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Original Article

Nutritional Profiling of Indonesian Superior Hybrid and Biofortification Rice Varieties: Macronutrient and Micronutrient Changes Under Different Heat Temperatures

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Abstract

Indonesia has developed rice varieties which are superior in cultivation yield. However, lack of information about the nutritional value and optimal temperature to preserve the nutrient content. This study was purposed to determine the nutritional values and micronutrient changes in different heat temperatures. Three varieties of rice namely Jeliteng black rice (JT), Inpari Arumba red rice (AR), and Inpari IR Nutri Zinc white rice (NZ) were analysed during September-October of 2021. Rice was provided from Indonesian Rice Research Centre, East Java, Indonesia. Macronutrient, lipid analysis, dietary fibre, sugar, salt, and micronutrient (vitamin and mineral) were analysed by proximate analysis, gas chromatography, enzymatic-gravimetry, luff-schoorl method, titrimetric, ultra-performance liquid chromatography (UPLC) and high- performance liquid chromatography (HPLC) respectively. All analyses were performed in duplicate. Rice of NZ had the highest protein and dietary fibre content with lowest moisture level. Kalium, magnesium, manganese, and zinc were mainly found in AR rice. However, vitamins were generally found in JT rice. Heating mostly diminished the vitamin B3, B7 and E in all rice, vitamin C in NZ rice as well as iron in colored rice. This study provided fundamental nutritional data for Indonesian rice superior variety. Future explorations are necessary for optimizing the process of milling, cooking, and fortification to maintain micronutrient values in these potential varieties.

Keywords: crop, health, heating, Indonesia, nutrition and rice
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Introduction

Rice (Oryza sativa) is one of important cereal crops in the world. Over half of global population consume rice as their major staple food. The annual number of total rice consumption reaches 480 million metric tons worldwide (Muthayya et al., 2014). Rice is cultivated in more than 100 countries across six continents with range variety of environments. The largest producer of rice is Asian countries (Rao et al., 2017).

Indonesia plays a key role both as producer and consumer of rice commodities. Indonesia produces about 34-million-ton rice per year. The number of annual rice consumption in Indonesia is estimated about 72,42 kg/capita. Rice cultivation land in Indonesia coverages about 31,5 among different types of geographical environment such as lowland, upland, irrigated and rainfall water sources. The environments ambient of Indonesia supports rice plants development (Anggraeni, 2020; Rao et al., 2017).

The variety of rice is responsible for plant adaptation in certain cultivation land (De Santis et al., 2022). Indonesia has approximately 40 local varieties of rice that tolerant to pathogen infection, diseases, and abiotic stress. However, local cultivar has limitation in longer harvest period and lower harvest yields. To maintain the quality and meet the rice consumption demand in Indonesia, hybridization of local rice varieties was conducted for superior variety development thus produced higher yield as well as environmental tolerance adaptation. Accordingly, Indonesian Rice Research Centre (IRRC) has developed new types of hybrid superior varieties that focused for irrigated rice field cultivation (Paiman et al., 2020).

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Superior hybrid rice varieties released as distinct colour grain types such as Jeliteng (JT) variety and Inpari Arumba (AR) variety. Black rice JT developed from crossbreed of black sticky rice and Pandan Wangi Cianjur variety with fluffier feature of cooked rice. Red rice AR has red color as crossbreed development from Sintanur and Bahbutong variety with fluffier and aromatic feature. The white rice NZ variety is a zinc biofortified white rice that refined to provide zinc supplementation. The physic and agriculture characteristics of those type of rice was fully identified. However, nutritional profiling was limited to amylose level, few minerals micronutrient and physical characteristics (Badan Penelitian dan Pengembangan Pertanian Kementrian Pertanian Republik, 2021; Balai Besar Penelitian Tanaman Padi, 2019).

Nutrition profiles information of new biotechnology-developed rice would be useful for commercial food industries and dietary guidelines, especially for rice which are recommended for further processing of functional food. Nutrients content in each rice varieties are influenced by genetically and environmental factor (Kanauchi et al., 2014; Oh et al., 2019). The improvement of rice nutritional value would be makes a better human health since rice is broadly consumed in world population (Das et al., 2020).

Therefore, rice cooking process is crucial to maintain the daily dietary requirements. Previous studies demonstrated physical changes and reduction of micronutrient values of rice following cooking process (Azam et al., 2021; Nawaz et al., 2016; Silveira et al., 2017). Given that the data about complete nutritional profiling as well as nutritional changes under different temperature are limited for Indonesian Superior Hybrid and Biofortification Rice Varieties. Therefore, this study was purposed to identify the macronutrient and micronutrient values of three varieties of JT, AR and NZ rice from Indonesia. This study was also evaluated the changes of micronutrient composition at different temperature of heating. This study would support basic nutrient data of tropical rice particularly from Indonesian and the maintenance of nutrient content during future food processing development of three superior varieties of rice.

Methods

Rice sample

Three selected varieties of rice that are black rice Jeliteng (JT), red rice Inpari Arumba (AR) and white rice Inpari IR Nutri Zinc (NZ) were provided from Indonesian Rice Research Center, Sukamandi, West Java, Indonesia. Each of sample was analysed for duplicate.

Macronutrient analysis

The standard method of Kjeldahl was used to determine the protein content. Soxhlet method was performed to measure the fat content by hexane extraction of sample for 3 hours and followed by 105°C of evaporation. Heating sample at 105°C and cooling in dessicator from 3 hours were carried out to identify the moisture content. The percentage of carbohydrate was calculated as previous described. Ash content determination was performed by heating sample at 550°C until greyish ash formed (Kurnianingsih et al., 2020).

Food analysis

The determination of cholesterol content was performed as previous protocol. In brief, lipid was extracted using KOH saponification. Hexane was involved to extract the non-saponifiable fraction then trimethylsilyl (TMS) ethers was form sterol derivation. Gas chromatograph was used to quantify with internal standard that is 5α-cholestane (Puwastien et al., 2011). Free fatty acid and Tran saturated fat were analysed using titrimetric method (Bazina & He, 2018). Sugar was determined by previous volumetric method (Puwastien et al., 2011). Salt was determined as NaCl using Mohr method (Sezey & Adun, 2019). Dietary fibre was analysed by gravimetric method (AOAC International, 2005).

Micronutrient Analysis

The micronutrient was analysed for vitamin and mineral content. Fat-soluble vitamins (A, D, E, and K) and vitamin C were analysed using high performance liquid chromatography (HPLC) as modification from earlier (Mazurek & Jamroz, 2015; Puwastien et al., 2011). The complex of vitamin B was analysed using ultra-performance liquid chromatography (UPLC) (Shimadzu Nexera X2, Shimadzu, Japan) with minor modification from previous procedures (Andrieux et al., 2012; Antakli et al., 2015; Yin et al., 2009). Mineral of Ca, Fe, P, Zn, Mg, K and Mn were determined using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) with concentric nebulizer type (Ahmad et al., 2015). Meanwhile, mineral of selenium was analysed by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) (AOAC International, 2005; Sezey & Adun, 2019).

Food analysis and micronutrients in different temperature

The effect of heating was performed by dissolving each rice fluor in two separated temperature of distillate water i.e., 95°C and 50 °C for 10 minutes with weight/volume ratio was 1:3. The pasting rice fluor was then utilized for further analysis (Azam et al., 2021; Nawaz et al., 2016).

Statistical analysis

The data was analysed as descriptive analysis as mean and standard deviation for detected values.

Results and Discussion

The difference morphological differences among three selected rice are demonstrated in Figure 1. Color pigment of rice exhibit the certain secondary metabolite compounds. Black pigment produces more anthocyanin content than red pigment (Fatchiyah et al., 2023; Sari et al., 2021). Rice with purple pigment exhibit ferulic acid compound (Wijayanti et al., 2022). The macronutrient analysis revealed the highest carbohydrate, protein, and ash content for NZ rice. However, NZ rice documented lowest level of moisture, fat, and calories from fat. Rice of JT had highest total calories than others rice (Table 1). This in line with previous work that showed lower moisture and higher protein in white rice cultivated in Java Island (Fatchiyah et al., 2020).

Figure 1. Three hybrid rice from Indonesia (A). White rice Inpari IR Nutri Zinc (B). Red Rice Inpari Arumba (C) Black rice Jeliteng

Table 1. The macronutrient composition in three varieties of Indonesian rice

Rice	Carbohydrate (%)	Protein (%)	Ash (%)	Moisture (%)	Fat (%)	Calories from fat (kcal/100 g)	Total calories (kcal/100 g)
Black Rice JT	77.84±0.07	7.67±0.03	0.95±0.04	12.26±0.07	1.28±0.01	11.52±0.13	353.56±0.04
Red Rice AR	75.55±0.30	8.68±0.19	0.94±0.00	13.22±0.13	1.62±0.02	14.54±0.19	351.44±0.62
White Rice NZ	78.20±0.09	9.36±0.11	0.97±0.005	11.3±0.02	0.18±0.00	1.62±0.00	352.34±0.56

The characters of soil are related with macronutrient composition in rice. A study by Ramzani et al., (2016) demonstrated the combination of Fe supplementation, immobilizing amendments and solubilizing agent attenuate the soil pH so that increase the percentage of crude fat, protein, and ash content. Other study was reported the alteration of proximate composition was associated with duration of storage following harvest. Longer period of storage is linked to the decrease of carbohydrate, ash, fat, and fibre contents. In contrast, longer storage elevates moisture level of rice (Fagbohun et al., 2015). Rice of NZ had lowest moisture level than others counterpart. Lower moisture in rice grain is associated with the necessary of more water according to faster water absorption during cooking process (Ohtsubo & Nakamura, 2017). The combination of lower moisture and higher protein percentage in white rice might impact the proposed cooking method. A study by Martin, et al was revealed that higher protein content in rice increase the viscosity (Martin & Fitzgerald, 2002).

In correlation with total calories level in all rice, all varieties had not detected level of cholesterol, trans fat, and sugar (Table 2). Free fatty acid was detected not more than 1% in all rice. The percentage of dietary fibre is higher in NZ rice. Dietary fibre reflects the plant component that resistant from enzymatic digestion in intestinal (Dhingra et al., 2012). Rice is one of cereals food that contain of fibre. The fibre component of rice is consisted of lignin, pectin, glucan, and others (Căpriţă et al., 2015).

Table 2. Food analysis properties in three selected varieties of Indonesian rice

Rice	Cholesterol (mg/100g)	Trans Fat (%)	Free Fatty Acid (%)	Sugar (%)	NaCl (%)	Dietary Fiber (%)
JT	n.d.	n.d.	1.00±0.63	n.d.	<0.07±0.00	6.58±0.18
AR	n.d.	n.d.	0.63±0.26	n.d.	<0.07±0.00	10.01±0.09
NZ	n.d.	n.d.	0.27±0.01	n.d.	<0.07±0.00	12.73±0.03

n.d=not detected

Previous study reported higher fibre content in brown rice which is related to the uncomplete milling process. In contrast, earlier analysis demonstrated the lowest fibre in white rice than coloured rice (Fernando, 2013). The increase of fibre in rice is associated with higher glycaemic index that provides a further health benefit against metabolic disorder particularly type 2 diabetic mellitus (Lovegrove et al., 2019). The heating process reduces the percentage dietary fibre in all rice. However, the percentage of dietary fibre was relatively higher in temperature of heating 95°C. Previous study was suggested that heating process related to conversion of insoluble fibre to soluble fibre thus affect the viscosity (Căpriţă et al., 2015). Previous study demonstrated that fibre is affected by longer duration of storage and soil characteristics. Decrease fibre content was discovered in longer storage. Meanwhile, soil supplementation increased the percentage of fibre content (Azam et al., 2021; Das et al., 2020).

The micronutrient profiles of rice are listed in Table 3. The vitamin A, B1, B5, B9, and D were not detected in three selected rice. The vitamin of B2, B12, and K was not detected in red and white rice. For overall, the vitamin level was higher in black rice varieties especially vitamin B7 and vitamin K. Minerals content analysis was revealed that phosphor is the highest mineral level in all rice. Other mineral content such as calcium was higher in white rice, kalium was higher in red rice, iron and magnesium were higher in coloured rice and zinc was higher in red rice. All rice were not detected for selenium content.

Table 3. Vitamin content in three selected varieties of Indonesian rice

Rice	Vitamin (mg/100g)												
	A	B1	B2	B3	B5	B6	B7	B9	B12	C	D	E	K
JT	n.d.	n.d.	1.14±0.01	0.65±0.00	n.d.	0.07±0.00	28.72±0.00	n.d.	1.09±0.01	<0.42±0.00	n.d.	0.19±0.00	15.15±0.05
AR	n.d.	n.d.	n.d.	0.22±0.01	n.d.	0.1±0.00	1.45±0.01	n.d.	n.d.	0.55±0.01	n.d.	0.29±0.00	n.d.
NZ	n.d.	n.d.	n.d.	0.2±0.00	n.d.	n.d.	1.16±0.00	n.d.	n.d.	<0.42±0.00	n.d.	n.d.	n.d.

n.d=not detected

Table 4. Mineral content in three selected varieties of Indonesian rice

Rice	Mineral (mg/100g)							
	P	Ca	K	Fe	Mg	Mn	Zn	Se
JT	3016.10±14.82	10.51±0.09	218.17±2.18	2.50±0.00	102.06±0.51	14.41±0.06	2.33±0.04	n.d.
AR	3136.95±14.70	14.09±0.03	238.24±0.66	2.50±0.00	104.83±0.21	17.50±0.04	4.26±0.01	n.d.
NZ	1283.97±0.79	20.27±0.26	72.96±0.35	0.61±0.015	26.44±0.105	11.98±0.15	2.53±0.02	n.d.

n.d=not detected

Vitamin C in coloured rice was more resistance to heating than other white colour. Vitamin B3 in white rice was reduce after heating as well as vitamin B7 that become not detected after 95°C of heating. Heating reduced the level of mineral in all varieties (Table.5). Vitamin and mineral matters in rice are predominantly ascertain in outer germ and bran layers. Consequently, rice milling process results in several vitamin and mineral loss about 70-90% of vitamin especially complex of vitamin B and vitamin E. Vitamin A is the most affected nutrient during milling. Accordingly, nutrient deficiencies are imminence to become public health issues among rice consumed population. In correlate to overcome the issues, some technological process has recognized to retain the nutrient component in rice endosperm such as fortification, parboiling and germination. Rice biofortification is reported as effective mechanism to provide large nutritional supplementary through major staple food (World Health Organization, 2018).

Our primary finding reveals the potential of three hybrid rice from Indonesia. The higher protein content of white rice NZ is suggested for further exploration of postharvest technology that preserves the protein level. Protein is important for many biological processes in humans such as nerve signal transmitter, immune function, biochemical catalyst, muscle function, molecules transportation, cell growth and development (Rizwan Hasan Khan, 2018). Protein in rice is relatively hypoallergenic and more digestible than other cereals food thus suitable for developed as functional food such as infant formulas (Shih, 2003). This research implicates essential information of broad advantages of three potential rice from Indonesia for food industries. Therefore, further cultivation biotechnologies and optimized of milling and cooking process would be enriched the nutrient value potential of all rice especially promotes the synergic benefit of antioxidant properties of coloured rice and nutritional values.

Conclusion

Among three varieties rice from Indonesia, white rice NZ is potential source of protein, dietary fibre, and calcium content. Red rice AR kalium, magnesium, manganese, and zinc. Black rice JT is a good source of total calories and vitamin. The difference effect of heating temperature arises the important of future research for food production technologies to preserve the micronutrient value of selected rice.

Table 5. The effect of heating on food analysis, vitamin, and mineral content in three selected varieties of Indonesian rice

Component	Black rice JT		Red rice AR		White rice NZ	
	50°C	95°C	50°C	95°C	50°C	95°C
Free Fatty Acid (%)	6.06	0.20	0.25	0.11	0.12	0.33
Dietary fiber (%)	0.08	6.16	4.87	6.73	5.28	6.04
Vitamin B3 (mg/100g)	n.d.	n.d.	n.d.	n.d.	0.75	1.23
Vitamin B7 (mcg/100g)	n.d.	n.d.	n.d.	n.d.	0.99	n.d.
Vitamin C (mg/100g)	1.38	0.86	2.19	1.36	n.d.	n.d.
Vitamin E (mg/100g)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ca (mg/100g)	9.47	n.d.	3.92	n.d.	113.56	10.09
K (mg/100g)	57.93	48.30	80.93	77.36	77.16	87.96
Iron (mg/100g)	n.d.	n.d.	n.d.	n.d.	1.97	0.55
Mg (mg/100g)	27.77	23.48	34.5	35.63	34.71	43.64
Mn (mg/kg)	6.38	5.59	4.23	4.78	11.8	13.32
Zn (mg/100g)	0.79	0.56	0.4	0.62	3.15	2.69

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