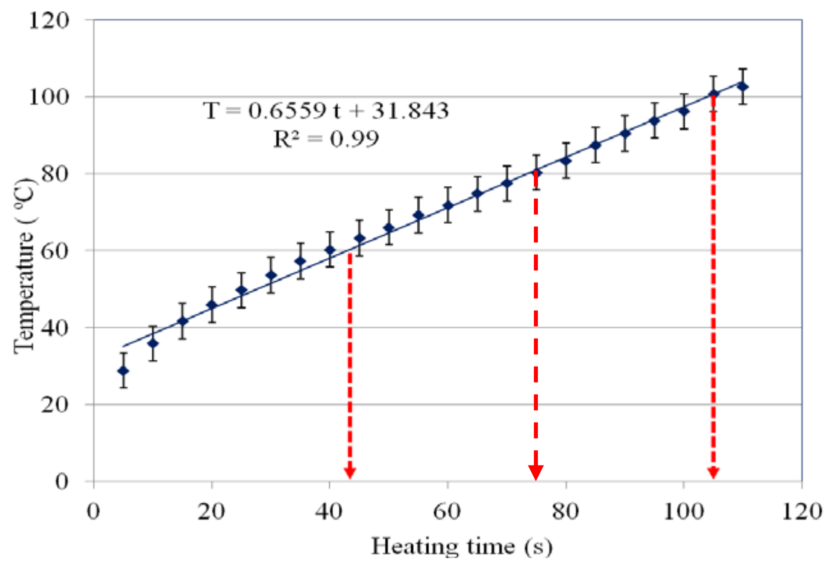


Fig. 14. Relationship between heating time and temperature of rice bran under infrared heating.

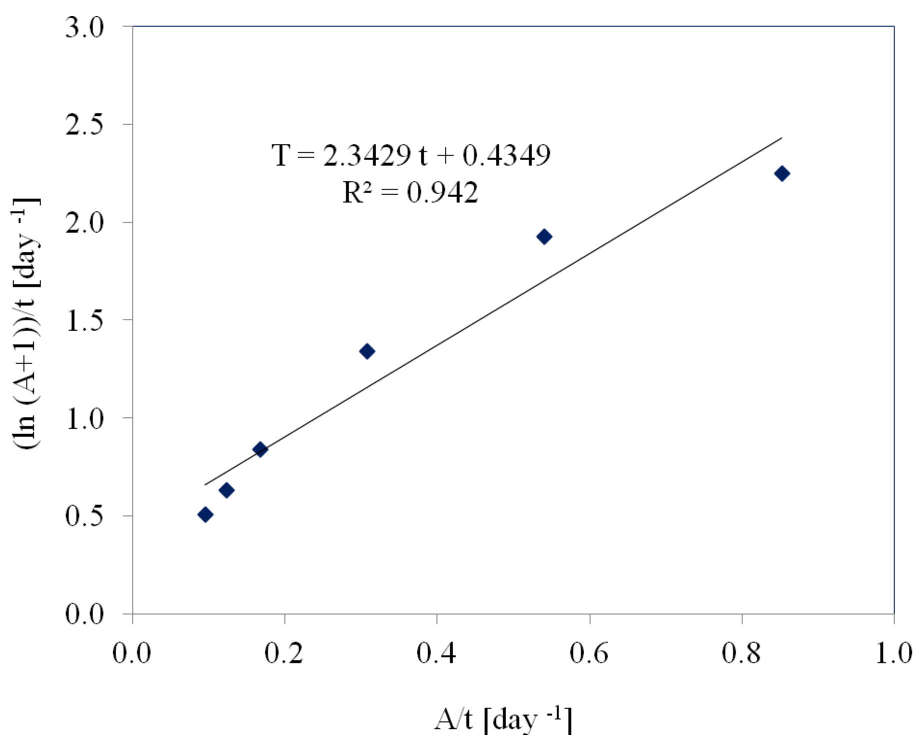


Fig. 15. Plot of (ln (A+1)) t^{-1} versus At^{-1} of untreated rice bran over storage time.

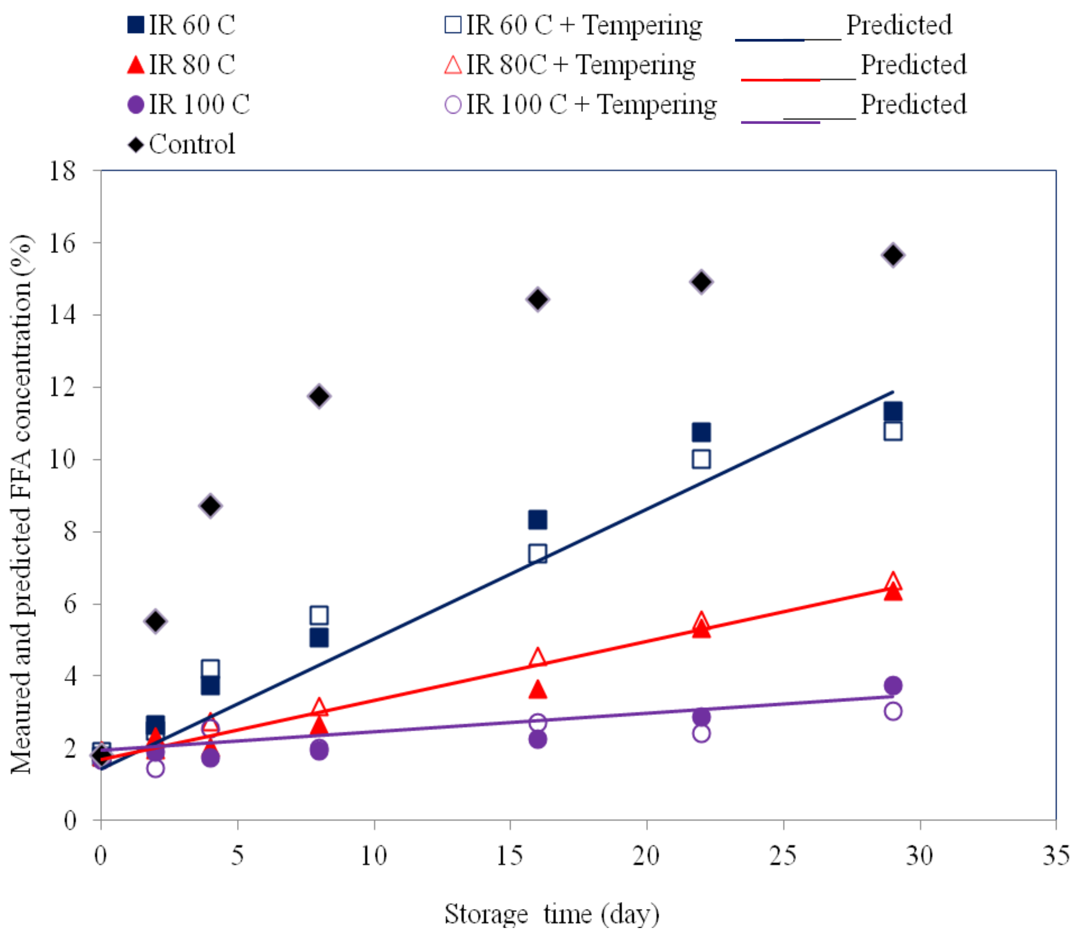


Fig. 16. Measured and predicted FFA concentration under different IR and tempering treatments for rice bran over storage time.

Quality of rice bran oil

Stabilization of rice bran to inactivate enzyme activity is the most important factor in rice bran oil extraction. Improper or no stabilization causes the increase in free fatty acids (FFA) and peroxide value (PV) contents and affects the oil quality. The FFAs produced by the hydrolysis reaction are harmful compounds which make rice bran oil (RBO) unsuitable for edible use. The PV measures the quantity of peroxides in the oil as a result of oxidation reactions caused by elevated temperatures during stabilization process. Consequently, FFA and PV were the parameters used for evaluating the quality of RBO. The effect of IR heating and tempering treatments on RBO quality (FFA, PV and lightness) is shown in tables 1, 2 and 3. RBO of treated samples had significantly ($P<0.05$) lower FFA content than that of untreated samples (control). For example, the FFA contents of RBO at storage time of 21 days were 4.34±0.16%, 4.49±0.05% and 13.29±0.07% for samples treated with IR to temperature of 100 ºC with and without tempering and control, respectively (Table. 1). The corresponding FFA contents at storage time of 29 days were 4.84±0.20%, 4.79±0.02% and 13.63±0.21%. There was no significant difference among FFA contents of BRO under IR heating with or without tempering conditions. It is important to notice that the maximum level of FFA is 5.5 % for refined edible oil

(CODEX Standers 210, 1999). For PV, the IR heating and tempering treatment led to increase the content compared to control. However, the PV level under tested conditions was less that of 20 milliequivalents peroxides/1000g accepted by (CODEX Standers 210, 1999) for crude oil. The PV values of BRO ranged from 7.16 to 17.9 milliequivalents peroxides/1000g under IR heating and tempering treatment (Table 2). The results of RBO color, another important characteristic for determining visual acceptance of oil, indicated that IR heating and tempering treatment slightly reduced lightness compared to control (Table 3). The values of lightness were 45% higher than which is visually accepted (Shin et al., 1986). However, there is no color standard for RBO. The results clearly reveled that the IR heating and tempering treatment can be used as an effective approach to stabilize the rice bran and control the enzyme activity in rice bran without affecting the quality of oil extracted from the bran.

Table 1. FFA content in oil from rice bran treated by IR heating and tempering

Treatment	Storage time (day)						
	0	2	4	8	14	21	29
Control	03.31±0.02abc	08.79±0.16e	10.47±0.25c	11.78±0.12d	12.84±0.04d	13.29±0.07f	13.63±0.21e
60 ^{o}C	03.51±0.16bcd	04.81±0.05d	05.59±0.09b	06.31±0.04c	07.80±0.16c	08.98±0.12d	10.21±0.12c
80 ^{o}C	03.42±0.14abcd	03.52±0.11bc	03.78±0.05a	04.16±0.05b	04.70±0.11b	05.34±0.02b	05.99±0.02b
100 ^{o}C	03.24±0.04ab	03.38±0.02ab	03.87±0.14a	03.95±0.07ab	04.20±0.00a	04.49±0.05a	04.79±0.02a
60 ^{o}C+T	03.70±0.07d	04.94±0.09d	05.39±0.20b	06.42±0.16c	07.97±0.04c	09.20±0.04e	10.94±0.14d
80 ^{o}C+T	03.56±0.16cd	03.64±0.09c	03.73±0.11a	04.07±0.02b	04.80±0.02b	05.76±0.00c	06.28±0.27b
100 ^{o}C+T	03.19±0.11a	03.21±0.02a	03.60±0.00a	03.77±0.04a	04.37±0.11a	04.34±0.16a	04.84±0.20a

Values (means ± standard deviation) in each column followed by the same letter are not significantly different at $p<0.05$.

Table 2. PV content in oil from rice bran treated by IR heating and tempering.

Treatment	Storage time (day)						
	0	2	4	8	14	21	29
control	08.84±0.06	07.14±0.98	08.50±0.93	05.3±0.64	06.60±0.41	06.03±0.14	05.56±0.79
60 ^{o}C	11.17±0.34	13.93±0.80	12.00±0.54	11.93±0.45	10.49±0.41	10.68±0.31	07.62±0.41
80 ^{o}C	14.99±0.72	15.10±0.65	13.06±0.44	11.99±0.01	11.47±0.04	10.22±0.25	06.09±0.04
100 ^{o}C	15.80±0.99	17.26±0.95	13.17±0.26	08.26±0.82	09.65±0.70	10.10±0.71	09.23±0.30
60 ^{o}C +T	12.50±0.71	12.32±0.78	09.23±0.33	07.58±0.71	07.34±0.23	08.96±0.89	08.21±0.54
80 ^{o}C +T	14.52±0.33	12.09±0.75	07.97±0.76	07.17±0.60	10.05±0.43	11.87±0.17	08.29±0.41
100 ^{o}C +T	14.90±0.50	08.57±0.92	10.22±0.75	10.22±0.39	09.69±0.72	12.76±0.36	07.16±0.23

Values (means ± standard deviation)

Table 3. Effect of IR heating and tempering treatment on lightness of rice bran oil.

Treatments	Storage time (day)						
	0	2	4	8	14	21	29
Control	60.94±0.14	64.70±0.27	63.97±0.08	58.38±0.21	63.52±0.20	60.89±0.15	58.27±0.17
60 ^{o}C	65.39±0.09	65.52±0.06	64.22±0.15	58.46±0.31	57.44±0.20	58.78±0.25	57.74±0.22
80 ^{o}C	57.07±0.09	56.77±0.13	61.84±0.19	58.20±0.37	53.16±0.08	58.05±0.17	56.67±0.45
100 ^{o}C	65.04±0.28	55.94±0.19	58.92±0.24	55.24±0.22	52.80±0.06	52.61±0.14	48.38±0.16
60 ^{o}C +T	57.53±0.18	47.36±0.11	63.87±0.09	62.36±0.59	59.26±0.19	57.30±0.23	55.12±0.22
80 ^{o}C +T	53.53±0.45	57.35±0.42	55.36±0.13	52.89±0.20	54.63±0.21	50.09±0.29	52.13±0.13
100 ^{o}C +T	46.01±0.52	52.08±0.11	53.77±0.09	49.13±0.27	50.86±0.07	45.04±0.20	45.32±0.11

Values (means ± standard deviation)

Conclusions and recommendations

The research clearly revealed that high drying rate and good milling quality can be achieved by heating the rice to about 60 ºC using IR followed by tempering and natural cooling. Moreover, the results demonstrated that the improvement of brown rice stability during storage can be achieved by heating rough rice using IR to temperature 60 ºC followed by tempering for 4 h and natural cooling. Stability of rice brown would lead to increase storage capacity, reduce energy use and increase its consumption. Additionally, the results indicated that IR heating and tempering treatment can be used as an efficiently alternative method to conventional heating methods to achieve a high heating rate and effective stabilization of rice bran. IR heating of rice bran to temperature of 100 °C followed by tempering treatment for 4 h has shown promising potentials to completely inactivate lipase enzyme and reduce the FFA concentration under 4% for a storage time of more than four weeks. Therefore, IR heating could potentially be used to inactivate the lipase and control the enzyme activity in rice bran without affecting the quality of oil extracted from the bran.

It is recommended to use IR to heat rough rice to 60 °C followed by tempering treatment for four hours for rice drying. This can be an effective approach to inactivate the lipase and extend the storage stability of brown rice under accelerated storage conditions. However, furthermore study is needed to investigate the effects of IR heating and tempering treatments on feasibility of brown rice storage under ambient conditions and evaluate the cooking and sensory quality of IR dried brown rice. Also, IR heating of rice bran to temperature of 80-100 °C followed by tempering treatment for 4 h can be used to inactivate the lipase and control the enzyme activity in rice bran without affecting the quality of oil extracted from the bran. This may lead to apply a new approach for processing and utilize the rice bran to obtain edible oil prior to its deterioration.

PUBLICATIONS OR REPORTS

N/A

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CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESEARCH

The objective of this research was to investigate the effects of IR heating and tempering treatments on storage stability of rough rice and brown rice, determine optimumal IR heating and tempering conditions to achieve effective stabilization of rice bran, and evaluate the quality of rice bran oil under IR heating and tempering treatment. The rice samples were split into three equal portions. The first portion of rice samples was heated using IR to surface temperature of 60°C followed by tempering treatment for 4h and natural cooling. The second and third portions were dried using hot and ambient drying methods. The dried samples were divided into two portions. One was used as rough rice and the other one was dehusked to produce brown rice. The rough rice and brown rice samples were stored at accelerated storage conditions for four months. Milling quality and degradation in lipids were evaluated over the storage time. To study the rice bran stability and the quality of rice bran oil, ambient air dried rough rice sample was dehusked and milled to produce rice bran. The rice bran samples heated to reach to corresponding temperatures of 60, 80 and 100 ºC using IR heating. After IR heating, the tempering treatment was conducted by keeping rice bran samples in closed containers placed in an incubator set at temperature equal to heated sample temperature for 4h. After the tempering treatment, samples were allowed to cool naturally to the room temperature. The treated samples were stored for 29 days. The stability of treated bran samples over storage time was determined. The quality of oil extracted from treated samples was evaluated as well.

The research clearly revealed that high drying rate and good milling quality can be achieved by heating the rice to about 60 ºC using IR followed by tempering and natural cooling. Moreover, the results demonstrated that the improvement of brown rice stability during storage can be achieved by heating rough rice using IR to temperature 60 ºC followed by tempering for 4 h and natural cooling. Stability of rice brown would lead to increase storage capacity, reduce energy use and increase its consumption. Additionally, the results indicated that IR heating and tempering treatment can be used as an efficiently alternative method to conventional heating methods to achieve a high heating rate and effective stabilization of rice bran. IR heating of rice bran to temperature of 100 °C followed by tempering treatment for 4 h has shown promising potentials to inactivate lipase enzyme and reduce the FFA concentration under 4% for a storage time of more than four weeks. Therefore, IR heating could potentially be used to inactivate the lipase and control the enzyme activity in rice bran without affecting the quality of oil extracted from the bran.

It is recommended to use IR to heat rough rice to 60 °C followed by tempering treatment for four hours for rice drying. This can be an effective approach to inactivate the lipase and extend the storage stability of brown rice under accelerated storage conditions. However, furthermore study is needed to investigate the effects of IR heating and tempering treatments on feasibility of brown rice storage under ambient conditions and evaluate the cooking and sensory quality of treated brown rice. Also, IR heating of rice bran to temperature of 80-100 °C followed by tempering treatment for 4 h can be used to inactivate the lipase and control the enzyme activity in rice bran without affecting the quality of oil extracted from the bran. This may lead to apply a new approach for processing and utilize the rice bran to obtain edible oil prior to its deterioration.

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