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Nutrient Composition of Indonesian Specialty Cereals: Rice, Corn, and Sorghum as Alternatives to Combat Malnutrition

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ABSTRACT: Stunted growth (stunting) caused by malnutrition is a growing concern in Indonesia. The nutritional composition of cereals is important information for improving people's nutrition. This research aimed to comparatively study the nutritional values of several Indonesian local cereal crops and provide a nutritional database for promoting local food with the aim of combating malnutrition. The cereals investigated included varieties of rice, corn, and sorghum. The nutritional analysis included ash, protein, fat, carbohydrates, dietary fiber, essential amino acids, vitamins, and minerals. A purposive sampling method was performed by collecting five lots from each sampling area and forming composite samples by combining 1∼2 kg of each sample, then mixed before laboratory analysis. The results showed that colored rice, colored corn and sorghum, contain richer essential nutrients, dietary fiber, and essential amino acids compared to white rice and corn. The highest protein content was found in sorghum (13.26%), followed by corn (9.18%), and rice (8.0%). The highest energy value was also found in sorghum (380.5 kcal/100 g), followed by corn (379.9 kcal/100 g), and rice (362.1 kcal/100 g). The same sequence was seen for the mineral contents, where the zinc and iron contents were 1.57 and 2.39 mg/100 g, respectively for sorghum; 1.36 and 0.79 mg/100 g for corn; and 0.93 and 0.58 mg/100 g for rice. Accordingly, it can be concluded that sorghum has the highest nutritional value and therefore potential for combating malnutrition, while corn and rice are also highly nutritious and can be grown locally in order to combat malnutrition.

Keywords: corn, malnutrition, nutritional composition, rice, sorghum

INTRODUCTION

Stunting (stunted growth under the age of 5) is a condition in which a child's growth and development are impaired due to poor nutrition and/or recurrent infection, mainly in the early years of life. Stunting can lead to cognitive and developmental delays. Stunting is a significant public health issue, particularly in developing countries. According to the latest prevalence data (World Health Organization, 2014), Indonesia has one of the highest rates of stunting in Southeast Asia. In Indonesia, the number of children suffering from stunting dropped from 27.7% in 2019 to 21.6% in 2022. However, the prevalence of wasting increased from 7.1% in 2021 to 7.7% in 2022, and the prevalence of underweight rose from 16.3% in 2021 to 17.0% in 2022 (Badan Kebijakan Pembangunan Kesehatan, 2022).

Although the prevalence of stunting is decreasing, this figure is still far from the 2020∼2024 National Medium Development Plan for Indonesia's target of 14% (Badan Kebijakan Pembangunan Kesehatan, 2022).

Stunting, wasting, and underweight are categorized under malnutrition and have become a national priority in Indonesia. Nutrient intake plays a vital role in supporting the development of children (Drennen et al., 2019) and low consumption of energy and protein causes growth failure. The causes of stunted, wasting, and underweight in children under 5 include lower intake of nutritious food and the presence of chronic infectious diseases. Toddlers are at 1.59 times more risk of experiencing stunting when their protein intake is below the nutritional adequacy level (Assis et al., 2004). Moreover, stunting often happens due to a dietary deficiency of zinc (Zn), iron (Fe), calcium (Ca), iodine (I), and vitamin A. The need for mac-

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ro and micronutrients is higher for infants than for other age groups.

Cereals rank first as a staple food in the world. Rice and corn are the primary sources of carbohydrate in Indonesia. Indonesia's national rice consumption averaged 103.62 kg/person/year in 2019 (Candraningtyas et al., 2021). Reardon and Timmer (2014) suggested that rural consumers in Asia consume approximately 70% of their daily calories from rice. Indonesia produces various types of cereal, including specialty rices (e.g., red and black) specialty corns (e.g., waxy and purple), and sorghum, which have specific nutritional contents and health benefits. Sorghum, in particular, has become part of Indonesia's national food security program. Apart from being a source of carbohydrate, these local cereals also contain other essential microelements such as vitamins, minerals, dietary fiber (DF), and amino acids, and other bioactive components that confer health benefits. Therefore, information on the complete nutritional composition of these local varieties is essential for making location-specific staple food development policies. In addition, the emergence of various health problems has a close relationship with the fact that most people consume only one type of staple food, resulting in the need to explore the nutritional components of these local varieties more comprehensively.

Based on the 2022 Indonesian Nutrition Status Survey Report, Aceh, East Nusa Tenggara (NTT), West Nusa Tenggara (NTB), Papua, and West Sulawesi are the provinces with the highest prevalence of stunting in Indonesia (above 30%). In addition, Aceh and NTT have the most increased waste and underweight rates (Badan Kebijakan Pembangunan Kesehatan, 2022). One of the efforts to overcome malnutrition is to utilize nutritious local resources such as cereals. Specialty sorghum is widely cultivated in NTT, NTB, and Sulawesi, while specialty corn is commonly grown in Sulawesi. Sorghum has high nutritional composition but the nutritional information is unknown and it is rarely used by food industries (Cheng et al., 2017).

This aim of this paper is to provide nutrition data to update the Indonesian Food Composition Table and to expand the database for adequate food security. Information regarding the nutrition and bioactive composition of cereals may help the promotion of local food for stunted or malnourished children's dietary intake. The paper involves a comparative study of the nutritional values of Indonesian rice, corn, and sorghum.

MATERIALS AND METHODS

Samples of local cereals were taken from their specific producing areas in Bali and West Java (rice) and South Sulawesi (corn and sorghum), harvested in 2022. The sampling method used was purposive sampling. The rice varieties used in this study were black rice (glutinous rice) (Fig. 1), red rice (Fig. 2), and white rice (IR-42 and Ciherang). The corn varieties were purple corn (Fig. 3) and waxy corn (Fig. 4). A single variety of sorghum used was Sorghum var. Super-1 (Fig. 5).

Five representative samples were collected from each lot. From every lot, 2∼5 kg of the cereals was placed in a plastic bag and sent to the laboratory. In the laboratory, the package contents constituting a unit sample were weighed individually. Before being analyzed, composite samples were prepared by combining 1∼2 kg of each sample prior to mixing. Compositing was employed to minimize the influence of outlier behavior from individual variations within sample types. Then, aliquots were taken in triplicate for analysis in the laboratory.

Fig. 1. Black rice.

Fig. 2. Red rice var. Cendana.

Fig. 3. Corn var. Srikandi (purple corn).

Fig. 4. Corn var. Pulut (white, waxy corn).

Analysis

The moisture content, ash, protein, fat, carbohydrates, amino acids, vitamins (A, B1, B2, C, D), folic acid, and minerals (Ca, Na, Co, Zn, Fe, K) were analyzed. All the analytical determinations were performed using AOAC methods, as reviewed by Qanytah et al. (2022).

Starch: amylose and amylopectin

Starch consists of two types of polysaccharide molecule: amylose and amylopectin. The starch content was determined by employing the Luff-Schoorl method (Subroto et al., 2020). The amylose content was quantified using a colorimeter developed by International Rice Research Institute and Juliano (1971). The amylopectin content was calculated by subtracting the amylose content from the starch content.

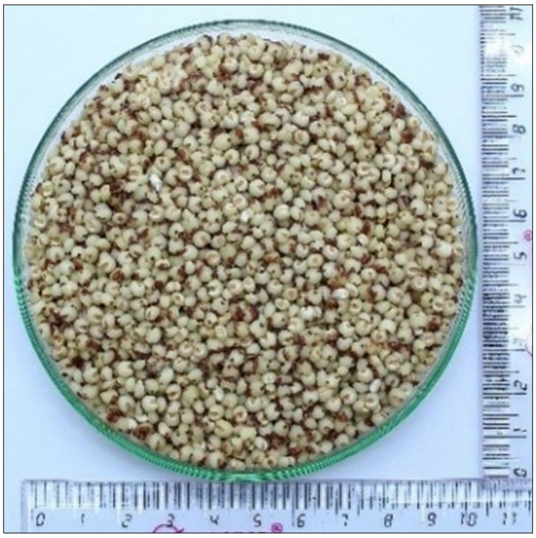

Fig. 5. Sorghum var. Super-1.

Fiber and ash contents

The fiber content was determined using Van Soest's method (1963; reviewed by Jocelyne et al., 2020). The same method was employed to determine the ash content. In this method, a sample is burned until white ashes are obtained. A cap containing the sample was placed in a muffle furnace (PYROLABO) at 550°C for 5 h. Then, the sample was removed from the muffle furnace and left to cool in a dryer before weighing.

Beta-carotene and total carotene

Beta-carotene content was determined using a procedure adapted from previously reported methods (Paradiso et al., 2020). Samples (1 g) were weighed in covered test tubes. Extraction solvent (acetone) was added to reach up 20 mL and 160 mmol/L of pyrogallol was added to improve the extraction efficiency. The mixture was then homogenized using an ultrasonic vibrator for 30 min in the dark. The extraction process was conducted three times and the mixtures obtained were then combined. The extracts were filtered using a 0.22 μm filter and immediately analyzed using a UHPLC Ultimate 3000 (Thermo Fisher Scientific). The concentration of the compound was determined using calibration data from newly prepared external standards at the time of analysis. The total carotene in all of the collected samples was determined using the method of Braniša et al. (2014). The method used for extract preparation was identical to the method described previously. An acetone : water mixture (4:1) was used as a solvent. The absorbance was measured at 663.6 nm for chlorophyll a, 646.6 nm for chlorophyll b, and 470.0 nm for carotenoids. The content of each was calculated using the following equations:

$$\text{Chlorophyll a } (\mu g/mL) = 12.25A_{663.6} - 2.25A_{646.6}$$

$$\text{Chlorophyll b } (\mu g/mL) = 20.31A_{646.6} - 4.91A_{663.6}$$

Total carotenoids (μg/mL)

$$=\frac{1{,}000A_{470}-2.27(\text{Chlorophyll a})-81.4(\text{Chlorophyll b})}{227}$$

The results were expressed as fresh weight of sample (mg/g).

Data analysis

All of the experiments were conducted in triplicate. The data were processed to obtain the standard deviation (±SD) to show their variability using Microsoft Office Excel in Windows 11.

RESULTS AND DISCUSSION

The nutritional properties of Indonesian black rice, red rice, purple corn, waxy corn, and sorghum grain were analyzed in this study. The proximate compositions of the cereals are listed in Table 1. The proximate composition included the moisture, carbohydrate, protein, lipid, energy, amylose, amylopectin, and DF contents.

Carbohydrates

Consuming starchy and carbohydrate-rich food can prevent malnutrition, stunting, and wasting. Illnesses caused by the lack of carbohydrates can be controlled with a daily intake of 50∼100 g of carbohydrates. According to the Australian Dietary Guidelines, carbohydrates should produce 45∼60% of the body's energy. The data from Table 1 show that the carbohydrate content of the corn, rice, and sorghum analyzed ranged from 73% to 83%. Waxy corn (Pulut) ranked as the lowest source of carbohydrate, while rice var. IR-42 ranked the highest. The carbohydrate content of white rice is high (more than 80%) compared to other cereals (73∼78%). The carbohydrate content results of colored rice and corn were comparable with those from the study by Kumar et al. (2016) who reported the carbohydrate content for brown rice and maize as 76.2% and 74.3%, respectively. Yankah et al. (2020) demonstrated that brown rice contains a high carbohydrate content (77.94±0.32%). Meanwhile, Suarni (2016) reported the sorghum (var. Kawali) carbohydrate content as 75.66%, while Niro et al. (2019) reported it to be 74.5%. According to Jocelyne et al. (2020), maize has a lower carbohydrate content (75.48%) than purple corn (78.64%).

Carbohydrates are required infant feeding because they supply energy for growth, bodily functions, and activities. Therefore, in infants over 6 months of age, additional carbohydrates must be given as complementary foods, such as cereals and products made from flour, fruits, and vegetables (Hardinsyah and Supariasa, 2016).

Starch is the main source of energy in most food crops.

Table 1. Proximate composition of the cereals

Commodity	Moisture (%)	Ash (%)	Carbohydrate (%)	Starch (%)	Amylose (%)	Amylopectin (%)	Protein (%)	Lipid (%)	Energy (kcal)	Dietary fiber (%)
Purple corn	6.47±0.28	1.46±0.12	78.65±0.43	68.59±0.79	20.75±1.25	47.85±2.04	9.14±0.13	4.28±0.12	389.67±1.10	14.95±0.64
Waxy corn	11.78±0.19	1.07±0.08	73.63±0.09	68.52±0.47	10.07±0.68	58.44±1.15	9.22±0.06	4.30±0.17	370.15±1.60	10.90±1.05
Red rice	11.98±0.15	1.18±0.07	76.17±1.21	69.69±0.22	22.90±0.92	46.79±0.70	8.19±1.21	2.48±0.07	359.77±0.72	5.27±0.09
Black rice	10.96±0.39	1.11±0.12	75.59±0.31	68.72±0.12	15.87±0.18	52.85±0.06	9.28±0.11	3.06±0.08	367.07±1.58	6.99±0.24
Rice var. IR-42	9.23±0.11	0.65±0.05	83.46±0.17	71.86±0.02	26.27±0.16	45.59±0.17	6.18±0.06	0.48±0.05	362.89±0.62	4.32±0.06
Rice var. Ciherang	10.41±0.20	0.58±0.05	80.13±0.31	71.47±0.56	16.81±0.68	54.66±1.24	8.36±0.09	0.52±0.09	358.64±0.88	6.10±0.96
Sorghum	6.81±0.12	0.68±0.04	77.16±0.52	68.34±0.41	26.48±0.54	41.87±0.95	13.26±0.50	2.09±0.10	380.53±0.45	6.23±0.72

Values are presented as mean±SD.

In the study, the starch contents of corn, rice, and sorghum were found to range from 68.34% to 71.86% (Table 1). The highest content was found in white rice (var. IR-42 and Ciherang), followed by colored rice (red and black rice), corn, and finally sorghum. Starch is the most important energy source for humans. However, the amount of energy intake and ability to increase circulation blood glucose levels do not always coincide with the starch content or carbohydrate intake. Resistant starch is defined as the amount of starch and starch digestion products that cannot be absorbed by a healthy human intestine. Therefore resistant starch does not produce energy. Carbohydrates that are broken down slowly, such as resistant starch, tend to decrease the glycemic response (Astawana and Widowati, 2011).

Among the cereals analyzed, sorghum had the highest amylose content (26.48%), followed by rice var. IR-42 (26.27%), red rice (22.90%), and purple corn (20.75%), while waxy corn had the lowest amylose content (10.07%). Amylopectin comprised a significant portion of starch in all the studied commodities, ranging from 41.87% (sorghum) to 58.44% (waxy corn). This is a characteristic of food crop sources of carbohydrate. Corn starch usually contains around 72% amylopectin and 28% amylose, and includes a little fat and protein (Wang et al., 2023). In this study, the amylose and amylopectin content of starch from Srikandi (purple) and Pulut (waxy) maize were found to be below these values, indicating that the botanical origin and type of corn determine the amylose and amylopectin content.

Protein

Protein is needed to support the growth of the human body. Deficiency of this nutrient creates conditions that result in system failures that can cause stunting (Golden, 2010). Protein functions as a builder of new tissue during the growth and development of the body, maintaining, repairing, and replacing damaged tissue (Wulandary and Sudiarti, 2021). Therefore, a high protein diet incorporating several local commodities such as sorghum, rice, and corn is an alternative technique for reducing stunting.

The protein content of the crops analyzed in this study ranged from 6.18% to 13.26%: white rice had the lowest protein content (7%), followed by colored rice (8∼9%), corn (>9%), and sorghum (13.26%). The protein level in sorghum Super-1 is much higher (13.26%) than that of other varieties of sorghum, such as sorghum Kawali (8.07%) and African sorghum (8.99%), and that of maize (7.1%) (Jocelyne et al., 2020). Sorghum seeds contain a 10.4% higher protein content compared to rice (Suarni and Aqil, 2020). Widowati and Luna (2022) reported that various varieties of sorghum contained between 8.72% and 12.10% protein content.

***Protein requirements*:** The daily protein requirement for adults is 0.66 g/(kg BW.d), while the requirement for children and infants is slightly higher (Holt and Snyderman, 1965; Otten et al., 2006d). Up to the age of 3, an infant requires an estimated 0.87 g protein/(kg BW.d), while children over the age of 3 years require 0.73 g/(kg BW.d) of protein for growth and maintenance.

***Estimated target cereal intake to meet the protein requirement*:** The total protein requirements proposed by World Health Organization (WHO) and Institute of Medicine (IOM) were used to generate theoretical cereal intake levels to meet dietary needs. The calculations of "target" daily intakes to meet nutrient requirements are the sole source of protein consumed in the diet. Although a daily diet should be combined with other food, this exercise helps us to understand cereals' maximum potential in adults and young children (Table 2). One hundred grams of cereal provides approximately 376 kcal (FatSecret, 2023). The average estimated energy requirement for Indonesian people is 2,100 kcal/d (Peraturan Menteri Kesehatan, 2019); therefore a daily cereal intake of ±550 g is required.

Lipids

One of the disturbances that can cause malnutrition in toddlers is the lack of consumption of essential fats. Fat intake during toddlerhood is recommended from foods with sources of essential fatty acids such as nuts, vegetable oils, whole grains, and brown rice.

In this study, lipid content of white rice (IR-42 and Ciherang) was found to be lower than that of the other cereals. The highest lipid content was found in purple and waxy corn (4.28% and 4.30%), values which were comparable with the results reported by Jocelyne et al. (2020) (4.85%). The lipid content of sorghum was found to be 2.09%, slightly lower than the value reported in previous studies by Suarni (2016), Niro et al. (2019), and Widowati and Luna (2022), who reported the lipid contents of sorghum to be 2.5, 2.6, and 2.48%, respectively.

Energy

Fulfilling the energy needs of infants and toddlers (infants under 5 years old) has the objective of physical and psychomotor growth and development, carrying out physical activity, and providing adequate nutrition for maintenance and/or restoration and improvement of health (Gat-Yablonski and Phillip, 2015).

DF

DF resists digestion and absorption in the human small intestine. During digestion, DF passes into the large intestine and can be entirely or partially fermented by the resident microbial population, promoting beneficial physiological effects (DeVries et al., 2001). DF promotes physiological benefits such as lowering the blood cholesterol

Table 2. Estimated target daily intakes to meet a reference adult's and child's protein requirements

Commodity	Nutrient reference	Amount (g) in 100 g commodities	Adult		Child	
			Requirement (g/d)	Intake to meet the requirement (g/d)	Requirement (g/d)	Intake to meet the requirement (g/d)
Purple corn	WHO	9.14	46.20[1)]	505	8.76	96
Waxy corn	WHO	9.22	46.20	501	8.76	95
Red rice	WHO	8.19	46.20	564	8.76	107
Black rice	WHO	9.28	46.20	498	8.76	94
Rice var. IR-42	WHO	6.18	46.20	748	8.76	142
Rice var. Ciherang	WHO	8.36	46.20	553	8.76	105
Sorghum	WHO	13.26	46.20	348	8.76	66
Purple corn	IOM	9.14	46.20	505	10.44	114
Waxy corn	IOM	9.22	46.20	501	10.44	113
Red rice	IOM	8.19	46.20	564	10.44	127
Black rice	IOM	9.28	46.20	498	10.44	113
Rice var. IR-42	IOM	6.18	46.20	748	10.44	169
Rice var. Ciherang	IOM	8.36	46.20	553	10.44	125
Sorghum	IOM	13.26	46.20	348	10.44	79

[1)]Requirements calculated for a 70-kg adult and 12-kg child using recommendations provided by World Health Organization (WHO) (Holt and Snyderman, 1965) and Institute of Medicine (IOM) (Otten et al., 2006d).

and blood glucose, thereby decreasing the risk of cardiovascular disease and diabetes (DeVries et al., 2001; Larsson and Wolk, 2014) and minimizing the risk of inflammatory bowel disease and colorectal cancer (Govers et al., 1999).

In the present study, corn var. Srikandi (purple corn) had the highest DF content (14.95%), followed by corn var. Pulut (waxy corn) (10.90%). The other cereals showed comparable values of DF contents (5.27∼6.99%), but rice var. IR-42 had a much lower DF content (4.32%). According to Foster-Powell et al. (2002), the DF content of corn is higher than that of white rice, and also has a lower glycemic index (62). For rice, the difference in DF can be attributed to the processing conditions. During the rice milling process, particularly those that use several rounds of polishing, the level of DF is reduced because the rice bran is removed. DF has a crucial role in maintaining human health. This component affects the assimilation of glucose and lowers serum cholesterol. According to Widowati et al. (2006), higher food fiber contents tend to reduce food's glycemic index. Therefore, the corns analyzed in this study have potential as DF sources. DF can also help improve malnutrition in people suffering from physiological alterations in alcohol disorders. DF intake, particularly soluble DF intake, is associated with reduced gastrointestinal discomfort (Amadieu et al., 2021).

Beta-carotene and total carotene

Carotenoids are the primary source of vitamin A in many developing countries where diets are primarily plant-based. Cereals provide most calories in developing countries, and most cereal grains accumulate carotenoids, particularly lutein, zeaxanthin, β-carotene, and β-cryptoxanthin. Previous studies have demonstrated that carotenoids are present in sorghum grains, and that β-carotene is the main provitamin A carotenoid (Afify et al., 2012). Carotenoids are a significant group of bioactive compounds with health-promoting properties (Fiedor and Burda, 2014) and are responsible for the color of a wide variety of grains (Fratianni et al., 2017). Some carotenoids are the precursors of retinol (vitamin A) and are powerful natural antioxidants. Carotenoids are known to be efficient physical and chemical quenchers of singlet oxygen and potent scavengers of other reactive oxygen species (Fiedor and Burda, 2014).

In this study, we found that sorghum had the highest beta-carotene and total carotene contents (3,347.66 and 6,428.10 μg/100 g, respectively) among the cereals tested (Table 3). The grain with the second highest carotenoid content was purple corn var. Srikandi (776.27 μg/100 g of β-carotene and 1,701.10 μg/100 g of total carotene). Purple corn was found to have the highest vitamin A content (116.50 μg/100 g), while sorghum contained only 1.20 μg/100 g of vitamin A. In a previous study (Niro et al., 2019), the β-carotene content was reported to be 9,860 μg/100 g.

Vitamins

Vitamins are organic compounds that are required in small amounts to perform at least one specific metabolic function. The body cannot synthesize these substances; therefore, they must be supplied from the food consumed. It is known that some vitamins play essential roles in the growth and development of children and thus have a relationship with stunting (Mikhail et al., 2013; Iqbal et al., 2019). Plenty of studies have shown the positive contribution of vitamins A and C to the growth of healthy children (Maggini et al., 2010).

Table 3. Carotenoid and vitamin composition of sampled cereals

Commodity	Beta-carotene (μg/100 g)	Total carotene (μg/100 g)	Vit A/retinol (μg/100 g)	Vit B1 (mg/100 g)	Vit B2 (mg/100 g)	Vit B3 (mg/100 g)	Folic acid (mg/100 g)
Purple corn	776.27±11.07	1,701.10±2.70	116.50±0.79	0.05±0.00	0.00±0.00	4.70±0.19	0.12±0.01
Waxy corn	0.26±0.00	87.00±7.50	0.37±0.01	3.76±0.47	0.23±0.04	3.71±0.15	0.08±0.00
Red rice	NA	NA	NA	0.34±0.00	NA	NA	0.02±0.00
Black rice	NA	NA	NA	0.26±0.03	0.15±0.34	NA	0.27±0.02
Rice var. IR-42	NA	NA	NA	0.32±0.00	0.01±0.00	1.48±0.34	0.07±0.00
Rice var. Ciherang	NA	NA	NA	0.18±0.02	0.01±0.00	1.55±0.03	0.06±0.00
Sorghum	3,347.66±202.5	6,428.10±1.07	1.20±0.04	0.36±0.01	1.12±0.00	3.14±0.10	0.05±0.01
RDA (Institute of Medicine of the National Academies, 2005)	1,942 (162 μg RAE) for men 31~50 years	1,353 to 1,966 μg/d for men and women	744 to 811 μg/d for men and 530 to 716 μg/d for women	2 mg/d for men and 1.5 mg/d for women	1.2 mg/d for men and 1.1 mg/d for women	16 mg/d for men and 14 mg/d for women	

Values are presented as mean±SD.
NA, not analyzed; RDA, Recommended Dietary Allowance.

Regarding the B vitamins, thiamine (vitamin B1) is a significant water soluble vitamin, as it is a co-factor of several key enzymes that are involved in carbohydrate metabolism and defense mechanism (Hrubša et al., 2022). The Recommended Dietary Allowance (RDA) for thiamine for infants aged 6～11 months is 0.4 mg; children aged 1～3 years, 0.5 mg; and adults, 1.1～1.2 mg (Ministry of Health of the Republic of Indonesia, Regulation No. 28/2019; Peraturan Menteri Kesehatan, 2019). The three types of cereal studied (rice, corn, and sorghum) generally contain water soluble B vitamins. In this study, the thiamine (vitamin B1) content ranged from 0.05～3.76 mg/100 g. The highest thiamine content was found in waxy corn (3.76 mg/100 g), followed by sorghum (0.36 mg/100 g). The thiamine content of waxy corn was much higher than that in the other cereals. We found that waxy corn contained 10 times more thiamine than the other cereals (rice and sorghum).

Riboflavin (vitamin B2) is a precursor of the coenzymes flavin mononucleotide and flavin adenine dinucleotide, which are components of oxidases and dehydrogenases. It is also essential for skin health and normal vision and can be found in whole cereals, bread, leafy green vegetables, and milk products (Zhang et al., 2018). In this study, we found that sorghum had the highest riboflavin content (1.12 mg/100 g; Table 3).

For niacin (vitamin B3), the data showed that corn had the highest niacin content (3.71～4.70 mg/100 g), followed by sorghum (3.14 mg/100 g), and rice (1.48～1.55 mg/100 g). The RDA for niacin is 4 mg for infants, 6 mg for children aged 1～3 years, and 14～16 for adults (Peraturan Menteri Kesehatan, 2019). Niacin functions as a co-substrate or coenzyme with numerous dehydrogenases for transferring the hydride ion. The primary method used to estimate the requirement for niacin relates intake to the urinary excretion of niacin metabolites. The condition is expressed in niacin equivalents, allowing some conversion of the amino acid tryptophan to niacin (Otten et al., 2006d). Tryptophan is also food source of niacin because this amino acid can be converted to nicotinamide adenine dinucleotide, mainly in the liver (Fricker et al., 2018). Despite of its richness in niacin, corn usually lacks tryptophan; nonetheless, niacin is bound to carbohydrates, which makes it difficult for the human body to absorb. To be absorbed, corn should be processed, such as by nixtamalization, where corn is treated with calcium hydroxide, cooked, and ground, or by combining corn with other niacin and tryptophan rich sources such as soybean (Rudini and Ayustaningwarno, 2013). By applying this method, the niacin content in cereal can be improved and can prevent pellagra disease, which is caused by deficiency of niacin and tryptophan.

Minerals

According to Tulchinsky (2010), minerals are essential nutrients that are required in small amounts for various physiological processes, such as building strong bones, transmitting nerve impulses, and regulating the body's fluid balance. Many different minerals are essential for maintaining good health, including calcium, sodium, copper, zinc, iron, potassium. These minerals can be obtained from various food sources, including fruits, vegetables, whole grains, and lean proteins. Therefore, it is essential to consume a balanced diet that includes a variety of nutrient-rich foods to ensure that our body is getting all of the minerals and other nutrients it needs to stay healthy.

***Calcium (Ca)*:** Calcium is an essential mineral that plays a vital role in maintaining healthy bones and teeth and supporting proper muscle function and nerve transmission (Tulchinsky, 2010). Table 4 shows that sorghum is a potent source of calcium, with an average content of 12.52 mg/100 g. This content was the highest compared to the other local commodities; red rice and black rice showed calcium contents of 9.26 and 7.50 mg/100 mg, respec-

Table 4. Mineral composition of the sampled cereals (unit: mg/100 g)

Commodity	Ca	Na	Cu	Zn	Fe	K
Purple corn	0.47±0.27	14.56±0.05	0.29±0.00	1.36±0.01	0.79±0.00	652.49±12.19
Waxy corn	2.48±0.41	14.03±0.06	0.06±0.00	0.39±0.00	0.38±0.01	312.64±3.29
Red rice	9.26±1.01	6.81±0.04	0.35±0.00	0.93±0.01	0.40±0.01	451.68±4.43
Black rice	7.50±0.15	3.44±0.09	0.18±0.00	1.26±0.01	0.17±0.01	1,032.91±19.26
Rice var. IR 42	2.10±0.33	1.04±0.04	0.34±0.00	0.20±0.00	0.15±0.01	62.21±1.96
Rice var. Ciherang	4.37±0.25	1.28±0.03	0.15±0.00	0.40±0.00	0.58±0.01	338.80±7.15
Sorghum	12.52±0.20	1.26±0.08	0.29±0.00	1.57±0.06	2.39±0.01	361.99±1.53

Values are presented as mean±SD.

tively. Similar to the results presented by Kumar et al. (2016), we established the calcium content of sorghum to be 13.00 mg/100 g. However, the results of a study by Yankah et al. (2020) showed that the calcium content of local Ghanaian corn, reached 21.40 mg/100 g. daily calcium intake varies depending on age and gender, but it is approximately 1.0 mg/d for most adults (Otten et al., 2006a).

Sodium (Na)**:** Sodium is vital in maintaining healthy blood pressure and supporting cardiovascular health. However, it is essential to consume sodium in moderation. Consuming too much sodium can increase the blood pressure and the risk of developing health problems such as heart disease, hypertension, and prehypertension (Doyle and Glass, 2010).

In this study, we found that the highest sources of sodium sources were purple corn and waxy corn (14.56 and 14.03 mg/100 g, respectively). These results were similar to those from the studies conducted by Kumar et al. (2016) and Jocelyne et al. (2020), where the average content of sodium in cereals and grains ranged from 2 to 7 mg/100 g. Therefore, with a high enough sodium content, purple and waxy corn can be the best choice to become a local food source as a good source of sodium for health. Meanwhile, Oria et al. (2019) showed that the daily sodium intake for most adults was no more than 2.3 mg/d, but some individuals, such as those with high blood pressure or certain medical conditions, may reduce the consumption.

Copper (Cu)**:** Copper is involved in forming red blood cells, connective tissue, and various enzymes, and it also helps to support immune function. The highest copper content in observed local products was found in red rice (0.35 mg/100 g). This result was lower that reported in the study conducted by Jocelyne et al. (2020), showing that grain products contain 0.74 mg/100 g copper. Meanwhile, the recommended daily intake of copper for most adults is around 900 μg per day. Copper deficiency is rare in developed countries (Otten et al., 2006b).

Zinc (Zn)**:** According to Hemalatha et al. (2007), zinc is the fourth most crucial micronutrient after vitamin A, iron, and iodine, and it is now receiving increasing global attention. Zinc is vital for proper immune function, wound healing, and DNA synthesis, and it also plays a role in taste and smell perception. Sorghum was found to have the highest zinc content (1.57 mg/100 g), followed by purple corn and black rice (1.36 and 1.26 mg/100 g, respectively). These results are almost the same as those reported in a study conducted by Jocelyne et al. (2020), where most cereals were reported to have a zinc content of 0.83∼2.37 mg/100 g, with the highest found in fonio and sorghum (2.27 and 4 mg/100 g, respectively). In addition, Hemalatha et al. (2007) reported that sorghum had the highest zinc content compared to other cereals (2.26 mg/100 g), including rice. Therefore, it is reasonable to use sorghum as one of the local cereal commodities to be used as a primary food source of zinc. The recommended daily zinc intake varies depending on age and gender, but for most adults, it is around 8∼11 mg/d (Otten et al., 2006e).

Iron (Fe)**:** Iron is a component of hemoglobin, a protein in red blood cells that carries oxygen from the lungs to the rest of the body. Iron is a common nutritional deficiency worldwide, leading to anemia, fatigue, and other health problems. With a content of 2.39 mg/100 g, sorghum can be used as a food source to reduce the occurrence of iron deficiency. However, the iron content in the sorghum tested was far lower than that reported in the sorghum analysis carried out by Hemalatha et al. (2007), where the Iron content of the tested sorghum reached 6.51 mg/100 g. This can be compared with the iron content in rice, the staple food of most Indonesians, which is 0.5 mg/100 g. Meanwhile, the recommended daily iron intake varies depending on age and gender, but for most adults, it is between 8 and 18 mg/d (Otten et al., 2006c).

Potassium (K)**:** Potassium helps to regulate fluid balance, maintain proper muscle and nerve function, and support heart health. The results showed that black rice had the highest potassium content (1,032.91 mg/100 g), followed by purple corn and red rice (652.49 and 451.68 mg/100 g, respectively). This makes black rice an excellent source of potassium. This result is higher than the potassium content in wheat, maize, sorghum, millet, and fonio (Jocelyne et al., 2020). The range of potassium wheat content has been reported to be 112.19∼283.80 mg/100 g (*Ibid.*). The recommended daily potassium intake for most adults is around 2.5 mg/d, although individual needs may vary depending on age, gender, and health status.

Amino acids

Dietary protein plays an essential role in childhood brain development and growth. Protein quality is determined based on the completeness of the amino acid content in the food intake. Insufficient intake of essential amino acids (EAAs) can disturb the metabolic process that directly impacts the linear growth of children (Rizky Maulidiana and Sutjiati, 2021). Semba et al. (2016) reported that children with stunting had lower serum concentrations of all nine EAAs (tryptophan, isoleucine, leucine, valine, methionine, threonine, histidine, phenylalanine, and lysine) compared with non-stunted children. In addition, stunted children had significantly lower serum concentrations of conditionally EAAs (arginine, glycine, glutamine), non EAAs (asparagine, glutamate, serine), and six different sphingolipids compared with non stunted children. These findings were agreed by Uauy et al. (2016), who emphasized the evidence regarding the link between inadequate protein and amino acid intake and stunting in children. Research conducted in Indonesia among under-fives in Malang City, East Java, also concluded that stunted children might not receive sufficient dietary intake of EAAs (Rizky Maulidiana and Sutjiati, 2021).

This study shows that the most complete EAA content is in sorghum, followed by corn and rice. The highest EAA content value in sorghum is for leucine (2.12 g/100 g), followed by histidine (1.28 g/100 g), phenylalanine (0.94 g/100 g), and valine (0.66 g/100 g; Table 5). According to Suarni (2016), the lysine content of sorghum seeds is much higher than that found in corn and slightly higher than that found in rice. Likewise, the leucine and isoleucine contents are relatively higher in sorghum than in rice and corn. The histidine content in the Super-1 sorghum in this research was found to be much higher (1.28 g/100 g) than that of colored sorghum from South Africa reported by Nemukondeni et al. (2022): 0.37 g/100 g for brown sorghum and 0.30 g/100 g for red sorghum. L-histidine is an EAA whose deficiency can cause neurological disorders, atopic dermatitis, metabolic syndrome, diabetes, uremic anemia, ulcers, inflammatory bowel diseases, malignancies, and muscle performance during strenuous exercise (Holeček, 2020).

In the study by Nemukondeni et al. (2022), the valine and leucine contents of the African brown variety of sorghum had a higher concentration (0.61 and 1.63 g/100 g) as well as white variety of sorghum (0.52 and 1.42 g/100 g), a bit lower compared to the research result of this study, which were 0.66 and 2.12 g/100 g for Super-1 sorghum variety. The phenylalanine content of our study was higher (0.94 g/100 g) than that reported by Nemukondeni et al. (2022) which contain 0.74 g/100 g. The EAA contents (leucine, histidine, and phenylalanine) in purple corn are higher (1.31, 1.49, and 0.89 g/100 g) than those in waxy corn (1.05, 0.96, and 0.46 g/100 g), respectively.

The analysis of tryptophan requires a special method, which is different from the analysis of other EAAs. The current study did not analyze tryptophan. However, Aqil and Firmansyah (2008) reported that new superior varieties of corn contain tryptophan contents of around 0.12∼0.13 g/100 g. The EAA contents of black and red rice are relatively comparable for all EAAs but lower compared to sorghum and purple corn, as shown in Table 5. According to Serna-Saldivar and Espinosa-Ramírez (2018), the lysine content of sorghum meets approximately 40%

Table 5. Amino acid composition of the sampled cereals (Unit: g/100 g)

Amino acid	Purple corn	Waxy corn	Red rice	Black rice	Sorghum
Essential amino acid					
Phenylalanine	0.89±0.14	0.46±0.01	0.64±0.09	0.56±0.05	0.94±0.06
Isoleucine	0.44±0.17	0.27±0.04	0.31±0.04	0.34±0.08	0.54±0.02
Valin	0.44±0.05	0.37±0.00	0.45±0.01	0.50±0.01	0.66±0.02
Threonine	0.44±0.02	0.34±0.01	0.34±0.03	0.38±0.04	0.50±0.03
Histidine	1.49±0.04	0.96±0.01	0.92±0.02	0.88±0.02	1.28±0.02
Leucine	1.31±0.53	1.05±0.42	0.67±0.19	0.76±0.23	2.12±0.06
Lysine	0.31±0.09	0.22±0.00	0.27±0.02	0.29±0.00	0.15±0.00
Non essential amino acid					
Alanine	0.63±0.08	0.58±0.07	0.42±0.08	0.47±0.12	1.14±0.02
Arginine	0.60±0.06	0.41±0.01	0.77±0.08	0.79±0.06	0.43±0.02
Glycine	0.35±0.17	0.49±0.01	0.42±0.08	0.45±0.10	0.37±0.12
Aspartic acid	0.44±0.10	0.40±0.00	0.58±0.00	0.66±0.05	0.59±0.00
Tyrosine	0.39±0.04	0.29±0.01	0.37±0.06	0.40±0.04	0.55±0.01
Proline	0.93±0.00	0.73±0.01	0.37±0.00	0.42±0.01	1.17±0.03
Serin	0.59±0.14	0.46±0.01	0.45±0.03	0.51±0.04	0.69±0.23
Glutamic acid	1.63±0.03	1.36±0.04	1.21±0.02	1.38±0.06	2.44±0.19

Values are presented as mean±SD.

of the RDA for infants. The lysine content of the Indonesian sorghum tested in this study was 0.152 g/100 g, much higher than that reported for South African sorghum (0.10～0.13 g/100 g; Nemukondeni et al., 2022). The highest lysine content in the observed cereals was found in purple corn (0.308 g/100 g), followed by black rice (0.290 g/100 g). The nonessential AAs content was also higher in sorghum than in the other cereals, especially the alanine, proline, serine, and glutamic acid content.

The implication of the superiority of local cereal for children's growth can be applied in the formulation of complementary food or weaning food for toddlers. To improve the nutritional quality of the food in terms of EAA profile, the use of two or more plant-based food materials, such as cereal and legumes, in the preparation of complementary foods for toddlers has been proven via various scientific studies (Kumari et al., 2017; Tasie and Gebreyes, 2020; Keyata et al., 2021). Kumari et al. (2017) used sorghum and soybean for weaning food; Keyata et al. (2021) utilized sorghum, soybean flour, and other local material from Ethiopia as complementary food. Tadesse and Gutema (2020) found that using sorghum, common bean, and carrot flour blends in complementary food could significantly enhance the protein content without compromising consumer acceptance. Other researchers formulated weaning food based on maize and crayfish (Ajibola et al. 2016). Onoja et al. (2014) mentioned that, like every other cereal, it is ideal to combine cereals with legumes as this will improve their nutritional value.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Concept and design: CW, SW, WN, SMW, NS, QN. Analysis and interpretation: CW, SW, WN, SMW, NS, QN. Data collection: all authors. Writing the article: WN, NS, SMW, QN. Critical revision of the article: CW, SW. Final approval of the article: all authors. Statistical analysis: CW, SMW, NS. Obtained funding: QN. Overall responsibility: all authors.

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