Improvement of Shelf Lives of Rough and Brown Rice Dried by Using Infrared Heating

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Introduction

Improvement of storage stability of rough and brown rice represents an area of great concerns for the rice industry. The current refrigeration storage method results in a high energy consumption to maintain rice quality. Additionally, in retail the plastic-film packaging used for brown rice storage still allows serious increase in fat oxidation. It may only take as less as two weeks for the brown rice in a plastic-film package to reach an unacceptable level of free fatty acids when temperature is high. As a non-chemical and emerging technology with high energy efficiency, Infrared (IR) radiation may have the potential to be used as an effective method to inactivate lipase, reduce free fatty acids and improve the storage stability of rice. Our previous studies on IR drying have demonstrated that high heating and drying rates, good milling and sensory quality, and effective disinfestation and disinfection can be achieved by heating rough rice using IR to temperature of 60 ºC followed by tempering and natural cooling. However, little is known about rice storage stability of rice dried by using IR.

Objectives

- Determine drying characteristics and milling quality of rice dried by using IR heating and investigate the Impact of IR on storage stability of rough and brown rice.
- Develop kinetic model for the change of free fatty acid in rough and brown rice during storage.

Materials and Methods

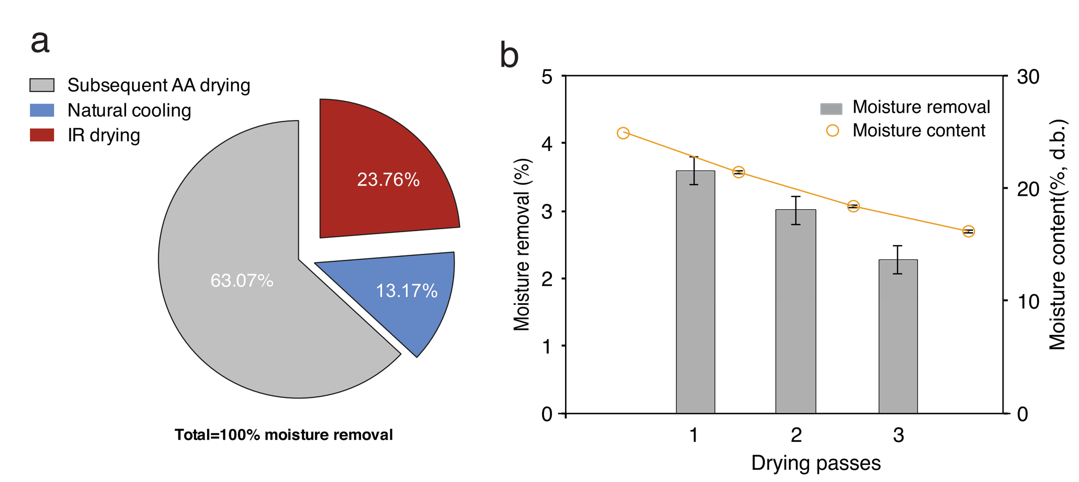
Freshly harvested medium grain rice, variety M206, with a initial moisture content (IMC) of 25.03±0.01% (dry basis, 19.98 in wet basis), was used for conducting this study.
The rice sample was split into three equal portions and prepared for IR drying (IRD), hot air drying (HAD) and ambient air drying (AAD). For IRD, the samples were heated using a catalytic emitter to temperature of 60ºC. After IR heating, the tempering treatment was conducted by keeping the samples in an incubator set at 60ºC for 4 hours. The dried samples produced by using IR, HA, and AA drying methods were divided into two portions. One was used as rough rice and the other one was dehulled to produce brown rice. The rough rice and brown rice samples were stored at accelerated storage conditions (temperature of 35 ºC and relative humidity of 65±3.0%) for ten months. The milling quality and storage stability were investigated.

IR drying Dehulling Milling

Rice storage Grain check Titration

Results

High heating rate and moisture removal were achieved by using IR heating. It took only 58 s to heat rough rice to 60 ºC with corresponding moisture removal of 2.17 percentage points. The total moisture removal after tempering and natural cooling reached 3.37 percentage points without additional energy input (Figure 1).



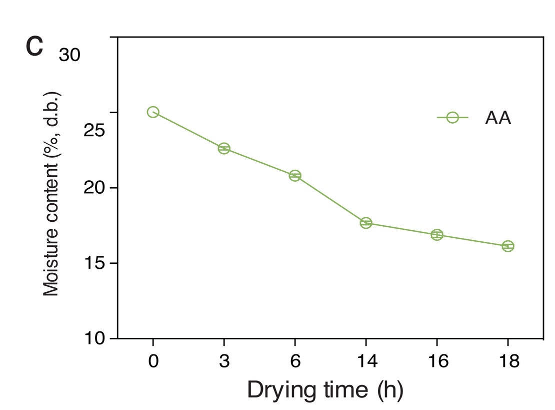


Figure 1 Drying characteristics of rough rice under infrared (a), hot air (b) and ambient air (C) drying methods.

The rice dried by IRD had higher TRY and HRY compared with that dried with HAD and AAD (Table 1). For whiteness, the results showed that the values of all milled rice samples at month zero and 1 were above 38.00 units. Compared with the samples dried by AAD, the rice dried by IRD and HAD had higher whiteness.

An effective inactivation of the lipase and consequent improvement in the long-term storage stability of rough and brown rice were achieved by using IR heating followed by tempering treatment. FFA concentration of the stored brown rice samples dried by IR was 6.91% after 10 months of storage, which was lower than that of the rough rice samples dried by HAD and AAD and stored for 10 months (Figure 2). The results showed that IR heating followed by tempering treatment could significantly improve the storage stability and extend the safe storage duration of rough and brown rice.

Table 1 Effect of drying methods and storage time on milling quality of rough and brown rice

Drying method	Storage time (month)	Milling quality (Rough rice)			Milling quality (Brown rice)		
		TRY (%)*	HRY (%)	Whiteness (unit)	TRY (%)*	HRY (%)	Whiteness (unit)
IRD	0	67.12±1.61	57.94±1.93aA	39.90±0.36aA	67.12±1.61	57.94±1.93	39.90±0.36aA
	1	68.23±1.64	58.69±1.49aA	40.60±0.28aAB	67.72±0.39	58.04±0.55	39.73±0.53aA
	2	68.91±1.37	59.66±1.02aA	39.20±0.71aAC	68.16±0.89	58.67±0.53	39.53±1.06aA
	4	69.05±1.26	59.67±1.25aA	39.45±0.07aAC	68.23±0.27	58.87±0.33	38.52±0.45aA
	7	69.26±1.16	60.81±1.04aA	35.92±0.50aD	68.63±0.39	58.19±0.97	35.45±0.44aB
	10	69.39±1.37	61.21±1.09aA	31.08±0.83aE	68.91±0.50	58.61±0.49	30.87±0.38aC
HAD	0	67.74±1.68	57.78±1.23aA	39.94±0.48aA	67.74±1.68	57.78±1.23	39.94±0.48aA
	1	67.93±1.35	57.98±1.03aA	40.40±0.28aAB	67.38±0.84	58.42±1.17	40.19±0.11aA
	2	68.97±1.41	58.42±1.39aA	39.20±0.57aAC	68.13±1.65	58.11±0.76	39.54±0.64aAB
	4	68.68±1.81	59.15±1.44aA	39.30±0.14aAC	68.92±0.66	58.44±0.75	38.10±0.45aB
	7	68.94±1.43	60.93±1.68aA	36.37±0.23aD	68.49±0.64	58.2±0.38	34.92±0.44aC
	10	68.97±0.93	61.67±1.40aA	32.18±0.21bE	68.83±0.67	58.99±0.34	30.01±0.57aD
AAD	0	66.52±1.15	56.07±1.40aA	38.37±0.46bA	66.52±1.15	56.07±1.40	38.37±0.46bA
	1	67.83±1.39	56.74±1.58aA	37.95±0.49bAB	67.63±1.28	57.37±0.54	37.88±0.77bA
	2	68.50±1.35	58.00±1.62aAB	37.15±0.07bB	67.80±0.76	57.44±0.47	36.68±0.29bAB
	4	68.71±1.36	59.23±1.53aAB	35.84±0.49bC	67.74±0.44	57.33±0.9	35.72±0.45bB
	7	69.10±1.33	60.77±1.19aB	33.57±0.27bD	69.18±0.71	57.62±0.55	33.25±0.77bC
	10	69.22±1.19	61.29±0.93aB	30.29±0.46aE	69.10±0.72	58.53±1.29	29.59±0.71aD

Values (means ± standard deviation) in each column without letter or followed by same letter are not significantly different at p<0.05. Letters in lowercase and uppercase represent the comparison between different drying methods and different storage durations, respectively.

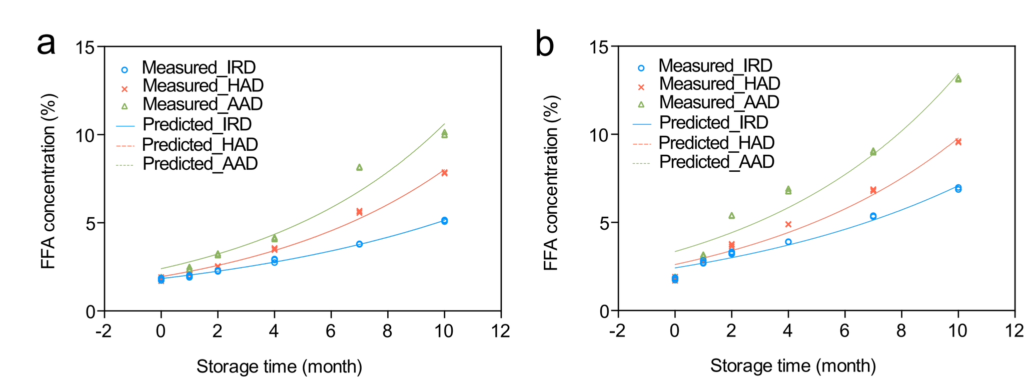


Figure 2 Effect of IR heating and storage time on FFA concentration of rough (a) and brown (b) rice

There was a high correlation between the FFA concentration and storage time (Figure 2). Regression models were developed to predict the FFA concentration over the storage time. Exponential model was applied to describe and predict the FFA concentration during the 10 months of storage.

$$FFAc = k \cdot \exp(m \cdot ST)$$

FFAc is FFA concentration percentage points; ST is the storage time, in months; The k and m are coefficients.

Peroxide values (POV) of all samples increased after the first month, and then decreased to the least at month 4. After that, POV dramatically increased at month 7 and became stable till month 10. The POV of brown rice was much lower than 20.00 mill equivalent/ 1000 g defined as an indicator of unstable state.

Table 2 Regression analysis of FFA concentration of rough and brown rice during storage

Categories	Drying methods	k	m	R^2	RMSE
Rough rice	Infrared	1.838	0.1029	0.9965	0.0678
	Hot air	1.948	0.1415	0.9908	0.1174
	Ambient air	2.401	0.1487	0.9523	0.2102
Brown rice	Infrared	2.424	0.1072	0.9666	0.1433
	Hot air	2.615	0.1320	0.9725	0.1695
	Ambient air	3.350	0.1391	0.9441	0.2427

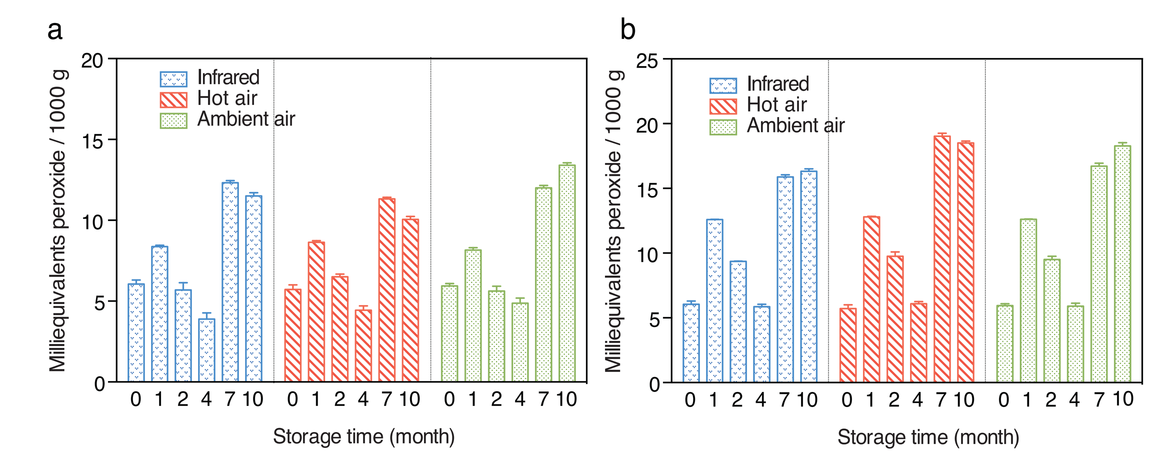


Figure 2 Effect of IR heating and storage time on FFA concentration of rough (a) and brown (b) rice

Conclusions

The research showed that the IR heating followed by tempering treatment could effectively inactivate lipase and significantly reduce the FFA concentration of rough and brown rice. 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 achieve high drying efficiency, good milling quality and simultaneously improve the storage stability of rough and brown rice.

Acknowledgements

Farmers, Rice Cooperative, CA
Food Processing Lab-UC Davis
Donald Olson, USDA-ARS-WRRC

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