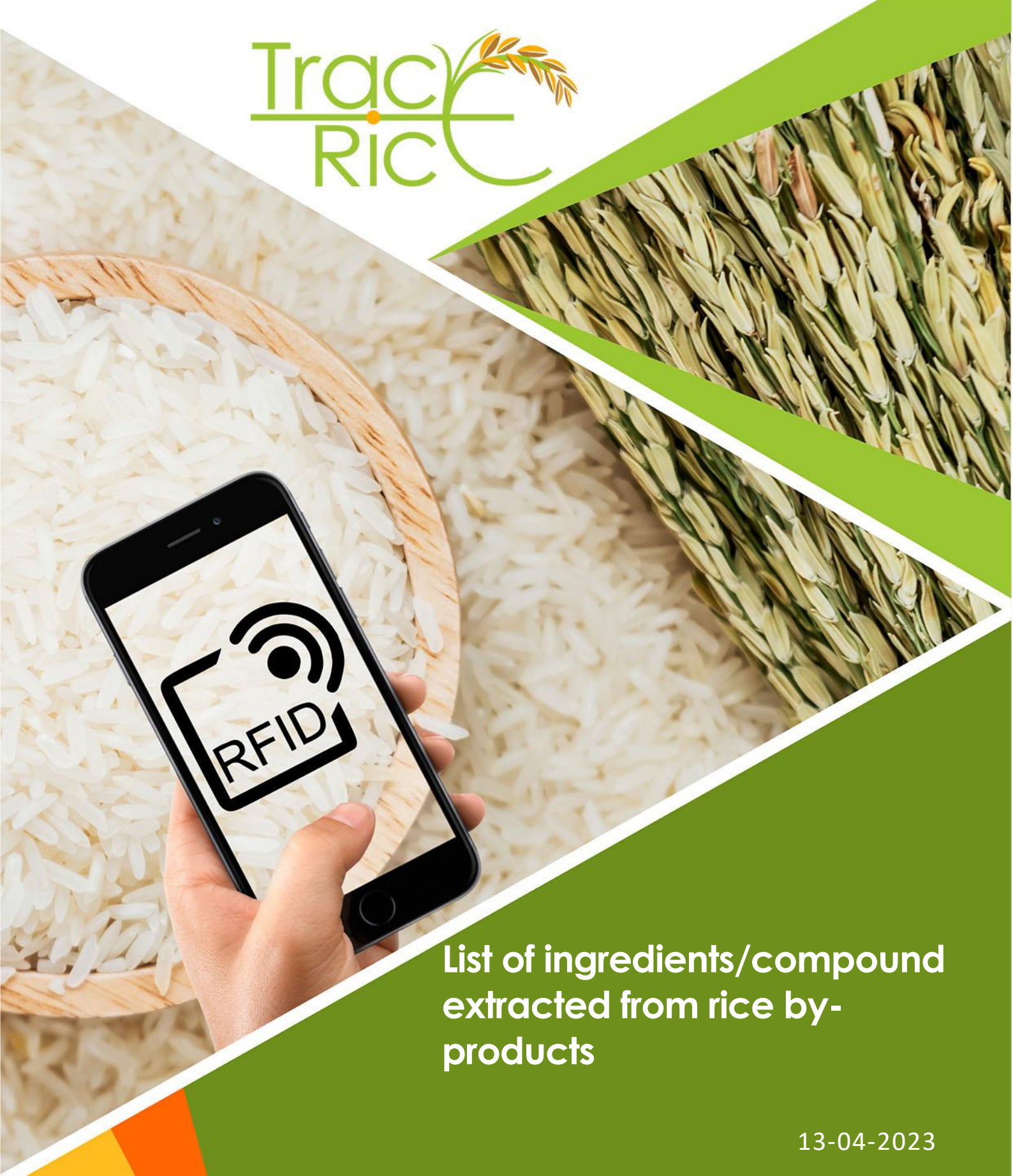

List of ingredients/compound extracted from rice by-products

13-04-2023

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PRIMA
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31-03-2023	CSIC-IATA	V2	Editing of Table has been modified
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Written by: Cristina M. Rosell

iata
Instituto de Agroquímica y Tecnología de Alimentos

Executive summary

The purpose of this task is to add value to the by-products resulting from rice milling practices. Overall, current milling methods, generate a great amount of waste, which decrease the process yields and what it is more important, many nutritious and bioactive compounds are thrown it away, increasing its inherent environmental impact. To revert that practice and increase sustainability and competitiveness of rice milling industry, by-products generated from rice processing, need to be explored. Rice bran containing bioactive compounds and germ were used to improve their technological properties, and to isolate bioactive compounds using different methodologies.

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1. Overview

The most common type of rice consumption is polished rice (endosperm 70% of the whole grain). To obtain white rice several milling stages are necessary resulting in a huge amount of by-products, such as husk (20%), bran (8%) and germ (2%) (Bodie et al., 2019; Van Hoed et al., 2006). Rice husk composed of fiber (hemicellulose, cellulose and lignin) and silica (Baetge & Kaltschmitt, 2018), is already use to produce fuel, soil fertilization, agricultural uses (bedding poultry houses) or animal feed (Bodie et al., 2019). Add value to the rice bran and germ is possible isolating its constituents. Those are rich in lipids (12-23%), fibers (8-10%), and proteins (14-16%) (Liu et al., 2021) and in recent years multiple benefits for human health have been described (Xia et al., 2019).

The objective of the present report is to provide a snapshot of the ingredients, that can be extracted from rice by-products in line with the circular economy strategy.

The spectrum of selected by-products to test was narrowed to address more sustainable production at industrial scale, so, the focus of this deliverable has been on the rice bran treatments and characterization of the nutritional and technological qualities. Main properties of the ingredients obtained from rice by-products are described below, and a table with all the treatments or extraction technologies tested is following.

1.1. Rice bran proteins

Rice bran proteins contain all the essential amino acids (including γ-aminobutyric (GABA)), with a protein efficiency (PER) of up to 2.0-2.5 and a high digestibility (Park et al., 2017). Several health benefits have been associated to them: anticancer or Alzheimer reduction (antioxidant peptides), antihypertensive (inhibition of angiotensin enzyme), antidiabetic (inhibition of α-amylase and α-glucosidase) and cholesterol reducer (binding proteins to bile acids), besides different applications as protein supplements, carriers of active compounds through hydrogen bonds, flavor enhancer (asparagine and glutamine), anti-retrogradation, and biodegradable films (Zheng et al., 2019).

1.2. Rice oil

Rice oil is one of the most explored by-products and is used by the cosmetic, pharmaceutical and food industries. This oil contains 42% monounsaturated fats, 40% saturated fats (including omega-6 (38%) and omega-3 (2%) fatty acids) and only 18% saturated fats (Park et al., 2017; Punia et al., 2021). Among others, it is a good source of tocopherols, tocotrienols and phytosterols, including significant amounts of gamma oryzanol (1.1-2.6%) (Punia et al., 2021; Vallabha et al., 2015). This has led to the description of innumerable health benefits, but also technologically it has qualities that make it attractive for the industry, such as a high melting point (254°C) that allows its use in frying and a reduction of oil absorption in foods (Garba et al., 2019).

1.3. Bran fibres

Bran fibres has more than 30% of dietary fibre (33 % cellulose, 54 % hemicellulose and 6% lignin) (Daou & Zhang, 2014). This fraction of the bran has been less explored than the rice lipids, being a residue from the revaluation of rice oil, since after its extraction the fibres and proteins are usually left for use in industrial applications and not for human consumption. However, due to its composition, health benefits have been described, such as the reduction of blood glucose levels, inhibition of lipase activity, and inhibition of the lipase activity in the blood (Qi et al., 2015; Qureshi et al., 2002).

2. List of tested ingredients-compounds from rice by-products

Thanks to all these benefits and properties, it is possible to study the different fractions to revalue this type of by-products by introducing them into the food chain. As mentioned above, rice bran could be divided into 2 types of products that could be studied because they are waste generated in different industries: i) the complete bran and ii) the defatted bran after fat extraction. In addition, the nutritional and technological qualities of lipids generate great interest in the industry, so it is important to know and improve their applications.

The following tables show the information on the different by-products studied during the development of the project.

SUMMARY OF FINDINGS

- The enzyme treatment modify the technofunctional properties of rice bran without significantly affecting its composition.
- Higher rice bran oil yield was obtained with combining hexane (18%) and ethanol (25%).
- Higher γ-Oryzanol content was obtained with supercritical CO_2 extraction.
- Higher soluble fiber and lower insoluble fiber was obtained with supercritical CO_2 extraction.

1	**Partner/Country**		**IATA/Spain**
2	**Type of by-product**		**rice bran**
3	**Picture**		
4	**ingredient/compound extracted or entire by-product**		**defatted rice bran**
5	**Brief description of the most important highlights regarding:**	**Main industrial applications (food)**	RiBran® stabilized rice bran for bakery applications, gluten free, snacks, pasta, among others.
		Main industrial applications (non food)	animal feed, extraction of components such as proteins, fiber or bioactive compounds
		Extraction conditions	the defatting was done with hexane using 3 cycles of 2 h and centrifuged each time.
		Analytical conditions	the analyses were made with the dried defatted bran. It was used directly for all analyses.
6	**Composition (compounds and amounts)**	**Moisture (g/100g)**	11.48
		N (g/100g) d.b.	2.57
		Total dietary fiber (g/100g) d.b.	33.52
		Insoluble fiber (g/100g) d.b.	30.30
		Soluble fiber (g/100) g d.b.	3.22
9	**Health benefits described**		• Inhibition of lipase activity (porcine pancreatic lipase) • Reduces blood glucose level (Diabetes) • Rice protein peptides = antioxidants (Cancer, Alzheimer's). • Molecular weight <4 kDa = Antihypertensive (angiotensin converting enzyme ACE inhibition). • Try-Ser-Lys tripeptide (Prevention of chronic diseases) • α-amylase and α-glucosidase activity inhibitors (Antidiabetic) • Proteins with bile acid binding (Cholesterol reducer) • Antihypertensive peptide Leu-Arg-Ala (Antihypertensive)
10	**Technological benefits described**		• Protein supplement • Carrier of bioactive compounds through H-bonding and hydrophobic interaction • Flavor enhancer (asparagine and glutamine) • Anti-retrogradation (hydrolyzed protein 15.1% suppresses starch retrogradation)

		• Biodegradable films • Depending on the extraction method emulsifying capacity
11	**Scientific data available on the incorporation of this by-product/compound in food? (number of related publications on Scopus since 2010)**	**153 papers (defatted rice bran + food)**
	Most important references	Abdul-Hamid, A., & Luan, Y. S. (2000). Functional properties of dietary fibre prepared from defatted rice bran. Food Chem, 68(1), 15-19. Daou, C., & Zhang, H. (2014). Functional and physiological properties of total, soluble, and insoluble dietary fibres derived from defatted rice bran. J Food Sci Technol, 51(12), 3878-3885. Gul, K., Yousuf, B., et al. (2015). Rice bran: Nutritional values and its emerging potential for development of functional food - A review. Bioactive Carbohydrates and Dietary Fibre, 6(1), 24-30. Hu, G., & Yu, W. (2015). Effect of hemicellulose from rice bran on low fat meatballs chemical and functional properties. Food Chem, 186, 239-243. Nugrahani, R. A., Fithriyah, N. H., & Nelfiyanti. (2019). Defatted rice bran a byproduct of oil extraction with ultrasonic method for protein supplement in cassava-flour biscuits. Paper presented at the IOP Conference Series: Materials Science and Engineering, 543(1) Sairam, S., et al. (2011). Physico-chemical characteristics of defatted rice bran and its utilization in a bakery product. J Food Sci Technol, 48(4), 478-483. Sharif, K., & Butt, M. S. (2006). Preparation of fiber and mineral enriched pan bread by using defatted rice bran. Int J Food Prop, 9(4), 623-636. Shi, M., et al (2015). Using defatted rice bran as a bioadsorbent for carrying tea catechins. J Food Sci, 80(10), C2134-C2139.
12	**Scientific data available on the incorporation of this by-product/compound in non food industry? (number of related publications on Scopus since 2010)**	**70 papers (deffated rice bran + industry or non food application or bioplastics)**
	Most important references	Alexandri, M., López-Gómez, J. P., Olszewska-Widdrat, A., & Venus, J. (2020). Valorising agro-industrial wastes within the circular bioeconomy concept: The case of defatted rice bran with emphasis on bioconversion strategies. Fermentation, 6(2). Kunanopparat, T., Menut, P., Srichumpoung, W., & Siriwattanayotin, S. (2014). Characterization of defatted rice bran properties for biocomposite production. J Polym Environ, 22(4), 559-568. Alonso-González, M., Felix, M., & Romero, A. (2022). Rice bran-based bioplastics: Effects of biopolymer fractions on their mechanical, functional and microstructural properties. Polymers, 14(1) Klanwan, Y., Kunanopparat, T., Menut, P., & Siriwattanayotin, S. (2016). Valorization of industrial by-products through bioplastic production: Defatted rice bran and kraft lignin utilization. J Polym Eng, 36(5), 529-536. Lee, J., Seo, E., Kweon, D. -., Park, K., & Jin, Y. -. (2009). Fermentation of rice bran and defatted rice bran for butanol production using clostridium beijerinckii NCIMB 8052. Journal of Microbiology and Biotechnology, 19(5), 482-490. doi:10.4014/jmb.0804.275. Klanwan, Y., Kunanopparat, T., Menut, P., & Siriwattanayotin, S. (2016). Valorization of industrial by-products through bioplastic production: Defatted rice bran and kraft lignin utilization. Journal of Polymer Engineering, 36(5), 529-536. doi:10.1515/polyeng-2015-0301. Ju, Y. -., & Vali, S. R. (2005). Rice bran oil as a potential resource for biodiesel: A review. Journal of Scientific and Industrial Research, 64(11), 866-882. Friedman M. Rice brans, rice bran oils, and rice hulls: Composition, food and industrial uses, and bioactivities in humans, animals, and cells (2013) Journal of Agricultural and Food Chemistry
13	**Expected difficulties related to the use of this by-product/compound?**	flavor, modification of product texture, excessive water absorption depending on application
14	**Potential counter measures**	physical or enzymatic treatments modifying their properties

1	**Partner/Country**		**IATA/Spain**
2	**Type of by-product**		**enzyme-treated rice bran**
3	**Picture**		
4	**ingredient/compound extracted or entire by-product**		**defatted rice bran**
5	**Brief description of the most important highlights regarding:**	**Main industrial applications (food)**	RiBalance@, only Amylase treated stabilized rice bran existed in the market. Additional functionality could be obtained with other non-starch hydrolases.
		Main industrial applications (non food)	animal feed, extraction of components such as proteins, fiber or bioactive compounds
		Extraction conditions	the defatting was done with hexane using 3 cycles of 2 h and centrifuged each time. Once defatted, it was enzymatically treated by suspending the bran in optimal enzyme conditions (wall degrading enzymes).
		Analytical conditions	the analyses were made with the dried defatted bran. It was used directly for all analyses.
6	**Composition (compounds and amounts)**	**Moisture (g/100g)**	11.97
		N (g/100g) d.b.	3.33
		Total dietary fiber (g/100g) d.b.	39.75
		Insoluble fiber (g/100g) d.b.	35.82
		Soluble fiber (g/100) g d.b.	3.94
13	**Expected difficulties related to the use of this by-product/compound?**		Increase in the cost of defatted rice bran processing
14	**Potential counter measures**		Process optimization

Partner/Country		**iBET/Portugal**
Type of by-product		**rice bran (indica and japonica)**
Picture		
ingredient/compound extracted or entire by-product		**milled rice bran**
Brief description of the most important highlights regarding:	**Main industrial applications (food)**	Bakery applications, gluten free, snacks, pasta, among others.
	Main industrial applications (non food)	Extraction of rice bran oil
	Extraction conditions	EXTRACTION MASS YIELD (JAPONICA) • Solid liquid extraction (Soxhlet) with hexane (18%) and ethanol (25%) • Supercritical CO2 (17%)
	Analytical conditions	the analyses were made with the dried extract.
Micronutrients (brief review, quantity and most important highlights) or bioactive compounds	**γ-oryzanol**	γ-Oryzanol (mg/g extract) • Solid liquid extraction (Soxhlet) with hexane (19), ethanol (21) • Supercritical CO2 (37)
	Fatty acids	Total Fatty Acid (mg/g extract) • Solid liquid extraction (Soxhlet) with hexane (1097) • Supercritical CO2 (787)
Health benefits described		γ-Oryzanol •Anticarginogenic, anti-inflammatory, antidiabetic and neuroprotective, which are mainly attributed to its antioxidant capacity. (doi: 10.3390/nu11040728; doi: 10.3390/foods9060829; Oct. doi: 10.1111/jfbc.13424)

Partner/Country		**iBET/Portugal**
Type of by-product		**broken rice (indica and japonica)**
Picture		
ingredient/compound extracted or entire by-product		**milled broken rice**
Brief description of the most important highlights regarding:	**Main industrial applications (non food)**	Animal feed
	Extraction conditions	EXTRACTION MASS YIELD (JAPONICA) • Solid liquid extraction (Soxhlet) with hexane (<5%) and ethanol (<5%) • Supercritical CO2 (<5%)
	Analytical conditions	the analyses were made with the dried extract.

1	**Partner/Country**		**DPL/Spain**
2	**Type of by-product**		**rice bran**
3	**Picture**		
4	**ingredient/compound extracted or entire by-product**		**rice bran oil**
5	**Brief description of the most important highlights regarding:**	**Main industrial applications (food)**	Mainly used for cooking (frying)
		Main industrial applications (non food)	It is mainly used as a moisturizer (cosmetic use)
		Extraction conditions	supercritical CO2 extraction technology
6	**Composition (compounds and amounts)**	**Moisture (g/100g)**	5,00
		N (g/100g) d.b.	<0,7

1	**Partner/Country**		**DPL/Spain**
2	**Type of by-product**		**rice bran**
3	**Picture**		
4	**ingredient/compound extracted or entire by-product**		**defatted rice bran**
5	**Brief description of the most important highlights regarding:**	**Main industrial applications (food)**	there are no known commercial defatted rice bran products, apart from whole rice
		Main industrial applications (non food)	Animal feed
		Extraction conditions	supercritical CO2 extraction technology
6	**Composition (compounds and amounts)**	**Total dietary fiber (g/100g) d.b.**	33,16
		Insoluble fiber (g/100g) d.b.	12,28
		Soluble fiber (g/100) g d.b.	20,88

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TRACE-RICE Consortium

Instituto Nacional de Investigação Agrária e Veterinária, I.P.

iBET Instituto de Biologia Experimental e Tecnológica

ITQB Universidade Nova de Lisboa

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Grupo Desarrollo

iata Instituto de Agroquímica y Tecnología de Alimentos

Alexandria University