COMPARISON OF MICROWAVE VACUUM DRYING WITH TRADITIONAL RICE BRAN STABILIZATION METHODS: IMPACT ON EXTRACTED OIL QUALITY

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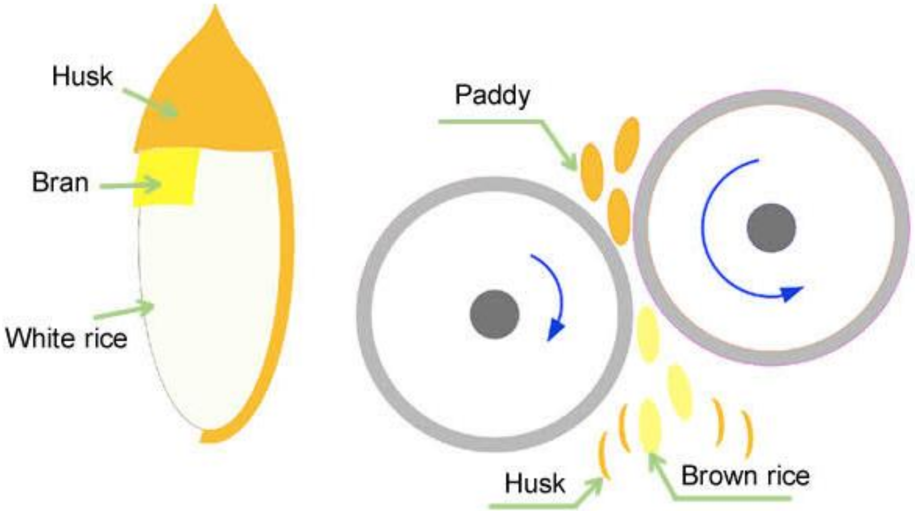
BACKGROUND

- **Rice bran** is the outer brown layer of the rice (*Oryza sativa*) grain that is obtained from the removal of the starchy endosperm during the milling process.
- It has high nutritional value and is an excellent source of **oil.**



Da Silva, Sanches, & Amante, 2006; Nagendra Prasad et al., 2011

Image from: http://www.knowledgebank.irri.org/images/stories/rice-husk-diagram.jpg

BACKGROUND

- **Rice bran oil** is a natural rich source of significant biologically active constituents such as γ-oryzanol, tocopherols, tocotrienols and phytosterols that have anti-cancer, antioxidant properties, and cholesterol-lowering effect on serum.

Selected bioactive components of rice bran and their biological activities (Borresen & Ryan, 2014).

Bioactive component	Examples	Biological activity
γ-oryzanol	Combination of ferulic acid, esters of sterol and triterpene alcohols	• Antibacterial • Antioxidant • Cancer chemoprevention • Reduces cholesterol absorption
Vitamin E	α-tocopherol, γ-tocopherol, tocotrienols	• Antibacterial • Antioxidant • Cancer chemoprevention • Reduces cholesterol absorption
Polyphenols	Ferulic acid, α-lipoic acid, caffeic acid, salicylic acid	• Antibacterial • Anti-inflammatory • Antioxidant • Antiproliferative effect on cancer
Phytosterols	ß-sitosterol, campesterol, stigmasterol	• Anti-inflammatory • Antioxidant • Cancer prevention • Reduces cholesterol absorption • Stimulates lymphocyte proliferation
Amino acids	Lysine	• Growth and development • Hypoallerginicity

Borresen & Ryan, 2014; Liang et al., 2014

BACKGROUND

- **However**, rice bran has limited applications in food due to the rapid development of rancidity upon rice milling, making it unsuitable for human consumption.

Lipolytic enzymes

i.e. lipase, lipoxygenase

Hydrolytic and oxidative rancidity

off-flavors

degradation of bioactive compounds

Malekian et al., 2000

BACKGROUND

- Stabilization is done to inactivate deteriorating enzymes in the rice bran and extend its shelf life.

fresh rice bran

STABILIZATION

stabilized rice bran with extended shelf life

Wang et al., 1999

BACKGROUND

- **Heat treatment** is the most common method of stabilization in rice bran.
- **↑ temperature → enzyme denaturation → inactivation of lipolytic enzymes**

Godber, 2016

BACKGROUND

- Common drying techniques include **dry heating (DH), microwave heating (MH)** and **vacuum drying (VD)**.

Heat treatment	Heating requirements	Disadvantages
Dry heating (DH)	↑ temperature ↑ time	Scorching of bran due to severe heating conditions
Microwave heating (MH)	↑ temperature ↓ time	Scorching of bran due to non-uniform heating
Vacuum drying (VD)	↓ temperature ↑ time	Inefficient use of energy

Sansak & Jongyingcharoen, 2018; Ibrahim et al., 2012; Ratti, 2008

BACKGROUND

- **Microwave vacuum drying (MVD)** is a potential stabilization method for rice bran that combines the advantages of microwave heating and vacuum drying.

- MVD utilizes microwave radiation in a vacuum environment **to generate heat at a lower temperature** and to **allow rapid mass and energy transfer for increased drying rate.**

Scaman et al., 2014

OBJECTIVES

- To investigate the effects of stabilization methods i.e. dry heating (DH), microwave heating (MH), vacuum drying (VD) and microwave vacuum drying (MVD) on important quality parameters of:
    - **rice bran (i.e. moisture content and color)**
    - **rice bran oil (i.e. oil yield, free fatty acid content, peroxide value and antioxidant capacity)**

SAMPLE COLLECTION

- Freshly milled rice bran was obtained from a local rice miller in Bulacan, Central Luzon, Philippines.

- The collected samples were sieved immediately using a Standard Test Sieve No. 45 to screen unwanted filth and to obtain a uniform particle size of less than 350μm. The sieved samples were collected in zip lock plastic bags and stored in a chest type freezer -20°C until stabilization.

STABILIZATION OF RICE BRAN

Stabilization method[1]	Heating parameters	Equipment	Reference
Dry heating	100°C, 30 min	Weber Electric Oven, Philadelphia, USA	Sharma et al. (2004)
Microwave heating*	720 W microwave power, 6.7 min, 500g bran load capacity	Microwave Oven Model X2-20ES Whirlpool, Michigan, USA	Ramezanzadeh et al., (1999)
Vacuum drying	65°C, 5 h, 30 mm Hg	Vacuum Oven Model Hinotek, Ningbo, Zheijang, China	AOAC (2000)
Microwave vacuum drying	992 W microwave power, 20 kPa vacuum pressure, 75 rotation speed, 24.66 min, 549g bran load capacity	Microwave Vacuum Dryer designed and developed by Metals Industry Research and Development Center (MIRDC), Department of Science and Technology, Philippines	Villarino et al.

[1]Stabilization methods were done in duplicate.

*moisture content of the sieved rice bran was adjusted through the addition of deionized water respective to a 20:3 w/v bran-to-water ratio to prevent charring

STABILIZATION OF RICE BRAN

- Unstabilized rice bran was set aside as control.

- All stabilized rice bran samples were placed in ziplock polyethylene bags upon cooling to room temperature and stored in a freezer at -20°C until further use.

HEXANE EXTRACTION OF OIL

20 g rice bran

↓

Addition of hexane in a 1:3 w/v bran-to-hexane ratio

↓

Stirring at 1150 rpm for 1 h at room temperature (25°C)

↓

Centrifugation at 6000 rpm for 30 min

↓

Vacuum filtration

↓

Rotary evaporation of oil miscella at 40°C for 10 min

Oil extraction yield was defined as percent (%) g oil/ g rice bran

Extracted oil samples are stored at -20 °C for further analysis

Wang et al., 1999

DETERMINATION OF RICE BRAN AND RICE BRAN OIL QUALITY

Sample	Factor	Parameters measured	Method
Rice bran	Moisture content	% moisture (dry basis)	Rapid moisture analyzer (Uni Bloc MOC63u, Shimadzu, Kyoto, Japan)
	Color	*L**, *a**, *b** values Color difference (ΔE) between the control and the stabilized rice bran	Colorimeter (Model Colorflex E2, Hunterlab Inc., Reston Virginia, USA)
Rice bran oil	Oil extraction yield	% g oil/ g rice bran	Hexane extraction by Wang et al. (1999) with modifications
	Free fatty acid content	% FFA as oleic acid	Titration (Chia et al., 2015)
	Peroxide value	milliequivalent of peroxide oxygen per kg of the oil sample (meq/kg)	Titration (Chia et al., 2015)
	Total antioxidant capacity	Trolox equivalents (TE)/g oil % scavenging activity (%SA)	Modified ABTS assay by Thaipong et al. (2006) and Martysiak-Zurowska & Wenta (2012) Modified DPPH assay by Thaipong et al. (2006)

STATISTICAL ANALYSIS

- All samples (i.e. DH, MH, VD and MVD) including the control were assessed in duplicates.
- **One-way Analysis of Variance (ANOVA)** was used to compare treatment means followed by Duncan's Multiple Range Test for mean separation when F was significant
- **Dunnett's Test** was used for the mean separation of unstabilized (control) and stabilized samples.
- All statistical tests were performed using SPSS software version 17 at a probability level of 0.05.

EFFECT ON MOISTURE AND COLOR OF RICE BRAN

Stabilization method[2]	Moisture content (% dry basis)	Color			
		*L**	*a**	*b**	Δ*E*
MVD	$8.43^{b*} \pm 0.27$	$70.58^{c*} \pm 0.09$	$3.30^{a*} \pm 0.03$	$20.59^{a} \pm 0.02$	$1.94^{ab} \pm 1.61$
MH	$13.03^{c} \pm 1.14$	$68.66^{a*} \pm 0.40$	$4.18^{c*} \pm 0.22$	$23.00^{c*} \pm 0.11$	$4.76^{c} \pm 1.84$
VD	$9.04^{b*} \pm 0.11$	$71.92^{d} \pm 0.79$	$3.15^{a} \pm 0.05$	$20.36^{a} \pm 0.22$	$0.67^{a} \pm 0.64$
DH	$2.77^{a*} \pm 0.44$	$69.91^{b*} \pm 0.37$	$3.71^{b*} \pm 0.15$	$22.24^{b*} \pm 0.49$	$3.39^{bc} \pm 0.83$
Unstabilized	*13.58 ± 0.47*	*72.45 ± 1.45*	*3.09 ± 0.11*	*20.14 ± 0.51*	–

[1]Mean ± standard deviation.

[2]MVD, microwave vacuum drying; MH, microwave heating; VD, vacuum drying; DH, dry heating

[abc]Values with different superscripts within the same column denotes significant difference (p<0.05) using Duncan's Test

*Denotes significant difference (p<0.05) with unstabilized rice bran using Dunnett's Test

- **No significant difference on moisture content of MH and unstabilized samples**
- **Highest ΔE values were observed in MH- and DH-stabilized samples**
- **Lowest ΔE values were observed in VD- and MVD-stabilized samples**

EFFECT ON MOISTURE AND COLOR OF RICE BRAN

- **No significant difference on moisture content of MH and unstabilized samples**
  - ➢Addition of water prior to drying to prevent charring contributed to additional moisture that needed to be removed during MH treatment

- **Highest ΔE values were observed in MH- and DH-stabilized samples**
  - ➢Elevated temperatures may have caused a larger extent of browning in samples

- **Lowest ΔE values were observed in VD- and MVD-stabilized samples**
  - ➢Reduced pressure during drying slowed down Maillard reaction in the bran

EFFECT ON EXTRACTION YIELD AND QUALITY OF RICE BRAN OIL

Stabilization method[2]	Oil extraction yield (%)	FFA (% oleic acid)	PV (meq/kg oil)
MVD	$9.34^{c*} \pm 0.64$	$11.15^{a*} \pm 0.94$	$12.28^{a*} \pm 0.64$
MH	$7.74^{a} \pm 0.35$	$13.71^{b*} \pm 1.25$	$15.33^{b*} \pm 1.21$
VD	$8.53^{b} \pm 0.66$	$17.01^{c} \pm 1.77$	$18.92^{c} \pm 0.90$
DH	$8.74^{bc*} \pm 0.68$	$12.05^{a*} \pm 1.03$	$14.73^{b*} \pm 0.90$
Unstabilized	*7.71 ± 0.60*	*17.44 ± 2.03*	*19.49 ± 1.07*

[1]Mean ± standard deviation.

[2]MVD, microwave vacuum drying; MH, microwave heating; VD, vacuum drying; DH, dry heating

[abc]Values with different superscripts within the same column denotes significant difference (p<0.05) using Duncan's Test

*Denotes significant difference (p<0.05) with unstabilized rice bran using Dunnett's Test

- **No significant difference on oil extraction yield between MH- and VD-stabilized samples and unstabilized**
- **No significant difference on FFA and PV between VD-stabilized samples and unstabilized**
- **Lowest FFA and PV values were observed in samples stabilized by MVD, DH and MH**

EFFECT ON EXTRACTION YIELD AND QUALITY OF RICE BRAN OIL

Stabilization method[2]	DPPH Assay		ABTS Assay	
	TE[3] (mg TE/100g oil)[ns]	% Scavenging activity[ns]	TE[3] (mg TE/100g oil)[ns]	% Scavenging activity[ns]
MVD	188.45 ± 3.24	76.85 ± 1.32	87.74 ± 5.98	76.36 ± 5.46
MH	184.20 ± 4.92	75.45 ± 2.00	91.65 ± 5.03	79.92 ± 4.59
VD	187.82 ± 3.51	76.64 ± 1.43	92.84 ± 3.70	81.01 ± 3.37
DH	187.36 ± 3.82	76.45 ± 1.55	90.72 ± 3.21	79.07 ± 2.93
Unstabilized	*184.58 ± 2.57*	*75.32 ± 1.05*	*91.62 ± 2.67*	*79.89 ± 2.43*

[1]Mean ± standard deviation.
[2]MVD, microwave vacuum drying; MH, microwave heating; VD, vacuum drying; DH, dry heating
[3]TE – Trolox equivalent
[ns]Denotes no significant difference (p<0.05) between stabilization methods using Duncan's Test
*Denotes significant difference (p<0.05) with unstabilized rice bran using Dunnett's Test

- **No significant interaction effects on Trolox equivalent and % scavenging activity of oils from different rice bran samples determined by both ABTS and DPPH assays**

EFFECT ON EXTRACTION YIELD AND QUALITY OF RICE BRAN OIL

- **No significant difference on oil extraction yield between MH- and VD-stabilized samples and unstabilized**
  - ➢ **MH**: high amount of moisture in samples possibly reduced the lipid extraction efficiency of hexane as it is insoluble in water
  - ➢ **VD**: low drying temperature may have created a lesser degree of tissue rupture in the bran, thus low solvent penetration on the cell membrane during extraction

- **Improved oil extraction yield by MVD and DH**
  - May be due to the modification of cell wall during drying resulting in increased porosity and enhanced solvent permeability during extraction

EFFECT ON EXTRACTION YIELD AND QUALITY OF RICE BRAN OIL

- **No significant difference on FFA and PV between VD-stabilized samples and unstabilized**
  - ➢Low drying temperature may not be adequate to cause inactivation of lipolytic enzymes in bran

- **Lowest FFA and PV values were observed in samples stabilized by MVD, DH and MH**
  - ➢Suggests that MVD, DH and MH suppressed activity of lipolytic enzymes in the bran

EFFECT ON EXTRACTION YIELD AND QUALITY OF RICE BRAN OIL

- **No significant interaction effects on Trolox equivalent and % scavenging activity of oils from different rice bran samples determined by both ABTS and DPPH samples**
  - Comparable antioxidant capacity of unstabilized and stabilized rice bran oil samples may be due to the preservation of heat-sensitive compounds in unstabilized samples because no heat treatment was applied

CONCLUSION

- Rice bran was successfully stabilized by MVD, resulting rice bran and rice bran oils with similar qualities to those stabilized using traditional methods.
- Further studies on the bioactive compounds of rice bran oil may be needed to verify the effects of stabilization methods on the antioxidant properties of oils.

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