ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2012– December 31, 2012

PROJECT TITLE: Development of New Techniques for Stabilization of Rice Bran

PROJECT LEADER:

Zhongli Pan
Processed Food Research Unit
USDA ARS WRRC
800 Buchanan St.
Albany, CA 94710

Department of Biological and Agricultural Engineering
University of California, Davis
One Shields Ave
Davis, CA 95616

PRINCIPAL INVESTIGATORS:

Zhongli Pan and Griffiths Atungulu
Department of Biological and Agricultural Engineering
University of California, Davis
One Shields Ave
Davis, CA 95616

REPORT PREPARED BY:

Ragab Khir, Griffiths Atungulu and Zhongli Pan
Department of Biological and Agricultural Engineering
University of California, Davis
One Shields Ave.
Davis, CA 95616

LEVEL OF 2010 FUNDING: $29,900

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

Objectives:

The main objective of this research was to develop alternative techniques for stabilizing rice bran. Alternatives are needed to replace the heating methods such as hot air, drum drying and dry extrusion which are commonly used in industry. These techniques subject rice bran to severe and non-uniform heating which damages valuable components and also result in high energy consumption. Infrared radiation (IR), Ultraviolet (UV) and Pulsed Electric Field (PEF) have promising potentials to be used for stabilizing rice bran. The objectives of this research were as follows:

1. Study the effects of IR heating and tempering treatments on moisture loss, milling quality and enzyme inactivation of rough rice with different initial moisture contents.

2. Investigate impact of UV and PEF treatments on enzyme inactivation of brown rice and rice bran.

3. Provide recommendations for conducting the most effective stabilization approach.

Experimental Procedures

<u>Study the effects of IR heating and tempering treatments on moisture loss, milling quality and enzyme inactivation of rough rice with different initial moisture contents.</u>

Samples

Freshly harvested medium grain rice, M206, obtained from Farmers' Rice Cooperative (West Sacramento, CA) was used for conducting this research. The moisture content (MC) of rough rice was 32.51±0.09% (high MC) at harvest. In order to obtain rice samples with different initial MCs, rice sample with high MC was equally divided into three portions and two of the portions were spread evenly on the floor and slowly dried to 25.54±0.11% and 20.07±0.04% at ambient air temperature of 19±1°C . The thickness of rice bed on the floor was less than 4 cm. During the slow drying, the rice was mixed frequently to ensure uniform drying. Then the rice samples with MC of 32.51%, 25.54% and 20.07% were then placed in polyethylene bags and sealed to ensure no moisture loss before they were used for the tests. The rice samples were further divided into 250 g samples with a sample divider at the test time. The control samples were prepared by drying rough rice from aforementioned initial MCs to MC of 14.60±0.30% using ambient air dying. All reported moisture contents are on dry weight basis and were determined by the air oven method (130°C for 24 h) (ASAE, 1995).

Infrared, tempering and cooling treatments

The rough rice samples with different initial MCs were 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). A single layer

of the samples with loading rate of 2 kg/m^2 were heated for one and two drying passes under radiation intensity of 5000 W/m^2. They were heated for 55s to reach surface temperature of 60ºC during each drying pass. 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 loss 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 various durations (1, 2, 3, 4 and 5 h). After the tempering treatment, samples were allowed to cool naturally to the room conditions (temperature of 21±1°C and relative humidity of 46±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 IR treatment, the milling quality was evaluated. Also, the enzyme inactivation and FFA of rice bran obtained by milling the rough rice samples were determined during 38 days of storage and compared to those of untreated samples (control). Three replicates were performed for each treatment.

Fig. 1. Infrared treatment of rough rice.

<u>Investigate impact of UV and PEF treatments on enzyme inactivation of brown rice and rice bran.</u>

UV treatment

Ambient air dried rough rice samples of 250 g with MC of 14.60±0.30% were dehusked to produce brown rice. The brown rice samples were treated under double side UV heating system as shown in Fig. 2. Two UV-C lamps (Sankyo Denki, G 15T8, Japan) were placed in an incubator to control the temperature during the treatment. The samples were preheated to 30 ºC during the UV treatment. The samples were heated for different exposure times of 10, 20 and 30 min. The samples were consistently mixed to achieve uniform exposure. After UV treatment, the milling quality was evaluated. Also, the enzyme inactivation and FFA of rice bran obtained by milling the brown rice samples over one month storage period was determined and quantified and compared to those of untreated samples (control). Three replicates were performed for each treatment.

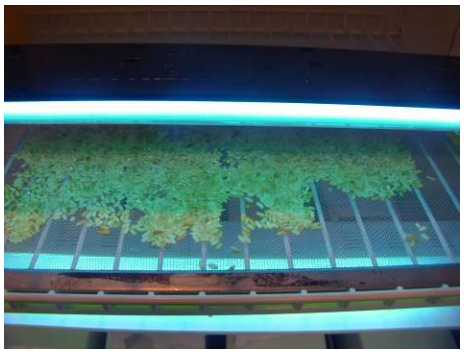

Fig. 2. Double sided UV treatment of brown rice.

PEF treatment

Ambient air dried rough rice sample with MC of 14.60±0.30% was dehusked and milled to produce rice bran. The MC of rice bran was 12.4± 0.30%, determined by oven method (105ºC for 3 h) (AOAC, 1995b). The rice bran samples of 50 g were treated in PEF chamber (22 KV/cm) as shown in Fig. 3. The samples were treated with 0, 200, 400, 600, 800, and 1000 pulses at frequencies of 0.25, 0.50 and 1.00 Hz. After PEF treatment the rice bran was stored and the enzyme inactivation and FFA studied during the storage period of 23 days. Three replicates were performed for each treatment.

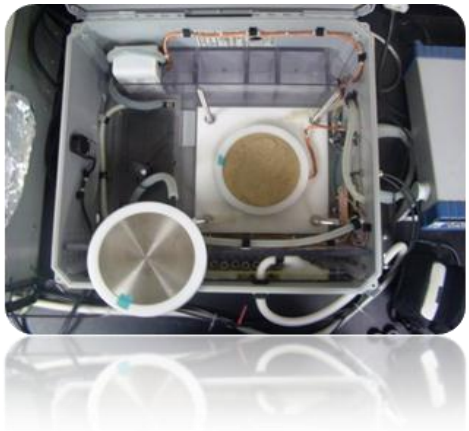

Fig.3. PEF treatment for rice bran.

Measurement of free fatty acid (FFA) concentration

All treated and untreated rice bran samples were packed in plastic ziplock bags and kept at temperature of 20±1°C and relative humidity of 46±3.0% during the storage periods. To measure FFA concentration, rice bran sample of 2g was mixed with 40 mL hexane and shaken for 1h at 20 ºC using mechanical shaker. The mixture was then centrifuged (Eppendorf 5810 R, Germany) for 6 min at 3500 rpm. The amount of extracted oil was then measured gravimetrically. 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 cm^3 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 (cm^3), N_{NaOH} is normality of titrant ($mmol/cm^3$), 282.5 is molecular weight of oleic acid and m_{oil} is weight of rice bran oil (g).

Evaluation of milling quality

The treated and untreated rice samples (250g 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 treatments 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.

Statistical analysis

The results were analyzed using PASS software (NCSS-2007).The data were statistically evaluated ($P<0.05$) in PASS using the t test with the assumption of equal variances.

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

<u>Study the effects of IR heating and tempering treatments on moisture loss, milling quality and enzyme inactivation of rough rice with different initial moisture contents.</u>

Moisture loss and milling quality

Rough rice samples with different initial MCs reached surface temperature of 60 ºC after 55s of IR heating in each drying pass. For one drying pass, corresponding moisture loss during IR heating only, were 1.7%, 2.2% and 2.9% for samples with initial MCs of 20.06%, 25.53% and 32.50%, respectively. For two drying passes, the moisture loss during IR heating was 5.8% for samples with initial MC of 32.50% (Table 1). For one drying pass, the total moisture loss during IR heating, tempering and cooling treatments, were 3.3%, 3.8% and 5.6% for samples with initial MCs of 20.06%, 25.53% and 32.50%, respectively. The total moisture loss during two drying passes was 12.2% for samples with initial MC of 32.50% (Table 1.). The results clearly showed

that a high drying rate can be achieved using IR heating for a short time. After IR heating, the tempering treatment significantly improved the moisture removal during cooling. The tempering process reduced the moisture gradient in rice kernels and allowed the moisture to equilibrate before the rice kernels were cooled. Therefore, the tempering process is a critical step to increase the moisture removal during cooling of the rough rice.

Additionally, the results revealed that the infrared dried rice with tempering followed by natural cooling had similar and higher TRY and HRY compared to the control (Tables 2 and 3). On average, the TRYs were 63.1±0.6, 66.5±0.3 and 67.4±0.5 percent for samples with initial MCs of 20.06%, 25.53% and 32.50%, respectively. The corresponding values for the control were 64.2±0.27, 62.8±0.1 and 62.6±0.4 percent (Table 2). The averages of HRY were 48.0±0.2, 51.5±0.4 and 49.4±0.3 percent for samples with initial MCs of 20.06%, 25.53% and 32.50%, respectively. The corresponding values for the controls were 49.8±1.5, 50.0±1.3 and 49.3±1.2 percent (Table 3). Also, on average, the TRY and HRY of rice samples dried with drying passes were 66.1±0.3% and 50.6±0.5% compared to 65.01±0.3% and 49.4±0.5% for samples with initial MC of 32.5%. The results showed that the WI of the treated samples was 35.1 units which was slightly less than that of control. It is suspected that storage of fresh rough rice samples in refrigerator for five weeks before starting the test could have contributed to the observed low WI. The obtained resulted clearly demonstrated that high drying rate and good milling quality can be achieved by heating the rice to about 60 ºC 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). Moreover, the results obtained from this research revealed that high drying rate and good milling quality can be achieved by heating the rough rice under two drying passes especially for rice with high initial moisture content.

Table 1. Moisture losses of rice samples with different initial moisture contents under IR heating and tempering treatment for different durations.

Drying pass	Moisture content (%)	Moisture loss (%)										
		IR	Tempering					Total (IR+ tempering)				
			tempering time (h)					tempering time (h)				
			1.0	2.0	3.0	4.0	5.0	1.0	2.0	3.0	4.0	5.0
One	20.1	1.7	0.8	1.0	1.3	1.5	1.6	2.5	2.7	3.0	3.2	3.3
	25.5	2.2	1.5	1.3	1.4	1.4	1.6	3.7	3.5	3.6	3.6	3.8
	32.5	2.9	2.2	2.6	2.6	2.6	2.7	5.1	5.5	5.5	5.5	5.6
Two	32.5	5.8	6.0	6.0	6.1	6.2	6.4	11.8	11.8	11.9	12.0	12.2

Table 2. Total rice yield (TRY) (percent) of rough rice with different initial MCs under IR heating followed by tempering treatments for different durations.

Tempering time(h)	One pass			Two pass
	Initial moisture content (%)			32.5
	20.06	25.53	32.5	
1	63.28±0.31abcd	65.92±0.88b	67.00±1.00bc	66.65±0.43b
2	63.08±0.22bcd	66.64±0.93b	67.36±0.27bc	65.81±0.51b
3	62.30±1.00c	66.63±0.46b	66.81±1.27bc	66.25±0.31b
4	62.15±0.54d	66.59±1.23b	67.63±0.07bc	66.03±0.07b
5	63.53±0.75ab	66.74±0.53b	68.14±0.91c	65.85±0.66b
Control	64.2±0.3a	62.8±0.2a	62.6±0.4a	65.0±0.1a

Means with same letters in each column are not significantly different at $p<0.05$.

Table 3. Head rice yield (HRY) percent of rough rice with different initial MCs under IR heating followed by tempering treatments for different durations.

Tempering time (h)	One pass			Two pass
	Initial moisture content (%)			32.5
	20.06	25.53	32.5	
1	48.04±1.43a	50.84±1.01b	49.50 ±1.20a	50.30±0.75a
2	48.13±2.39a	52.00±1.56b	49.29±1.36a	49.99±0.70a
3	47.60±1.09a	51.41±0.73b	49.81±2.46a	51.39±0.81a
4	47.99±2.41a	51.61±0.62b	49.80±0.83a	50.89±0.54a
5	48.11±1.43a	51.54±0.25b	49.02±0.59a	50.65±2.92a
Control	49.84±1.47a	50.01±1.34a	49.3±1.24a	49.38±0.47a

Means with same letters in each column are not significantly different at $p<0.05$.

Enzyme inactivation

To evaluate the effectiveness of IR heating on inactivation of lipase enzyme, the FFA concentration was determined in rice bran produced from rough rice samples with different initial MCs treated with IR followed by tempering treatments and stored for different durations. The results indicated that FFAs concentration was affected by initial MC and tempering duration (Figs 4, 5, 6, and 7). The concentration of FFAs increased in the course of storage time under all tested conditions. However, concentration profiles of treated samples and control are different. For untreated samples (control), the FFA concentration increased sharply to more than 10% during less than seven days of storage. This means that FFAs formed as a result of hydrolysis reaction in the rice bran and lipase enzyme catalyzed this reaction to proceed rapidly. Thus untreated rice bran cannot be utilized for oil production after one week from the date of milling.

On the other hand, for samples treated with IR followed by tempering treatment for more than three hours, the FFA concentration increased gradually to 10% after 17, 19 and 30 days for samples with initial MC of 20.06%, 25.53% and 32.5 (Figs. 4, 5 and 6). Moreover, for two-pass treatment, the FFA concentration reached 10% after 38 days for rough rice samples with initial MC of 32.5% treated with IR followed by tempering treatment for more than 4 hours during each pass (Fig. 7). This means that the IR heating followed by tempering treatments have a destructive effects on lipase activity. The Lipase activity declined with increase of tempering time and initial moisture content of the rough rice.

The obtained results clearly indicated that the heating of rough rice to 60 ºC using IR followed by tempering treatment for at least three hours can be an effective approach to inactivate the lipase and extend the storage stability of rice bran for up to 38 days after milling. At the same time, high drying rate and good milling quality can be simultaneously achieved for rough rice. Further studies are vital to ascertain the potential of using IR heating and tempering treatments to improve the storability of brown rice.

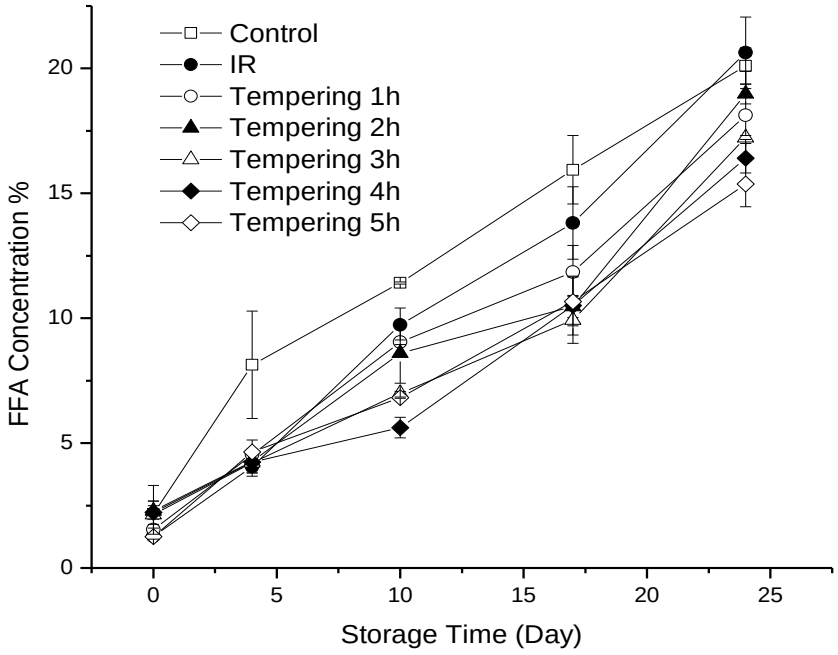

Fig. 4. Total FFAs concentration over storage time for treated rough rice with initial MC 20.06% under different tempering treatment durations.

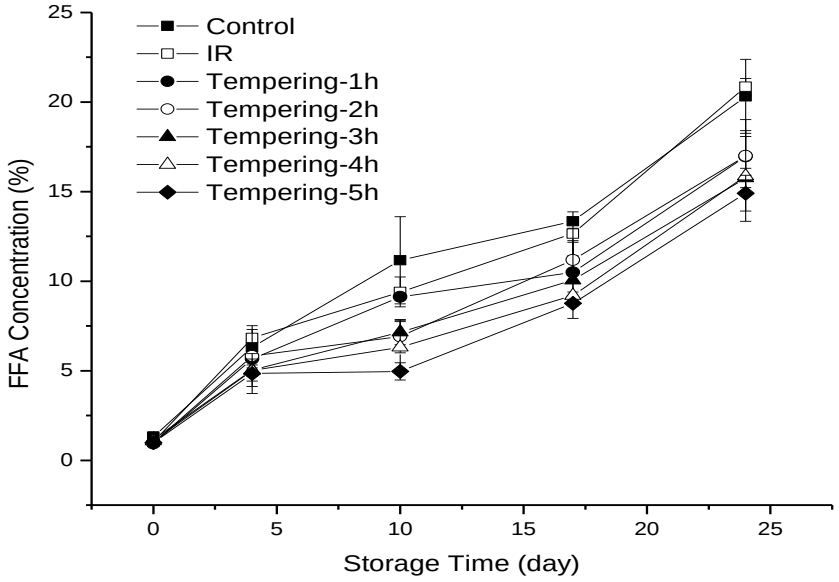

Fig. 5. Total FFAs concentration over storage time for treated rough rice with initial MC 25.53% under different tempering treatment durations.

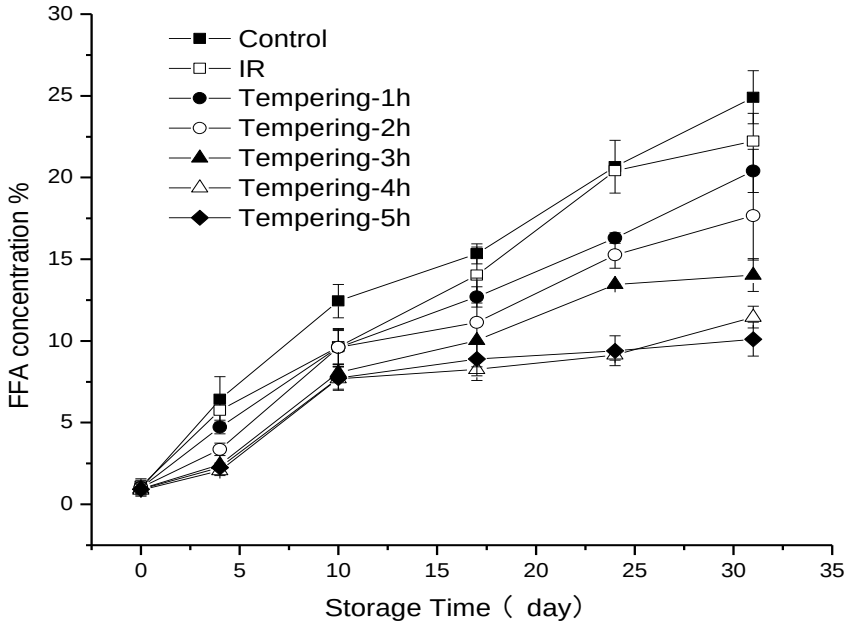

Fig. 6. Total FFAs concentration over storage time for treated rough rice with initial MC 32.50% under different tempering treatment durations.

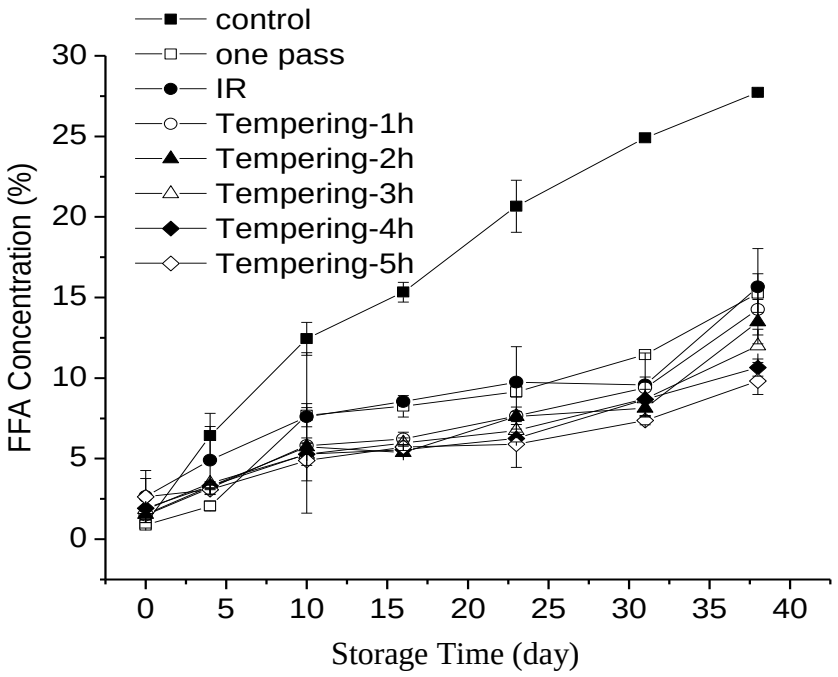

Fig. 7. Total FFAs concentration over storage time for rough rice with initial MC 32.50% treated with two passes under different tempering treatment durations.

Based on our preliminary tests of IR heating of rice bran to temperature levels ranging from 80 to 100ºC, it was observed that the concentration of FFAs could be kept under 4% for more than four weeks. Therefore IR heating could potentially be used to inactivate the lipase enzyme and improve the utilization of rice bran. However, furthermore study is needed to optimize the IR-heating conditions and evaluate the effect of IR heating on rice bran oil quality.

Investigate impact of UV and PEF treatments on enzyme inactivation of brown rice and rice bran.

UV effect

The concentration of FFAs over storage time in rice bran produced from treated brown rice samples using UV for different durations is presented in Figs 8, 9 and 10. The results indicated that the concentration of FFAs increased sharply in the course of storage time for treated and untreated sample (control). There was no significant difference in terms of FFAs between treated and untreated samples under all treated conditions. This means that the UV doses studies have no significant effect on lipase activation.

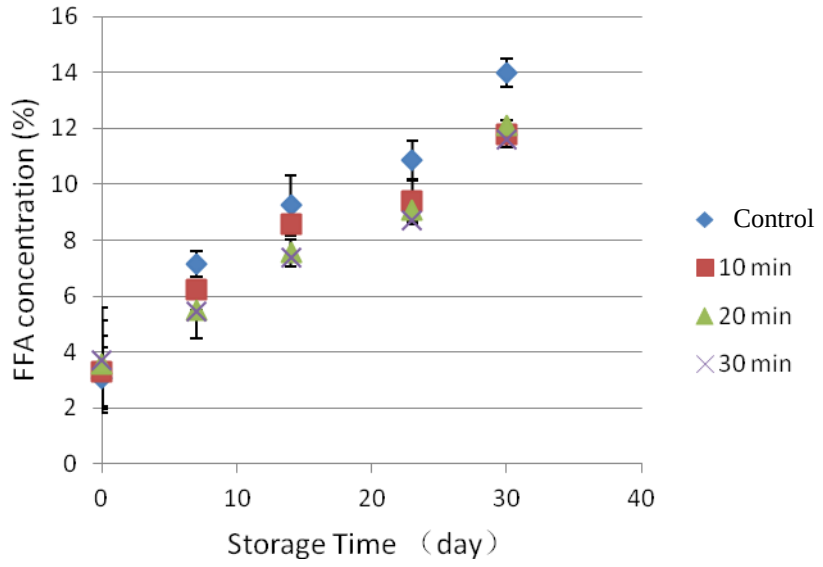

Fig. 8. Total FFAs concentration over storage time for brown rice with initial MC 20.06% treated with UV for different durations.

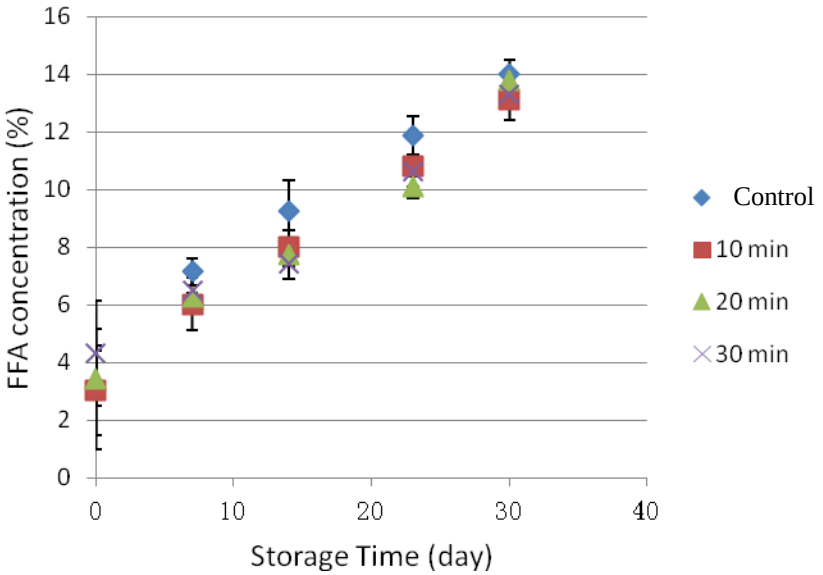

Fig. 9. Total FFAs concentration over storage time for brown rice with initial MC 25.06% treated with UV for different durations.

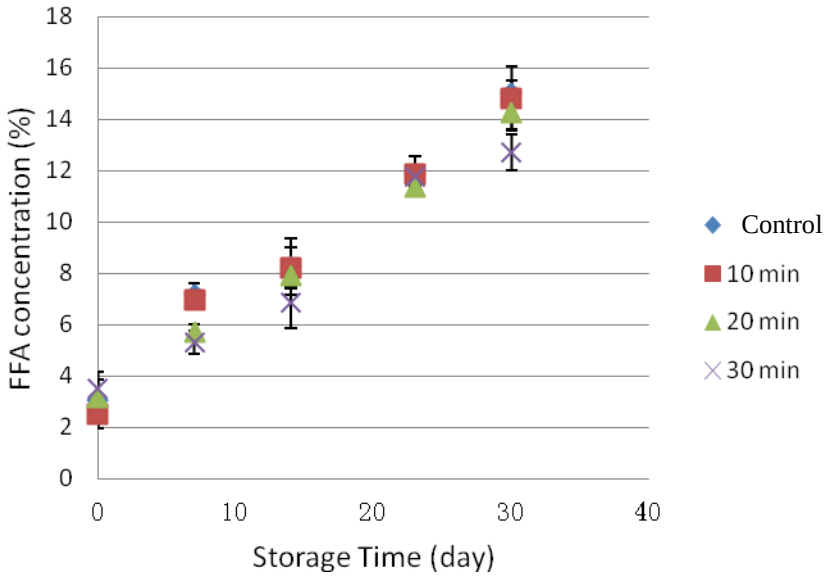

Fig. 10. Total FFAs concentration over storage time for brown rice with initial MC 32.5% treated with UV for different durations.

PEF effect

The concentration of FFAs over storage time in treated rice bran using PEF for different number of pulses at varied frequencies is presented in Figs. 11and 12. The results demonstrated that the concentration of FFAs increased sharply in the course of storage time for treated and untreated samples (control) of rice bran under different number of pulses (Fig.11). Also, the same trend was noticed for bran rice samples treated under different frequencies (Fig.12). There was no significant difference in terms of FFAs between treated and untreated samples of rice bran under all tested conditions of number of pulses and frequencies. This means that the PEF treatment protocol used in the study does not have a significant effect on lipase activation.

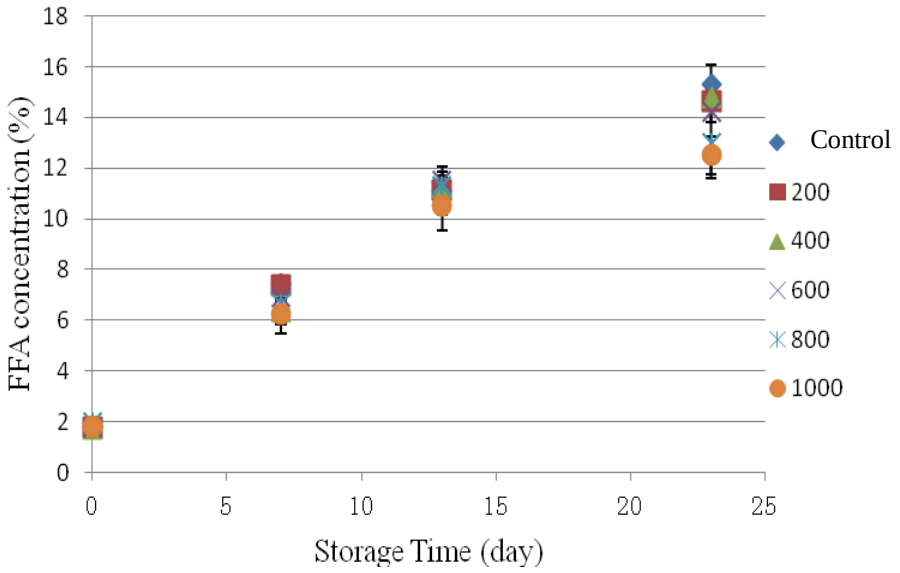

Fig. 11 Total FFAs concentration over storage time for rice bran treated with PEF for different cycles.

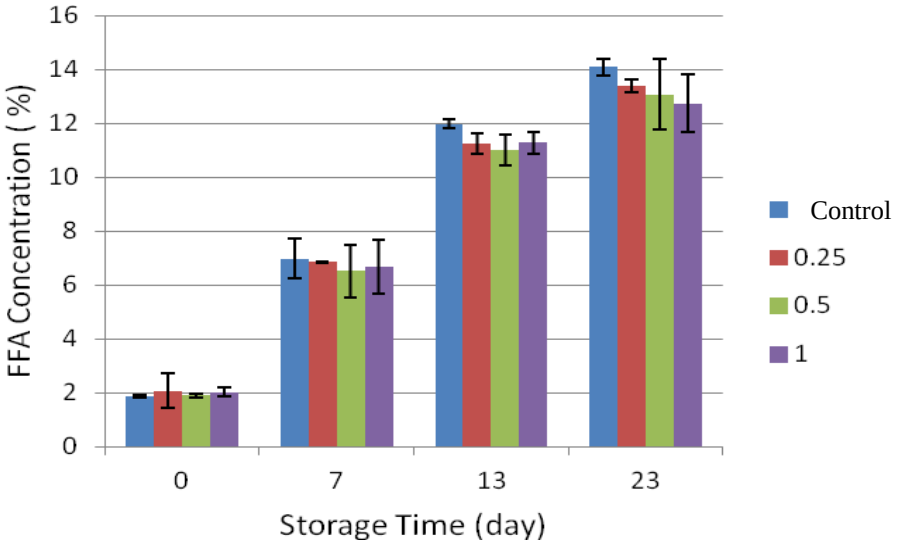

Fig. 12. Total FFAs concentration over storage time for rice bran treated with PEF for different frequencies.

Conclusions and recommendations

The research showed that high heating and drying rates, good milling quality and effective lipase inactivation of rough rice can be achieved with a short IR heating time followed by tempering treatment for at least three hours. It took only about 55 s to achieved about 60°C rice temperature and remove 1.7 to 5.8 percentage point of MC during IR heating alone. The amount of moisture removal depended on the original MC of rice and number of drying passes. The total moisture removal after tempering and cooling was up to about 5.6 and 12.2 percentage points for one and two drying passes, respectively. Additionally, IR-heating followed by tempering treatments was an effective approach to inactivate the lipase enzyme and extended the storage stability of rice bran after milling up to 38 days. The tempering process after the rapid IR heating and moisture removal is essential to achieve high rice milling quality, improve the amount of moisture removal during cooling and enhance the enzyme inactivation. The UV and PEF treatments for the brown rice and rice bran did not have a significant effect on lipase activation.

It is recommended to use IR to heat rough rice to 60 °C followed by tempering treatment for at least three hours. This can be an effective approach to inactivate the lipase and extend the storage stability of rice bran for up to 38 days after milling. Also, the treatments result in high drying rate and good milling quality of rough rice. Based on our preliminary tests, IR heating of rice bran to temperatures higher than 80°C has shown promising potentials to completely inactivate lipase enzyme. However, optimization of the process and effect IR heating on storability of brown rice and the quality of rice bran oil need to be investigated in the future. These findings can lead to new approaches of rice bran stabilization and utilization.

PUBLICATIONS OR REPORTS

N/A

REFERENCES

AOAC, 1995b. Official Methods of Analysis of AOAC International. Method 925.10, Solids and Moisture in Flour-Air Oven Method-Final Action

ASABE Standards. 2006. S352.2: Moisture measurement-Ungrounded grain and seeds. *in* ASABE Standards, American Society of Agricultural and Biological Engineers, St. Joseph, Mich.

Khir, R., Pan, Z., Salim, A., Hartsough, B.R., Mohamed, S., 2011. Moisture diffusivity of rough rice under infrared radiation drying. LWT- Food Sc. and Technol., 44, 1126-1132.

Khir, R., Pan, Z., Thompson, J. F., Salim, A., Hartsough, B.R., El-Amir, S. M., 2012. Moisture removal characteristics of thin layer rough rice under sequenced infrared radiation heating and cooling. J. Food Processing and Preservation. In press.

Pan, Z., Khir, R., Godfrey, L. D., Lewis, R., Thompson, J. F., Salim, A., 2008. Feasibility of simultaneous rough rice drying and disinfestations by infrared radiation heating and rice milling quality. J. Food Eng., 48, 469-479.

Pan, Z., Khir, R., Bett-Garber, K.L., Champagne, E.T., Thompson, J. F., Salim, A., Hartsough, B.R., Mohamed, S., 2011. Drying characteristics and quality of rough rice under infrared radiation heating. Trans. of ASABE, 54(1), 203-210.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESEARCH

The objective of this research was to develop alternative techniques for stabilizing rice bran using infrared radiation (IR), Ultraviolet (UV) and Pulsed Electric Field (PEF). Rough rice samples with different initial moisture contents ranging from 20.7% to 32.5% (d.b) were used to conduct this study. The rough rice samples were heated using IR to surface temperature of 60°C followed by tempering treatments for durations ranging from 1h to 5h. In case of UV treatments, ambient air dried rough rice samples were dehusked to produce brown rice and the brown rice samples were treated under a double sided UV heating system for 10, 20 and 30min. In case of PEF treatments, rice bran samples were treated in PEF chamber (22 KV/cm) under different pulse numbers and frequencies. The samples were treated with up to 1000 PEF pulses and under frequencies ranging from 0.25Hz to 1 Hz. After IR, UV and PEF treatments, the enzyme inactivation and FFA in rice bran were quantified over a storage period of up to 38 days. Three replicates were performed for each treatment.

The results showed that high drying rates, good milling quality and effective lipase inactivation of rough rice can be achieved with a short IR heating time followed by tampering treatment for at least three hours. It took only about 55 s to achieved about 60°C rice surface temperature and remove 1.7 to 5.8 percentage point MC during IR heating alone. The amount of moisture removal depended on the original MC of rice and number of drying passes. The total moisture removal after tempering and cooling was up to about 5.6 and 12.2 percentage points for one and two drying passes, respectively. Additionally, IR-heating followed by tempering treatments was an effective approach to inactivate the lipase enzyme and extended the storage stability of rice bran for up to 38 days after milling. The tempering process after IR heating is essential to achieve high rice milling quality, improve the amount of moisture removal during cooling and enhance the enzyme inactivation. The UV and PEF treatments for the brown rice and rice bran did not have a significant effect on lipase inactivation.

It is recommended to use IR to heat rough rice to 60 °C followed by tempering treatment for at least three hours. This can be an effective approach to inactivate the lipase and extend the storage stability of rice bran for up to 38 days after milling. Also, the treatments result in high drying rate and good milling quality of rough rice.

ACKNOWLEDGEMENT

The investigators would like to express their appreciation for the great support received from the following personnel and organization.

Tianxin Wang
UC Davis
USDA-ARS-WRRC
California Rice Research Board
Farmer's Rice Cooperative