

Characterization of Local Rice Varieties and Their Fe and Zn Contents in Agam Regency, West Sumatra, Indonesia

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ABSTRACT

Micronutrient deficiencies, particularly iron (Fe) and zinc (Zn), remain a critical global health challenge. Biofortification of rice offers a cost-effective and sustainable solution. This study aimed to characterize morphological grain traits and evaluate Fe and Zn content in three locally registered rice varieties *Kuruik Kusuik*, *Ampek Angkek*, and *Kusuik Putih* from Agam Regency, West Sumatra, Indonesia. Fe and Zn contents in brown rice (*beras pecah kulit*/BPK) were determined using X-ray fluorescence (XRF) spectrophotometry (X-Supreme 8000, Oxford Instruments). Results showed that *Kuruik Kusuik* exhibited the largest grain size, with the highest Fe content ($21.2 \pm 0.8 \text{ mg kg}^{-1}$) and Zn content ($22.8 \pm 0.6 \text{ mg kg}^{-1}$) among local varieties. Compared to the national biofortified standard Inpari Nutri Zinc (Fe: 24.0 mg kg^{-1} ; Zn: 33.1 mg kg^{-1}), *Kuruik Kusuik* showed Fe and Zn values approximately 11.7 and 31.1% lower, respectively. Notably, all three varieties are officially registered and possess a *pera* (non-sticky) texture uniquely preferred by Minangkabau communities—a trait absent in all existing biofortified varieties. The documentation of registered local rice varieties with *pera* texture and relatively high Fe and Zn content is the key novelty of this study. Further breeding using marker-assisted selection is recommended to improve mineral content while preserving local variety advantages.

Keywords: Biofortification; Fe and Zn content; Local rice varieties; Morphological characterization; Nutritional quality

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INTRODUCTION

Micronutrient deficiency, commonly referred to as 'hidden hunger' remains among the most critical global nutritional challenges. Iron (Fe) and zinc (Zn) deficiencies are the most prevalent, affecting over two billion people worldwide, particularly in developing nations where rice serves as the primary dietary

staple (Majumder et al 2019). In Indonesia, anemia largely driven by Fe deficiency affects approximately 21.4% of adolescent girls, with 54.7% consuming Fe-inhibiting foods frequently and 68.4% exhibiting low Fe bioavailability (Atta 2025). Zinc deficiency contributes to impaired immune function, stunted growth, and increased child mortality, accounting for

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nearly two-thirds of total child deaths globally (Minsas and Warsidah 2024). The multi-factorial nature of anemia encompassing nutritional status, menstrual duration, Fe and protein intake, malabsorption, and infectious diseases demands integrated, context-sensitive interventions (Warda and Fayasari 2021).

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population and forms the cultural and nutritional foundation of Indonesian society, particularly in West Sumatra. Despite its central role, conventional rice breeding in Indonesia has historically prioritized grain yield, pest resistance, and abiotic stress tolerance, while nutritional quality has received considerably less attention. Of more than 200 varieties released, very few address the critical need for elevated Fe and Zn content (Singh et al 2022). This gap has driven interest in biofortification a strategy to enhance micronutrient concentrations in staple crops through genetic improvement or agronomic management (Hartoyo 2022). Biofortification through improved varieties is considered more cost-effective and accessible than food fortification, particularly for remote communities (Majumder et al 2019). Surveys of rice germplasm have confirmed that Fe and Zn concentrations can vary substantially across genotypes, underscoring the potential for improvement through breeding (Susanto and Rohaeni 2021).

Indonesia has officially released four Zn-biofortified rice varieties: Inpari IR Nutri Zinc, Inpago 13 Fortiz, Inpara 11 Siam HiZinc, and Inpara 12 Mayas (ICRR 2022). Inpari IR Nutri Zinc, the first released in 2019 in collaboration with IRRI, contains up to 34.51 ppm Zn and has demonstrated yields 40.8% above the Ciherang variety in Jambi Province (Hairmansis et al 2019). Inpago 13 Fortiz (released 2020) contains up to 34 ppm Zn and resists blast disease in upland systems (Subekti and Umar 2023). In 2022, Inpara 11 Siam HiZinc and Inpara 12 Mayas were released for tidal swamp ecosystems (Sitaresmi et al 2023). However, none of these biofortified varieties possess *pera* (non-sticky) grain texture a texture highly preferred by Minangkabau communities in West Sumatra, where firm, non-sticky rice is a cultural staple. This gap represents a significant barrier to the adoption of biofortified rice among these communities.

Local rice varieties in Agam Regency, West Sumatra, Indonesia (0°01'–0°28'S; 99°46'–100°32'E), represent an underexplored genetic resource for biofortification. Maintained by local farming communities over generations, these

varieties are prized for their adaptability to local agroecological conditions and cultural qualities, particularly their *pera* texture. Despite their importance, their nutritional composition especially Fe and Zn content has not been systematically characterized. Research on the exploration and characterization of Fe and Zn content in local rice germplasm is therefore essential for identifying genetic donors with high mineral potential (Sitaresmi et al 2013).

The novelty of this study lies in the first systematic documentation and comparison of grain morphology and Fe/Zn content in three officially registered, *pera*-textured local rice varieties from Agam Regency *Kuruik Kusuik*, *Ampek Angkek*, and *Kusuik Putiah*—against nationally released biofortified varieties. This characterization provides the foundational data needed to initiate biofortification breeding programs targeting the Minangkabau community's dietary preferences. Specifically, this study aimed to: (1) characterize morphological grain traits of local rice varieties from Agam Regency, and (2) evaluate and compare their Fe and Zn content against nationally released biofortified rice varieties.

MATERIALS AND METHODS

Study Location and Period

Exploration and grain characterization were conducted from August to September 2024 across three sub-districts of Agam Regency, West Sumatra, Indonesia (0°11'–0°22'S; 100°21'–100°33'E; altitude 500–900 m above sea level). Initial morphological characterization was performed at the Laboratory of the Faculty of Science, Social Sciences, and Education, Universitas Prima Nusantara, Bukittinggi. Fe and Zn content analysis was conducted at the Genetics Laboratory, Indonesian Center for Rice Research Instrument Standardization (Balai Besar Pengujian Standar Instrumen Padi/BB PSIP), Sukamandi, West Java, Indonesia.

Plant Material and Sampling

Paddy samples were collected using purposive sampling from three major centers of local rice production in Agam Regency, representing varieties *Kuruik Kusuik* (G01), *Ampek Angkek* (G02), and *Kusuik Putiah* (G03). Genotype codes G01–G03 were assigned by the authors for ease of reference. Sampling locations were selected based on information from the Agam Regency Agriculture Office, community leaders, farmer groups,

agricultural extension officers (PPL), and direct field observation. Rice plants were harvested at full physiological maturity (approximately 30–35 days after heading), when grains had achieved maximum dry weight and mineral accumulation. Mature panicles were collected directly from farmers' fields following [ISTA \(2006\)](#) protocols (1,000 g per location), and grains were sorted to exclude damaged or moldy samples.

Grain Morphological Characterization

Morphological characterization followed the Standard Evaluation System for Rice ([IRRI and WARDA 2007](#)). Quantitative traits measured included: (a) grain length (mm), (b) grain width (mm), (c) length-to-width ratio (L/W), (d) dehulled grain length (mm), (e) dehulled grain width (mm), (f) dehulled grain L/W ratio, and (g) 100-grain weight (g). All measurements were performed on 30 grains per variety and are reported as mean $\pm$ standard deviation (SD). Grain shape was classified based on L/W ratio: >3.0 = slender; $2.1\text{--}3.0$ = medium; <2.1 = bold ([IRRI and WARDA 2007](#)).

Husk color and rice color were assessed visually and standardized using the Munsell Color Chart ([Color 2009](#)). Rice texture (*pera/pulen*) was determined based on amylose content documented in official variety descriptor sheets and published literature [Indrasari and Kristamtini \(2018\)](#), as all three varieties are officially registered with documented physicochemical properties.

Sample Pretreatment for Mineral Analysis

Paddy samples were oven-dried at 60°C for 48 hours to standardize moisture content to approximately 14%. Milling was performed using a laboratory-scale huller (Satake, Japan) under standardized single-pass conditions (without polishing) to produce brown rice (*beras pecah kulit/BPK*). Brown rice retains the aleurone layer, where Fe and Zn are predominantly concentrated ([Indrasari and Kristamtini 2018](#)). Polishing was deliberately avoided, as it is known to significantly reduce Fe and Zn concentrations. Brown rice samples were ground to fine powder using a laboratory mill (IKA, Germany) prior to analysis.

Fe and Zn Content Measurement

Fe and Zn contents were determined using the XRF X-Supreme 8000 instrument (Oxford Instruments, UK) following the certified Rice15

analytical method based on X-Ray Fluorescence Spectroscopy. This non-destructive method enables simultaneous multi-element analysis. The instrument was calibrated using certified reference materials before each analytical session. Each sample was analysed in triplicate ($n = 3$), and results are expressed as mean $\pm$ SD in ppm (mg kg^{-1} dry weight basis). Data were processed using X-Ray Analysis Software (Oxford Instruments, UK). Grain morphology classification referenced [IRRI and WARDA \(2007\)](#) standards as cited in the methodology.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) was used to assess differences in Fe and Zn content among varieties. When ANOVA indicated significant effects ($p < 0.05$), group means were compared using Duncan's Multiple Range Test (DMRT). Results are expressed as mean $\pm$ SD.

RESULTS AND DISCUSSION

Exploration and Identification of Local Rice Varieties

Three local rice varieties *Kuruik Kusuik* (G01), *Ampek Angkek* (G02), and *Kusuik Putiah* (G03) were identified through exploration across Agam Regency, West Sumatra, Indonesia (**Table 1**). All three varieties are officially registered with the Indonesian Ministry of Agriculture and represent valuable genetic resources of the Minangkabau farming heritage ([Sitaresmi et al 2013](#)). Agam Regency's tropical highland climate, fertile volcanic soils (altitude 500–900 m above sea level), and rich biodiversity have supported the long-term cultivation and adaptation of these varieties, which farmers value for their sensory qualities especially their *pera* texture and environmental adaptability ([Zul et al 2024](#)).

Kuruik Kusuik (G01) is recognized for resistance to brown planthopper (*Nilaparvata lugens*) and blast disease, along with superior taste and aroma preferred by local consumers ([Salfiati et al 2024](#)). *Ampek Angkek* (G02) demonstrates stable yield performance in moderately fertile soils and resistance to bacterial leaf blight. *Kusuik Putiah* (G03) exhibits moderate resistance to brown planthopper biotype 2 and bacterial leaf blight pathotype VIII ([Sasmitha et al 2022](#)). These agronomic strengths, combined with their nutritional potential, position these varieties as

strong candidates for participatory biofortification breeding.

Grain Morphological Characteristics

Kuruik Kusuik exhibited the longest grain (8.39 ± 0.12 mm), widest grain (2.66 ± 0.08 mm), and highest 100-grain weight (2.40 ± 0.05 g) among the three varieties (**Table 2**). According to [IRRI and WARDA \(2007\)](#), grain lengths of 7.5–12 mm fall into the medium category; all three varieties conform to this classification (average: 8.05 mm). Grain widths of 1–3 mm are also considered medium (average: 2.58 mm). The length-to-width ratios of all varieties exceeded 3.0 (average: 3.11), classifying them as slender a morphology associated with higher consumer preference and milling efficiency ([Jumali and Guswara 2015](#); [Setiawati 2020](#)).

Husk color was evaluated using the Munsell Color Chart: *Kuruik Kusuik* showed yellowish-brown (10YR 6/6), while *Ampek Angkek* and *Kusuik Putih* exhibited straw yellow (2.5Y 8/4). These differences reflect genotypic variation in pigment expression in the aleurone layer and endosperm ([Syahbanu et al 2023](#)). All three varieties have white milled rice and *pera* texture (high amylose content >25%), distinguishing them from the *pulen* (soft, sticky) texture of all nationally released biofortified varieties. The 100-grain weight ranged from 2.20 ± 0.04 g (*Ampek Angkek*) to 2.40 ± 0.05 g (*Kuruik Kusuik*), consistent with their slender grain morphology ([Widiastuti et al 2020](#)).

Morphological diversity among the varieties is shown in Figure 1. Panel A depicts *Kuruik Kusuik* (G01) with its distinctive yellowish-brown husk and larger oval grain; Panel B shows *Ampek Angkek* (G02) with straw-yellow husk and medium-slender grain; Panel C presents *Kusuik Putih* (G03) with pale straw-yellow husk and medium-slender grain. Each panel displays whole paddy grain (left), dehulled brown rice (center), and milled white rice (right).

Fe and Zn Content in Local Rice Varieties

The Fe and Zn contents of brown rice from the three local varieties, along with comparison data from nationally released biofortified varieties and the reference variety Cisokan, are presented in **Table 3**. Among the local varieties, *Kuruik Kusuik* demonstrated the highest Fe content (21.2 ± 0.8 mg kg⁻¹) and Zn content (22.8 ± 0.6 mg kg⁻¹), followed by

Kusuik Putih (Fe: 15.8 ± 0.9 mg kg⁻¹; Zn: 22.1 ± 0.7 mg kg⁻¹) and *Ampek Angkek* (Fe: 14.7 ± 1.1 mg kg⁻¹; Zn: 22.3 ± 0.9 mg kg⁻¹). One-way ANOVA revealed significant differences in Fe content among varieties ($p < 0.05$), while Zn content differences were not statistically significant ($p > 0.05$).

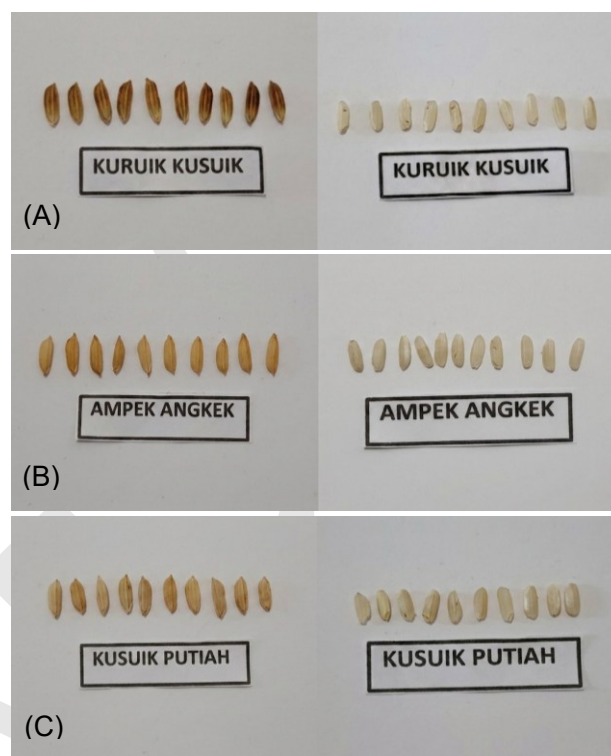


Figure 1. Morphology of local rice varieties from Agam Regency, West Sumatra: (A) *Kuruik Kusuik* (G01); (B) *Ampek Angkek* (G02); (C) *Kusuik Putih* (G03). Each panel shows paddy grain, brown rice (BPK), and milled white rice

Compared with nationally released biofortified varieties, the Fe content of *Kuruik Kusuik* (21.2 mg kg⁻¹) was 11.7% lower than Inpari Nutri Zinc (24.0 mg kg⁻¹), but 16.0% higher than Inpago 13 Fortiz (18.3 mg kg⁻¹) and 7.1% higher than Inpara 12 Mayas (19.8 mg kg⁻¹). The Zn content of *Kuruik Kusuik* (22.8 mg kg⁻¹) was 31.1% lower than Inpari Nutri Zinc (33.1 mg kg⁻¹) and 23.0% lower than Inpago 13 Fortiz (31.5 mg kg⁻¹), but higher than the reference variety Cisokan (21.3 mg kg⁻¹) by 7.0%. The Fe and Zn content of *Ampek Angkek* and *Kusuik Putih* were comparable to Cisokan, indicating moderate mineral potential consistent with other non-biofortified *pera* varieties from West Sumatra.

Table 1. Local rice varieties identified in Agam Regency, West Sumatra, Indonesia

Variety	Genotype Code	Origin (Location / Farmer Group)							
Kuruik Kusuik	G01	Jorong PGRM	Nagari Gadut,	Tilatang	Kamang,	Agam	Regency		
		(Baringin Jaya)							
Ampek Angkek	G02	Jorong Koto Tuo, Nagari Balai Gurah, Ampek Angkek, Agam Regency (Karya Pembangunan)							
Kusuik Putihah	G03	Nagari Lambah,	Ampek	Angkek,	Agam	Regency			
		(Komera Jaya)							

Table 2. Quantitative and qualitative grain characteristics of local rice varieties from Agam Regency (mean $\pm$ SD, n = 30)

Variety	Whole Grain			Dehulled Grain			100-grain Wt. (g)	Husk Color (Munsell)	Texture
	L (mm)	W (mm)	L/W	L (mm)	W (mm)	L/W			
Kuruik Kusuik	8.39 $\pm$ 0.12	2.66 $\pm$ 0.08	3.15	5.97 $\pm$ 0.09	2.42 $\pm$ 0.07	2.47	2.40 $\pm$ 0.05	Yell. Brown (10YR 6/6)	<i>Pera</i>
Ampek Angkek	7.86 $\pm$ 0.15	2.57 $\pm$ 0.10	3.06	5.73 $\pm$ 0.11	2.36 $\pm$ 0.08	2.43	2.20 $\pm$ 0.04	Straw Yellow (2.5Y 8/4)	<i>Pera</i>
Kusuik Putihah	7.90 $\pm$ 0.13	2.52 $\pm$ 0.09	3.13	5.95 $\pm$ 0.10	2.29 $\pm$ 0.07	2.60	2.30 $\pm$ 0.05	Straw Yellow (2.5Y 8/4)	<i>Pera</i>

Table 3. Fe and Zn content (mean $\pm$ SD) in brown rice of local Agam varieties compared to national biofortified varieties

Variety	Release Year	Agroecosystem	Texture	Fe (mg kg ⁻¹)	Zn (mg kg ⁻¹)
Inpari Nutri Zinc	2019	Lowland	<i>Pulen</i>	24.0	33.1
Inpago 13 Fortiz	2020	Upland	Medium	18.3	31.5
Inpara Siam HiZinc	2022	Swamp	Slightly <i>Pulen</i>	22.8	29.6
Inpara 12 Mayas	2022	Swamp	Medium	19.8	25.6
Kuruik Kusuik (G01)*	2009	Lowland	<i>Pera</i>	21.2 $\pm$ 0.8	22.8 $\pm$ 0.6
Ampek Angkek (G02)*	2017	Lowland	<i>Pera</i>	14.7 $\pm$ 1.1	22.3 $\pm$ 0.9
Kusuik Putihah (G03)*	2023	Lowland	<i>Pera</i>	15.8 $\pm$ 0.9	22.1 $\pm$ 0.7
Cisokan (reference)	1986	Lowland	<i>Pera</i>	14.9	21.3

Remarks: *Local varieties analyzed in this study (mean $\pm$ SD, n = 3 analytical replicates). Values for biofortified varieties are sourced from published literature (Sitaresmi et al 2023; Hairmansis et al 2019; Subekti and Umar 2023). ANOVA p < 0.05 for Fe; p > 0.05 for Zn among local varieties

These findings align with previous reports that Fe content in rice ranges from 11.93 to 26.46 ppm, with genotypic variation driven by both genetic factors and growing environments (Hartati and Suwanto 2010; Indrasari and Kristantini 2018). Zn content in rice lines has been reported in the range of 16–29 ppm (Rohaeni et al 2016; Safitri et al 2019; Anggraeni et al 2021). A notable high-Zn line (IR 97477-115-1-CRB-0-SKI-1-SKI-0-2; 29.61 ppm Zn) was released as Inpari IR Nutri Zinc without yield penalty (Barokah et al 2018; Chairuman et al 2022), demonstrating feasibility of improving Zn through targeted breeding.

In rice grains, Fe is primarily concentrated in the aleurone layer while Zn is distributed between the aleurone and endosperm (Indrasari and Kristantini 2018). This distribution explains why milling (polishing) substantially reduces both minerals. Analyzing brown rice in this study with the aleurone intact therefore provides the most accurate baseline for biofortification potential. Importantly, genotypes with high soil Zn uptake capacity do not always accumulate proportionally high grain Zn, as transport and loading into the grain are governed by distinct physiological mechanisms (Indrasari and Kristantini 2018). Environmental factors including soil mineral status, irrigation, and micronutrient fertilization also significantly affect grain Fe and Zn concentrations (Juwita and Yustisia 2018; Yuriyah et al 2024).

The strategic significance of these local varieties lies in their *pera* texture, which is a firmly embedded cultural preference among Minangkabau communities and is currently absent in all nationally released biofortified varieties. This creates a cultural adoption barrier for existing biofortified varieties. Incorporating the high-Zn genetic background of Inpari IR Nutri Zinc into the *pera*-textured Kuruik Kusuik through marker-assisted backcrossing represents a high-impact, culturally relevant breeding strategy (Aristya and Taryono 2019; Majumder et al 2019).

CONCLUSIONS

This study reports the first systematic characterization of grain morphology and Fe/Zn content in three officially registered local rice varieties from Agam Regency, West Sumatra, Indonesia. All three varieties *Kuruik Kusuik*, *Ampek Angkek*, and *Kusuik Putih* exhibited slender grain morphology ($L/W > 3.0$), white milled rice, and *pera* texture, a culturally important attribute absent in all currently released national biofortified varieties.

Kuruik Kusuik (G01) showed the highest Fe content ($21.2 \pm 0.8 \text{ mg kg}^{-1}$) and Zn content ($22.8 \pm 0.6 \text{ mg kg}^{-1}$) among local varieties, approximately 11.7% lower in Fe and 31.1% lower in Zn compared to the national biofortified standard Inpari Nutri Zinc (Fe: 24.0; Zn: 33.1 mg kg^{-1}). ANOVA revealed significant differences in Fe content among varieties ($p < 0.05$), while Zn content was relatively uniform ($p > 0.05$).

The key novelty of this study is the documentation of registered, *pera*-textured local rice varieties with moderate Fe and Zn content as strategic genetic resources for biofortification breeding. Future research should prioritize marker-assisted backcrossing to transfer high-Zn traits from Inpari IR Nutri Zinc into *pera*-textured local varieties, particularly *Kuruik Kusuik*, without compromising agronomic and sensory qualities. Multi-location trials and soil mineral analyses are recommended to account for genotype $\times$ environment interactions. Collaboration among farmers, plant breeders, nutritionists, and policymakers is essential to translate these findings into practical improvements in food security and community nutrition.

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Conflict of Interest Declaration

The authors declare that they have no known competing interests that could have appeared to influence the work reported in this paper.

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