Iodine Fortification of Poor Rice to Address IDD in Indonesia as Hidden Cause of Hunger in Children and Adolescents

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Abstract. Iodine deficiency disorder (IDD) is one of Indonesia's most serious health problems since it directly or indirectly affects the physical and non-physical qualities of individuals in the community, including intellectuality and mental retardation. All age groups are at risk of IDD. According to reference data, iodine deficiency causes approximately 140 million IQ (intelligence quotient) points to be degraded. Besides, 42 million people live in endemic areas, while the iodine requirement for normal growth in adult humans is 120–150 g/day. In this case, rice is the staple food of almost 50% of the world's population, especially Indonesia, with data on rice consumption in Indonesia currently around 139.5 kg/capita/year or around 200 g/day. On the other side, iodine as a fortifier in the form of a solution with the addition of a binder atomized with a fogger coupled with a rice thresher is one of the breakthroughs that can be taken significantly to improve the nutritional quality of the community in iodine endemic areas. This research, therefore, aims to observe the effectiveness and factors causing micronutrient degradation in iodine-fortified rice to overcome IDD, which leads to hidden hunger. This research used a literature review method obtained from secondary data. The results of 25 research journals reviewed showed that iodine fortification in rice could use dextrose and sodium bicarbonate binders. The recommendation of adding iodine fortification in rice at one ppm is considered effective and sufficient for the daily needs of adult humans. The organoleptic test results of several research journals also revealed that iodine fortification of one ppm in rice using dextrose and sodium bicarbonate binders indicated that the taste, aroma, and quality of rice from the rice were acceptable and showed the potential for iodine fortification in poor rice to have a positive path.

Keywords: IDD · Iodine · Fortification · Poor Rice

1 Introduction

Amidst the advancement of time and technology, it turns out that the world is also faced with severe health problems, i.e., micronutrient deficiencies. One is the problem of iodine deficiency, which causes iodine deficiency disorder (IDD). It is proven that the prevalence of IDD in the world is still very high, with around 2.5 billion (38%)

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of the world's population experiencing iodine deficiency. Southeast Asia (504 million), Europe (460 million), and Indonesia (41.3 million) have the highest iodine deficiency rates in the world. When viewed based on age stratification, approximately 31.5% or 264 million school-age children and 30.6% or 2 billion adults are shown to suffer from iodine deficiency. In addition, the impact of IDD is enormous and threatens the human population. People living in IDD-endemic areas can experience intellectual decline, abortion, disability, and mental retardation. These can threaten the quality of human resources.

The most critical consequences of iodine deficiency are the effects of neuro-psychomotor disorders, including mental retardation, low intellectual potential, and poor academic performance. These consequences are not easily recognized by the common people. Also, characterizing the person as normal is not necessarily normal. This Boyage's statement was followed by 1989 and other researchers. Until the child is 12 years old, neuro-psychomotor disorders due to iodine deficiency can still be detected. Moreover, the visible consequences are abortion (miscarriage), stillbirth, premature birth, and an increased risk of infant mortality [1].

Specifically, Indonesia is one country facing various malnutrition problems, one of which is micronutrient deficiency. Based on its geographical location, some parts of Indonesia are endemic to IDD. People living in mountainous areas are at greater risk of iodine deficiency and creating pandemics in various regions worldwide. The IDD problem is often found in mountainous areas where the population's food consumption highly depends on local products grown from iodine-poor soils. In Indonesia, the prevalence of IDD in highland and mountainous areas reached 30.3% [2]. Several efforts have been made to overcome the problem of IDD in this country with various strategies, including Universal Salt Iodization (USI) or "iodized salt for all," administration of iodine oil capsules, both orally and injected (lipiodol) to the regions, and iodination of drinking water.

By 2013, 77.1% of households had consumed salt with sufficient iodine in Indonesia. The daily requirement for iodine is 50 mg/day for 0–12 months, 90–120 mg/day for up to 11 years, 150 mg/day for adolescents and adults, and 200 mg/day for pregnant/lactating women [3]. This achievement increased from 2007, which reached 62.3%. Nevertheless, the coverage still did not meet the target of USI coverage by WHO and the National Action Plan for Food and Nutrition (RANPG) 2011–2015, targeting 90% and 80%, respectively [4, 5]. Therefore, IDD is often referred to as a silent pandemic rarely exposed in socialization and health policies.

On the other hand, the rice distribution program for the poor is a plan that has been implemented since 1998 called the Special Market Operation (OPK) program; then, in 2002, it was known as the poor people's rice program (*Raskin*). In 2008, it was changed to subsidized rice for the poor. In its implementation, based on recognition from Target Beneficiary Households (RTS-PM), the rice distributed is often of low quality. The rice quality does not follow the predetermined medium-quality rice standard, where the subsidized rice received by the beneficiaries smells musty and has a yellowish color, making it unfit for consumption [6].

For that reason, the selection of iodine fortification in rice, primarily poor rice, has many benefits for several aspects: the community, educational institutions and government, industry, and researchers. This research is expected to help overcome and reduce the prevalence of IDD problems in Indonesian society. In addition, this research is expected to be a solution, research, and development program in universities or the government to overcome the problem of IDD and fulfill iodine in the population, especially adolescents, to improve human resources in the future. This research has the potential to be further tested to produce innovation in food by adding micronutrients to a staple that is useful for humans so that it has a selling value commercialized by the industry. This research is also expected to expand the literature on food and health research, especially on fortification, iodine, and the IDD problem.

The study, therefore, aims to assess the potential effectiveness of iodine fortification in foods such as rice, which is the staple food of the Indonesian population, to overcome IDD in adolescents with great potential experiencing it and activate iodine consumption in residents in endemic iodine areas.

2 Method

This literature study used several research journals from different sources, including Google Scholar, E-Resource of PERPUSNAS (National Library), and Garuda KEMDIKBUD. The literature period started from 2012 to 2022. The search keywords were "IDD," "Iodine," "Fortification," and "Poor Rice." The related literature collection was conducted step-by-step, including searching articles by topic outline and categorizing articles based on relevance to the topic and publication year. In addition, the inclusions applied in the selection of articles were journals of the last ten years, a discussion of iodine fortification in food, the effect of IDD, its prevention, iodine fortification content, and an organoleptic test of fortified rice. Meanwhile, the exclusion criteria implemented were journals above the last ten years and outside the discussion of inclusion criteria.

3 Results

3.1 Article Search Results

The article search stage in several databases resulted in 927 articles. A total of 821 articles were from Google Scholar, 58 from Garuda, and 48 from PERPUSNAS. After deducting the duplication results, the number of articles was 861. Then, 798 articles were selected, with irrelevant title categories, as many as 431 articles, and 127 non-experimental studies. The full-text screening left 94 articles. Finally, 56 articles were eliminated by the exclusion of eligibility criteria. Thus, seven articles that fell under the inclusion eligibility criteria were then analyzed using narrative techniques. The resulting search for the PRISMA flowchart is depicted in Fig. 1 below.

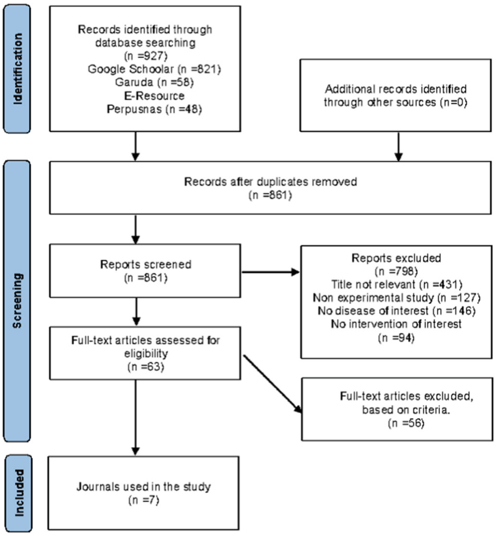

Fig. 1. The Flow of Literature Selection

3.2 Study Characteristics

The research characteristics included five experimental studies, seven observational studies, and one literature study, in which one study was in Geneva, while six studies were conducted in various cities in Indonesia. The studies were also conducted within the last ten years (2012–2022). Besides, two studies were conducted in 2012, two studies were carried out in 2013, one study was done in 2014, two studies were performed in 2018, and two studies were conducted in 2021.

3.3 Subject Characteristics

Table 1 below presents the characteristics of the research subjects: regions in Indonesia with the highest prevalence of IDD and the impact on sufferers, primarily on children and adolescents, and areas in Indonesia included in endemic iodine areas.

3.4 Study Results

Table below also displays the potential for fortification of poor rice after observing the effectiveness and factors causing the degradation of micronutrients in the form of iodine in salt, wheat flour, and rice, which acts as a staple food to overcome hidden hunger.

Table 1. Data Extraction

Authors	Year	Study	Study Design	Origin
D. Astuti et al. [3]	2021	There is a relationship between the stunting category and iodized food consumption with a p-value of 0.038.	Observational	Indonesia (Kudus)
Bahja, W [7]	2021	KIO3, as an iodine fortifier, experiences shrinkage when the temperature gets lower. The shrinkage conditions that occur are 0 °C (17.4%), 5 °C (7.3%), 13 °C (6.8%), and 15 °C (2.4%), and the temperature ranges from 29 to 33 °C (2.3%).	Experimental	Indonesia (Palu)
S. Supadmi et al. [8]	2018	Different processing methods uncovered varying results of iodine degradation in rice, with significant differences ($p \leq 0.05$). The lowest iodine degradation was 33.64 ± 3.13% (steamed, 40 ppm), WI 42.79 ± 1.02% (boiled, ten ppm), and L*33.98 ± 0.47% (boiled, ten ppm). The highest iodine degradation was 59.39 ± 2.46% (boiled, ten ppm). Therefore, the steamed processing method is the best and recommended processing option.	Experimental	Indonesia (Magelang)
K. Novitriani et al. [9]	2014	The requirement of Indonesian National Standard (SNI) No.01–3556- 2000/Rev.9 on iodized table salt is 30–80 ppm. Thus, the entry of KIO3 into food such as rice is 50% (from a KIO3 concentration of 1500 ppm). The iodine component will change processing, distribution, and storage. It will then affect the flavor and stability of KIO3 because KIO3 may evaporate during boiling or cooking.	Experimental	Indonesia (Tasikmalaya)
World Health Organization (WHO) [4]	2018	Fortifying staple foods can be efficient, simple, and inexpensive when appropriately implemented. Rice is an appropriate ingredient for fortification as it is widely cultivated and a staple food in many parts of the world. Rice grains can be fortified with several micronutrients, such as iron, folic acid, and others: B-complex vitamins, two vitamins, and iodine.	Observational	Ganeva

(*continued*)

Table 1. (*continued*)

Authors	Year	Study	Study Design	Origin
Wafiyah, N and Muwakhidah [10]	2013	Iodine-fortified food requires proper storage, i.e., in a closed and dry container and away from sunlight, so that the iodine content in the food does not decrease or evaporate. The iodized salt's quality is influenced by where it is stored, how it is stored, and its use during processing.	Observational	Indonesia (Surakarta)
Arfiyanti [11]	2013	Regarding acceptance, iodine-fortified foods have excellent acceptability and long shelf life. The samples used in this study were iodine-fortified biscuits tested for liking using semi-trained panelists.	Experimental	Indonesia (Lampung)

4 Discussion

From the literature review results, the prevalence of IDD in the world is still very high; about 2.5 billion (38%) of the world's population experience iodine deficiency. The highest iodine deficiency rate in the world is in Southeast Asia, with 504 million people (Indonesia 41.3 million), and Europe, with 460 million people. Based on age stratification globally, the number of children with mental abnormalities related to iodine deficiency disorders (IDD) is estimated at 43 million. Meanwhile, data on the proportion of iodine-deficient school-age children is 31.6% or 266.7 million children. Although this proportion is relatively similar to the proportion of iodine deficiency in the earth's population in general, the risk of the school-age children segment does not reflect the risk of the pregnant women and women of the childbearing age segment [1].

Moreover, the impact of IDD is enormous and threatens the human population. Children born, raised, and residing in endemic IDD areas are more at risk of experiencing growth and developmental deficits at the age of fewer than 12 months and equally in four aspects: gross motor, fine motor, socialization and independence, and speech and language. Meanwhile, iodine deficiency during pregnancy at a severe level can cause children to be born with cretinism, characterized by learning difficulties, motor disorders, hearing and speech impairments, and mental retardation that can threaten the quality of human resources [12].

According to research by Budiman [1] in conjunction with Arif Musoddaq [13], it has been proven that the IDD level in Indonesia is not small. Many children and adolescents, in particular, are experiencing micronutrient malnutrition. The journal review showed that IDD cases in Indonesia are still high; it can be caused by several things, including lack of knowledge from parents and economic cases [14]. In this regard, fortified food generally has a high price because the fortification tools, materials, and knowledge are difficult to obtain and apply. Consequently, it encourages families to buy makeshift food.

Several efforts to overcome IDD have been made. Based on a study by Budiman [1], various preventive measures have been taken by utilizing the developing technology of prophylaxis in the form of intra-muscular injections of iodized oil and iodized oil capsules for short-term programs and iodine fortification of table salt for long-term programs. These efforts helped reduce the iodine deficiency problem but created a new problem of excessive consumption, causing coronary heart disease (CHD), autoimmune diseases, and cancer.

In this case, Indonesia is a country that faces various malnutrition problems, one of which is micronutrient deficiency. According to Astuti [3], there is a relationship between the stunting category and the consumption of iodized food. Based on their geographical location, some parts of Indonesia are endemic to IDD. It has also been studied by Arif Musoddaq [13] in Dayakan and Watubonang Villages, Ponorogo Regency. The case of IDD in these regions does not indicate that it is entirely iodine-poor, but the case is that iodine is not evenly mobilized. It is also exacerbated by heavy metal mercury exposure in the environment; based on research with soil and water samples in the villages, Hg contamination in water and Pb in soil were found. Mercury pollution in the environment has the potential to inhibit iodine utilization in the thyroid gland.

Therefore, fortification is an appropriate solution to overcome the problem of micronutrient deficiencies, especially iodine. In the journal, fortification of staple foods [4], if implemented correctly, can be an efficient, simple, and cheap way. Mainly, rice is cultivated in many parts of the world as it grows in diverse climates. Many rice fortification industries in several countries have successfully helped overcome the problem of micronutrient deficiencies.

As the main foodstuff, rice is also known to have inadequate macronutrients, potentially leading to malnutrition for consumers. Here, food fortification is the addition of one or more nutrients. The primary objective is to increase the added nutrients' consumption level to improve the population's nutritional status. The main fortifiers used in iodine fortification in salt are potassium iodide (KI) and potassium iodate (KIO3) [15]. With the addition of iodine fortification in rice, it is expected to increase the amount of iodine consumption in the community in Indonesia so that the iodine deficiency cases will decrease. Furthermore, the human body needs very little iodine, usually only about 150 μg per day for adults. Nevertheless, a deficiency can lead to serious health problems. The opportunity for iodine fortification in rice is open because the carbohydrate content of rice is relatively high, 85–90% dry weight, mainly in the form of starch. Rice starch consists of amylose and amylopectin. The nature of this compound can bind iodine, paving the way for efforts to enrich rice with iodine.

Fortification of food ingredients in rice is generally done on quality rice. However, it is considered less effective and does not reach all circles because the price is relatively high. Hence, the use of rice with low-quality rice but still quality is demanded. Based on the results of a journal review from Hartoyo [16], low-grade rice can be better quality if reprocessed through polishing, sieving, sorting, and grading. This rice is commonly purchased by the lower class of society. In addition, the iodine fortification of rice is the right step to overcome the case of IDD in Indonesia. The reviewed journal also explained that iodine fortification of rice does not show significant changes in taste, aroma, and texture. Thus, it is still acceptable to the consumer's tongue.

Supadmi's journal [8] further explains a relationship between processing methods and the degradation of iodine levels in foodstuffs. It was elucidated that there were significant differences in each cooking process. The lowest iodine degradation was 33.64 ± 3.13% (steamed, 40 ppm), WI 42.79 ± 1.02% (boiled, ten ppm), and L*33.98 ± 0.47% (boiled, ten ppm). Conversely, the highest iodine degradation was 59.39 ± 2.46% (boiled, ten ppm). While WI and L* were not significantly different, the fried method processing with a concentration of 40 ppm was more visible, i.e., WI 50.02 ± 0.99% and L* 44.00 ± 1.11%. Hence, steamed method processing is the best and recommended steamed method.

Moreover, iodine is used as a fortifier in rice fortification in the form of KIO3 because it is more stable than KI. Iodine components will change processing, distribution, and storage. Thus, it will affect the taste and stability of KIO3 since KIO3 may evaporate during boiling [9]. Iodine levels will evaporate significantly during processing/heating because the spiral-shaped starch molecules will stretch, and iodine can be released. Iodine is also firmly bound in starch complex cations. Besides, variations in iodine loss have different values depending on the processing method used: boiling, steaming, and frying. A decrease in iodine content indicates a decrease in double bonds in fats or oils and indicates oxidation [8].

The fortification begins with making rice as usual; then, the shredded rice is fortified with iodine using the fortifier fogging technique on the rice in the shredding machine. The fogging system uses a fogging device equipped with an air fogging compressor with a pressure of 40–50 psi. The fortifier solution is atomized with the help of air pressure (± 40 psi) coming from the compressor, which makes the iodine fortifier foggy. The amount of iodine fortifier solution discharge used is about 4–5 l/hour, depending on the moisture content or dryness of the iodized rice. Rice milling removes the husk from the grain and the aleurone layer, partially or entirely, to produce as small white rice and broken rice as possible [17].

Iodine-fortified rice must be stored at room temperature because iodine is very easily oxidized, so in its storage, iodized salt must be good and not stored in a place that will affect the loss of iodine content in the rice. The lower the storage temperature, the smaller the concentration of KIO3 in the iodized salt or the more significant the percentage of shrinkage. The factor affecting the reduction of KIO3 concentration is the stability of KIO3 storage, which ranges from 15 °C to 25 °C. Given the concentrations of 0.70 and 0.85 ppm, fortifiers did not have a clear difference in the rice. In comparison, the fortification concentrations of 1.00 and 1.15 ppm showed a clear difference in the rice. The fortification concentration of 1.00 ppm is estimated to meet the iodine requirement of 120 μg[7]. In addition, storage with red-colored plastic and covering can help reduce the shrinkage of iodine content in rice. In the preference test, iodized rice with a fortifier concentration of 1 ppm was still favored by 90%, who stated that they liked it, and only 10% stated that they did not like it [17].

5 Conclusion

The mandatory fortification of iodine in rice is highly expected; in the future, the mandatory fortification program is not limited to iodized salt as it has been but also to poor rice. This fortification can reduce the degradation of micronutrients, such as iodine, in Indonesian society.

Based on this journal review, it is hoped that the points made in this study can serve as a foundation for further research. It is highlighted that high-pressure air-fogging compressors in rice mills can be used to fortify iodine in poor rice. The iodine fortifying agent used is KIO3, as much as 4–5 l/h, depending on the moisture content or the rice's dryness being iodized. In addition, concentrations of 0.70 and 0.85 ppm of iodine fortifier did not have a clear difference in the rice. In contrast, the fortification concentrations of 1.00 and 1.15 ppm showed a clear difference in the rice. The fortification concentration of 1.00 ppm is estimated to be enough to meet the iodine requirement of 120 μg, with a note that the rice plastic bag was red to prevent iodine evaporation from the fortified rice due to the entry of light through the packaging.

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