Rice fortification and biofortification as a potential strategy to alleviate stunting and bolster food security in Indonesia

Prima Luna[1*] and *Esty A.* Suryana[1]

[1]Indonesian Center for Agricultural Socio-Economic and Policy Studies, Ministry of Agriculture, Bogor, Indonesia

Abstract. Indonesia has regained its status as an upper-middle income country in the latest category released by the World Bank in July 2023, owing to a robust post-pandemic recovery. The present economic recovery is anticipated to result in a GDP growth rate of 5.1% by 2022. Furthermore, Indonesia has significantly reduced its stunting prevalence, declining from 37% in 2013 to less than 21.6% in 2022. Nevertheless, further tasks need to be accomplished to guarantee the robust and effective development of human capital. Biofortification and rice fortification with micromineral zinc to increase nutritional value are potential strategies to combat stunting and enhance food security. The methodology employed a literature review and both qualitative and quantitative data analyses. This article discusses the implementation of this policy in Indonesia. Key issues arising from the implementation of this policy are: 1) rice is widely consumed and suitable for adoption as a food vehicle for fortification; 2) the rice seedling system must be robust to produce targeted varieties; 3) ensuring premix vitamins and micronutrients are halal certified; and 4) ensuring rice fortification and biofortification meet the standards and guidelines for food safety and quality before donation to the targeted community.

1 Introduction

The world continues to be concerned about toddler malnutrition. According to the Ministry of Health of the Republic of Indonesia, toddlers are a specific age group that encompasses children aged from birth to 59 months. This age group is known to be more susceptible to experiencing nutritional deficiencies. Toddlers require a sufficient and balanced diet because healthy food contains key components that the body requires to function in its growth and development. Moreover, the nutritional status of children under the age of five is included as an indicator within the Millennium Development Goals (MDGs) framework, which is utilised to assess the overall health state of a nation [1]. The issue of malnutrition is a significant concern within the Sustainable Development Goals (SDGs).

One of the persistent nutritional challenges frequently encountered is stunting. Over the past few years, Indonesia has emerged as the tenth-largest economy based on buying-power

* Corresponding author: primaluna305@gmail.com

parity, exhibiting significant advancements in poverty reduction, with a reduction of over 50%. Nevertheless, Indonesia still needs to achieve progress in its pursuit of attaining global nutrition targets. In 2022, 21.6% of children under five were stunted. Stunting is determined through the assessment of anthropometric indicators, namely the height-for-age index, which takes into account an individual's age. Stunting, if not adequately addressed, has the potential to reduce life expectancy. Reducing stunting and wasting rates among infants and toddlers is a global objective to be achieved by 2025. It is anticipated that by 2030, all nations will be able to eradicate all manifestations of malnutrition effectively.

Several factors contribute to the occurrence of stunting in children. These factors include the child's birth weight and length, the educational level of the head of the family and the mother, as well as the family's income, attitude, and behaviour. Family income has emerged as the predominant influence [2]. Children from families with wages below the regional minimum wage exhibit a significantly elevated likelihood, approximately 6,625 times greater, of experiencing stunting than their counterparts do.

Biofortification techniques provide a viable approach for improving the nutritional composition of staple foods commonly consumed by socioeconomically impoverished populations. One of these methods, traditional breeding programs, has distinct advantages over genetically modified approaches. This garnered broader acceptance on a global scale. This choice is due to its perceived affordability and sustainability, which makes it especially appealing to poor farmers living in areas where micronutrient shortages are common, such as Africa, Asia, and Latin America. [3]. However, despite their overall positive outcomes, traditional plant breeding and agronomic biofortification are frequently considered inadequate in entirely eliminating specific micronutrient deficits [4]. This study examines the implementation of the aforementioned policy in the context of Indonesia.

2 Methodology

The current study utilised an observational, descriptive design. It employed a cross-sectional approach, drawing data from pertinent agencies such as the Health Research and Development Agency, Ministry of Health, Statistics Indonesia [5] Ministry of Agriculture of the Republic of Indonesia, and National Planning Agency. The data analysis employed a decision matrix approach of 20 cells to evaluate the effectiveness of four alternative strategies and five factors, namely effectiveness, acceptability, accessibility, responsiveness, and legal suitability.

3 Result and discussion

3.1 Current stunting state in Indonesia

The significance of addressing and mitigating malnutrition and stunting lies in the consequential impacts they induce. The occurrence of malnutrition and stunting results in a dual burden [6]. The phenomenon of stunting has the potential to impede economic growth and labour productivity, resulting in a notable impact on the gross domestic product (GDP) by approximately 11%. Moreover, it has been shown that stunting can lead to a significant decline in the income of adult workers, potentially reaching up to a 20% reduction [5]. According to a nutrition study conducted in 2022, all provinces in Indonesia exhibited cases of stunted growth among infants and toddlers. Among these provinces, Bali had the lowest prevalence of stunting (8%), whereas East Nusa Tenggara had the highest prevalence (37%), as illustrated in Figure 1 [7].

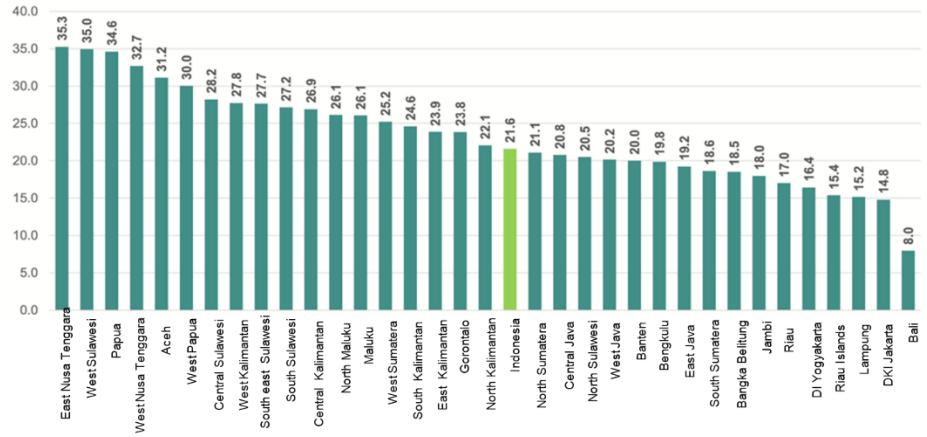

Fig. 1. Prevalence of stunted toddlers in Indonesia.
Source: [7]

3.2 Rice fortification and biofortification to combat stunting and improve food security

In several developing countries, biofortification is now embedded in local nutrition strategies. Biofortification has successfully improved nutrient intake and status in some areas where micronutrient deficiency is common [8]. Rice fortification and biofortification are two strategies that can have significant impacts, particularly in regions prone to nutritional deficiencies. The concurrent fortification of iron, zinc, and vitamin A exhibits a plausible synergistic interaction in terms of human health, hence enhancing the bioavailability of these essential minerals. Zinc plays a crucial role in synthesising vitamin-A1 (retinol) binding protein and enhances the lymphatic absorption and transportation of vitamin A. Similarly, the impact of vitamin A on the absorption and transport of zinc within the lymphatic system is mediated through the regulation of proteins that are dependent on zinc [9].

More than two billion individuals, or more than a quarter of the global population, suffer from micronutrient deficiency, also known as hidden hunger. Therefore, a strategy is needed to close the nutrient gap, which is believed to be filled by agriculture. The inherent responsibility of agriculture is to produce essential minerals and vitamins, thereby ensuring overall national health. Consequently, it can be predicted (as depicted in Figure 2) that the voids filled through supplementation, fortification, and other techniques will diminish over time. Adequate financial resources would be allocated towards the implementation of supplementation, fortification, and other treatments to address immediate deficiencies, as well as towards agricultural investments to resolve the issue in the long term.

Again, there is an insufficient quantity of capital available for investments in both alternatives. Thus, when weighing the trade-off between preserving human lives and improving the nutrition and health of current and future generations, complex investment decisions are frequently made implicitly. However, it should be noted that fortification, which addresses immediate deficiencies, and biofortification, which addresses long-term deficiencies, should not be viewed as competing strategies, but rather as mutually beneficial approaches, especially if adequate funding is available [10]. Fortification of staple foods with essential vitamins and minerals is an established, cost-effective, and sustainable approach for delivering vital nutrients to large populations.

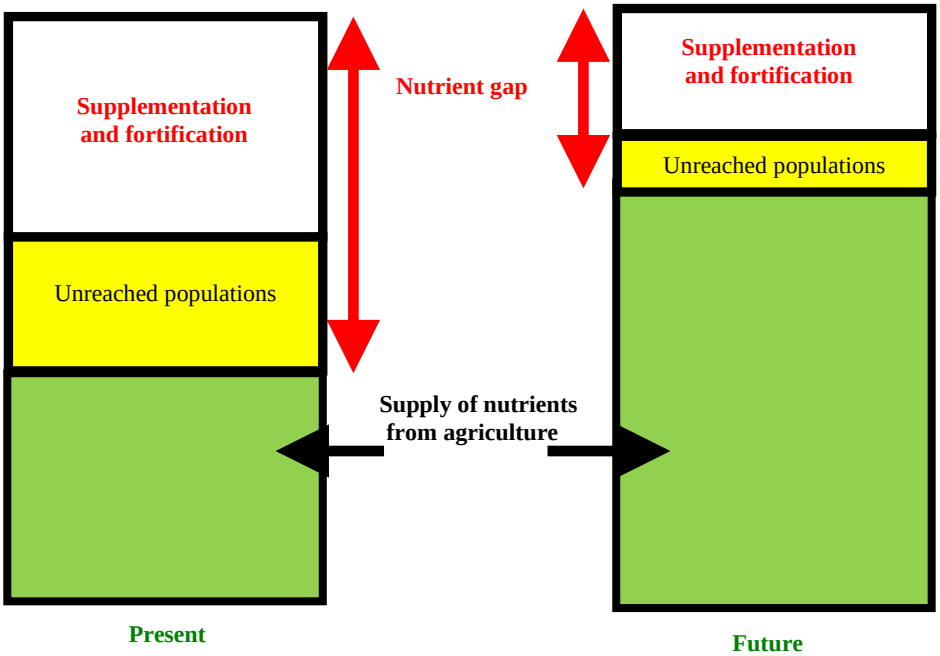

Fig. 2. Role of biofortification and fortification provided by the agricultural sector.

Biofortification can enhance micronutrient content in food crops, including rice. It has made biofortified rice varieties available to populations that lack access to or cannot afford diverse diets. Biofortification has been recognised as one of the most impactful interventions for addressing micronutrient deficiencies in low- and middle-income countries, as highlighted in the 2008 Copenhagen Consensus and the 2013 Lancet series on maternal and child malnutrition. Additionally, according to the Copenhagen Consensus, it is considered one of the most cost-effective approaches for addressing micronutrient deficiencies, delivering a USD 17 return on investment. The concept of biofortification was initially put into practice in the mid-1990s, and since then, it has received substantial financial support through initiatives [11].

Rice Biofortification involves developing varieties rich in essential nutrients, such as iron-rich rice or vitamin A-rich maise. These varieties grow naturally and contain more nutrients than the regular varieties. Biofortification can enhance food security in regions heavily reliant on single-staple foods. Biofortified rice can help communities that previously suffered from stunting due to iron or vitamin A deficiency obtain the necessary nutrients from their agricultural produce. Biofortification can have long-term positive effects on community health and wellbeing. Biofortified rice can provide additional nutrition in daily diets for years. Developing biofortified rice requires good resource management, including selecting suitable varieties, farmer training, and monitoring rice yields, to ensure that the rice delivers the expected nutritional benefits. Several biofortified rice varieties, including Inpari IR Nutri Zinc, Inpago 13 Fortiz, and Inpara Siam Hizinc are available in Indonesia. These varieties have a potential zinc concentration between 29.54 and 34 ppm [12].

3.3 Strategies for the prevention and mitigation of stunting

Based on studies and current policies, implementing an integrated and multisectoral program aimed at enhancing family income, knowledge, attitudes, and skills concerning children's nutrition, as well as promoting exclusive breastfeeding, is essential [13]. To mitigate the

occurrence of stunting in children, it is imperative to reinforce primary health care through the implementation of various strategies. These include family empowerment initiatives and the establishment of intervention programs, such as supplementation, the utilisation of health care services, routine follow-up checks, nutritional awareness campaigns, and the promotion of protective or micronutrient-rich foods. In addition, political will in the realm of governance is closely linked to the formulation and implementation of governmental measures pertaining to crucial aspects, such as food security, access to uncontaminated water, sanitary facilities, appropriate nourishment, and healthcare professionals, as well as the allocation of financial resources for program execution and prompt emergency interventions.

Given the beneficial direction, it is imperative to focus on an agenda centred on proactive measures and comprehensive policy guidelines to expand the implementation of rice biofortification, thereby enhancing nutritional security for the human population. Indonesia had put this priority agenda setting on the national strategic planning 2020-2024. Incorporating fortification and biofortification strategies into nutrition and food security programs can effectively address stunting and improve food security. It is essential to consider local, cultural, and economic factors when designing and implementing these programs to ensure their effectiveness and sustainability. Fortification and biofortification programs must be financed sustainably, either through government funding, donations, or sustainable business models. A robust monitoring and evaluation system is needed to ensure that the program runs well and achieves the expected impact, allowing for necessary improvements and changes in strategy if required.

3.4 Effectiveness analysis of fortification and biofortification to stunting

Alternative critical solutions arising from the implementation of the stunting policy in Indonesia are: 1) rice is widely consumed and suitable for adoption as a food vehicle for fortification; 2) the rice seedling system must be robust to produce targeted varieties; 3) ensuring premix vitamins and micronutrients are halal-certified; and 4) ensuring rice fortification and biofortification meet the standard for food safety and quality prior to donation to the targeted community.

After analysing the options using a paired comparison approach, it was found that the policy analysis matrix produced the highest overall score, ranging from 1 to 10 according to the established criteria. This suggests that the adoption of a resilient rice seedling system for the cultivation of biofortified rice varieties would be the policy option with the highest level of all criteria. The analysis was obtained from the results of in-depth interviews and webinars with several experts (National Standardization Agency, stunting ambassadors in sub-districts) and policy analysts' judgment. Rice is believed to be an effective medium for fortification so long as its accessibility meets the requirements; however, it will impair decision-making. This rice fortification has also been conducted in several countries, namely India [14], Brazil [15], Indonesia [16], and the Philippines [17], as the best solution to prevent stunting and is recommended by the World Health Organization.

The success of fortification programs relies on widespread coverage and compliance among the target population. Fortification programs must be sustainable in the long term to have a lasting impact. This program requires ongoing monitoring, quality control, and public awareness campaigns. Fortification is generally cost-effective and can quickly reach a large population. The grid analysis of the alternative solutions is shown in Table 1.

Table 1. Comparison matrix of alternative solutions.

Alternative solutions	Effectiveness* (20%)	Acceptability* (20%)	Accessibility* (25%)	Responsiveness* (15%)	Legal aspect* (20%)	Total
Rice is the vehicle for fortification/ biofortification	8 (1.6) Rice is believed to be effective as a good medium for fortification, especially in terms of adding important nutrients such as vitamins and minerals.	6 (1.2) People in areas that rely on rice as a staple food may be more receptive	5 (1.25) The rice must be distributed to markets and food shops in an efficient manner	7 (1.05) Ensure that rice is suitably fortified and reaches the right target population. The evaluation also needs to be carried out to measure the program's impact on public health.	6 (1.2) There are no relevant regulations that allow and regulate rice fortification and ensure producers' compliance with these guidelines.	5.1
The rice seedling system must be robust to produce targeted varieties	8 (2.4) Strengthening the rice seed system is an important step in efforts to increase rice production, reduce its vulnerability to climate change, and meet the nutritional needs of the population	7 (1.4) Farmers must be trained and educated on good seed techniques, crop management, and selecting varieties that suit their conditions. This can help increase their productivity and crop quality.	8 (2) The seed system can be strengthened through partnerships with government institutions, universities, and private companies with expertise in plant breeding and seeds.	8 (1.2) The varieties developed must be tested extensively in the field to ensure that they hit the target	8 (1.6) The government must issue strict regulations to regulate the production, distribution, and certification of rice seeds	8.6

https://doi.org/10.1051/bioconf/202411905004

Alternative solutions	Effectiveness* (20%)	Acceptability* (20%)	Accessibility* (25%)	Responsiveness* (15%)	Legal aspect* (20%)	Total
Ensuring premix vitamins and micronutrients are halal-certified	6 (1.8) Halal certification can help reach a wider market, especially among consumers who adhere to halal principles in food and product selection	7 (1.4) An important step if you want to market the product to consumers who pay attention to compliance with halal principles	7 (0.7) There needs to be strict supervision of the supply chain for all raw materials used in making vitamin and micronutrient premixes	6 (1.2) Halal information to consumers can increase consumer confidence and help increase sales	6 (1.2) Law no. 33 of 2014 concerns Halal Product Guarantees, which regulates halal product guarantees and certification.	6,3
Ensuring rice fortification and biofortification meet the food safety and quality standards and guidelines prior to donation to the targeted community.	8 (2.4) Ensuring the food safety and quality of food products is a primary responsibility for protecting public health, with the adoption of best product practices and strict monitoring	7 (1.4) Nutrients to be fortified or optimised through biofortification must follow the nutritional needs of the target community. Make sure that these nutrients are safe to consume in appropriate amounts	7 (0.7) Rice produced under this program must be produced according to strict production guidelines. Including the use of quality raw materials, the use of safe fertilisers and pesticides, as well as good agricultural practices	6 (1.2) It is essential to provide education to the target community about the nutritional benefits and the correct way to cook rice so that its nutrition is maintained	6 (1.2) There are no regulations yet to ensure that rice fortification and biofortification meet food safety and quality standards	6,9

*The scoring system ranged from 1 to 10

However, based on the perspectives of a few experts, animal protein is the best remedy for stunted children in Indonesia. The need for protein consumed by stunted children is approximately 12 grams per day for at least two weeks of intervention. Proteins derived from animal sources have a higher degree of completeness regarding essential amino acid content than those derived from plant sources. In contrast to animal proteins, plant-based protein sources typically exhibit reduced protein completeness due to diminished digestibility and the absence of specific critical amino acid sources. Dietary animal protein sources include eggs, meat, poultry, fish, and dairy.

The findings of a study conducted by Khusun et al. [18] indicated that a significant proportion (precisely 35.4 %) of the protein sources ingested by the population in Indonesia are animal-based protein sources. More specifically, 12% of the total dietary intake is derived from meat and poultry, 12.8% is attributed to eggs and milk, and 9.8% is obtained from fish [19]. The Indonesian government is presently implementing a program in which the consumption of one egg is sufficient to prevent stunting in infants aged 6–9 months, thereby reducing the prevalence of stunting by 47%. To prevent stunted growth, however, infants older than one year must consume two eggs.

4 Conclusions and policy recommendations

4.1 Conclusions

Both fortification and biofortification are regarded as important solutions for addressing the issue of stunting; however, their efficacy is based on a number of factors, including the extent of implementation, compliance, sustainability, and acceptability by the target population. The integration of these approaches with existing programs and stakeholder engagement, community engagement, and public participation is frequently the most effective strategy for addressing the complex and multifaceted issue of stunting. In addition, continuous monitoring and evaluation of programs are essential for determining their impact and implementing any necessary adjustments.

4.2 Policy recommendations

Implementing rice fortification and biofortification as strategies to alleviate stunting and bolster food security in Indonesia requires a multifaceted approach involving government policies, research and development efforts, public awareness campaigns, and collaboration with various stakeholders. The following are some policy recommendations for effectively implementing these strategies:

1. Allocate government funds and resources to support the research and standardisation of biofortified rice varieties.
2. Establish and enforce regulatory frameworks and standards for fortification and biofortification processes.
3. Offer tax incentives or subsidies to encourage private sector involvement in rice fortification and biofortification.
4. Implement rigorous quality control measures to ensure that fortified and biofortified rice meet safety, halal, and nutritional standards.

References

1. National Institute of Health Research and Development, Riset Kesehatan Dasar (RISKESDAS) 2013 (National Institute of Health Research and Development, Jakarta, 2013)
2. R. A. Utami, A.Setiawan, , and P. Fitriyani, Enferm. Clin. **29**, 606 (2019)
3. Food and Agriculture Organization of the United Nations, The future of food and agriculture – Trends and challenges (FAO, Rome, 2017).
4. E. Koç, B. Karayiğit, J. Soil Sci. Plant Nutr. **22**, 475 (2022)
5. Ministry of Health Indonesia, Survei status gizi (SSGI) 2022 (Ministry of Health Indonesia, Jakarta, 2022)
6. M. Vaezghasemi. Nutrition transition and the double burden of malnutrition in Indonesia A mixed method approach exploring social and contextual determinants of malnutrition. PhD dissertation, Umeå Universitet, Umeå (2017)
7. E. A. Suryana and M. Azis, J. Ekon. Kesehat. Indones. **8**, 52 (2023)
8. S. Lockyer, A. White, and J. L. Buttriss, Nutr. Bull, **43**, 319 (2018)
9. S. Majumder, K. Datta, and S. K. Datta, Agronomy **9**, 803 (2019)
10. H. E. Bouis, in Food fortification in a globalized world, edited by M.G. Venkatesh Mannar, and Richard F. Hurrell (Elsevier Inc., Frisco, 2018)
11. K. Das, R. Priyabrata, and R. K. S. Tiwari, Plant-Based Diet. **1** (2023)
12. Ministry of Agriculture, Indonesian Agency of Agriculture Instrument Standardization (Ministry of Agriculture Indonesia, Jakarta, 2022)
13. H. Hadi, F. Fatimatasari, W. Irwanti, C. Kusuma, R. D. Alfiana, M. I. N. Asshiddiqi, S. Nugroho, E. C. Lewis, and J. Gittelsohn, Nutrients **13**, 4264 (2022)
14. S. Mahapatra, M. E. Parker, N. Dave, S. C. Zobrist, A. D. Shajie, A. King, A. Betigeri, and R. Sachdeva, J. Food Sci. Nutr. **72**, 690 (2021)
15. F. P. Arcanjo, P. R. Santos, A. J. Leite, F. S. Mota, and S. D. Segall, Int. J. Vitam. Nutr. Res. **83**, 59 (2013)
16. I. Hardinsyah, D. Briawan, S. Budianto, P. Hustina, N. Ghifari, and S. Suhandono, Production and clinical impact study of micronutrients fortified rice for teen girls in Islamic boarding school in Medan, Indonesia. Final report (Food and Nutrition Society of Indonesia, West Java, 2016)
17. I. Angeles-Agdeppa, M. V. Capanzana, C. V. C. Barba, R. F. Florentino, and K. Takanashi, Int. J. Vitam Nutr. Res. **78**, 74 (2008)
18. H. Khusun, J. Februhartanty, R. Anggraini, E. Mognard, Y. Alem, M. I. Noor, N. Karim, C. Laporte, J. Poulain, P. Monsivais, and A. Drewnowski, Front. Nutr. **9**, 7624591 (2022)
19. A. Endrinikapoulos, D. N. Afifah, M. Mexitalia, R. Andoyo, I. Hatimah, and Nuryanto, SAGE Open Med. **11**, 1 (2023)