IRON AND ZINC FORTIFICATION OF RICE: TECHNOLOGIES, FORTIFICATION LEVELS AND PRODUCT QUALITY

[1]*Sh. Bekmirzayev, U. Azamatov, F. Raxmatov, M. Jahongirova ,*
M. Tursunqulova, H. Shodmonqulova.
[1]*Yangiyer Branch of the Tashkent Institute of Chemical Technology*
Republic of Uzbekistan, Yangiyer

Abstract. This thesis analyses a review article on the fortification of rice, a staple food, with iron and zinc. It covers the loss of minerals and vitamins during milling, three fortification technologies (parboiling, dusting and extrusion) with their advantages and limitations, the cooking and sensory properties of fortified rice, and the consequences of micronutrient deficiency. The optimum iron fortification level is 250 mg/kg, while fortifying paddy with 50–400 mg/kg of zinc raises grain zinc concentration 1.3–4.5 times.

Keywords: rice fortification, parboiling, dusting, extrusion, iron, zinc, micronutrient deficiency.

Introduction

Rice ranks second after wheat in production and food use; about 90% of the world's rice is grown and eaten in Asia, and it is the staple food of more than half of the world population [1, 2]. At the same time rice is poor in minerals, particularly iron (Fe) and zinc (Zn). An estimated 870 million people suffer from chronic undernourishment, most of them in developing countries where food security is closely tied to rice. Micronutrient deficiency affects roughly two billion people worldwide and is called “hidden hunger” because it often shows no physical symptoms [1]. To date, 87 countries have passed legislation making fortification mandatory for the milling and processing industry [1, 3].

The problem is that wheat fortification has been studied extensively, whereas rice is eaten mainly as an intact kernel and therefore needs dedicated fortification methods [1]. The aim of this work is to assess rice as a carrier of micronutrients and to compare the technologies used to fortify it with iron and zinc. The objectives are: 1) to describe the nutritional losses that occur during milling; 2) to identify the advantages and limitations of the fortification technologies; 3) to summarise fortification levels and their effect on product quality.

Methods

The object of the study is rice (rough, brown, white and polished rice) and the technologies for fortifying it with micronutrients. The work was carried out as a literature review: the material of a review article [1], whose reference list contains 134 entries, was analysed and summarised.

The analysis covered the following areas: types of food fortification (mass, targeted and market-driven); losses during de-hulling and milling of rice; fortification technologies and levels; cooking and sensory properties; and the consequences of malnutrition. Three technologies – parboiling (a hydrothermal treatment consisting of soaking, steaming and drying), dusting or coating, and extrusion – were compared by process parameters, cost and limitations.

Results

Consequences of deficiency. The effects of micronutrient malnutrition are shown in Figure 1: 20% of all maternal deaths are due to iron deficiency anaemia; about 250 million preschool children suffer from vitamin A deficiency and 5,000,000 lose their sight.

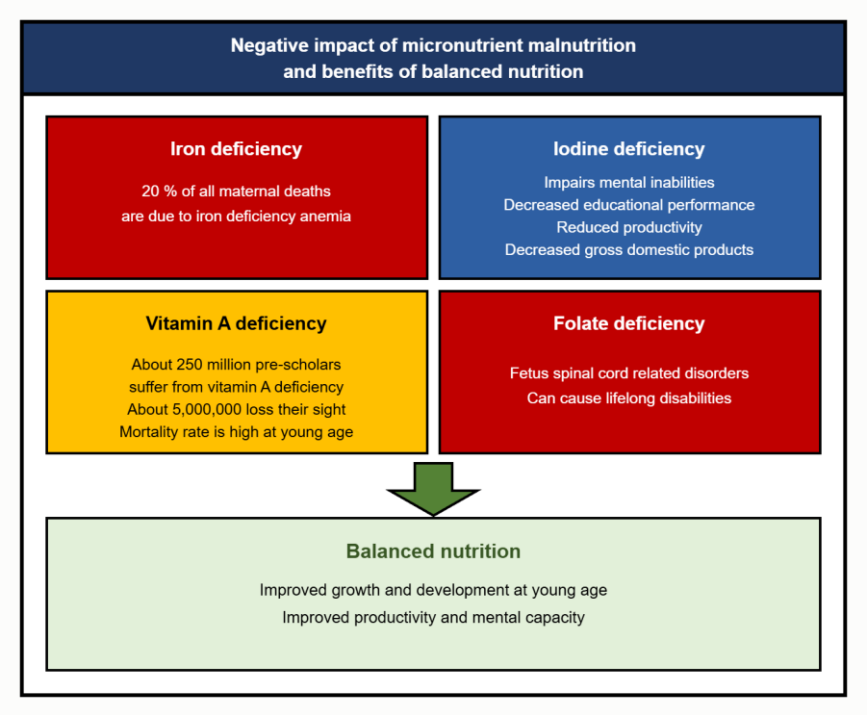


Figure 1. Malnutrition versus balanced nutrition [1]

Milling losses. Hull makes up 20% of rough rice, bran and germ about 10%, and the starchy endosperm 70%. Milling losses amount to roughly 5–10%, and weight losses in white rice production to 8–10%. On average, 100 kg of paddy gives 60–65 kg of white rice, 10 kg of broken germ and bran and 20 kg of hull. Vitamin concentrations in the outer layer of the kernel are 2–10 times higher than in white rice. Milled rice contains only 4–8 mg of iron per kg, which does not meet the body's requirement.

Technologies. About 15% of milled rice worldwide is parboiled; Bangladesh, Sri Lanka, India, Thailand and West Asia account for about 90% of it. Fortification during parboiling raises iron content to as much as 140 mg/kg of dry weight [6]. In dusting, rice is tempered for 30–40 min at 20–25 °C and then dried at 50 °C for 30–60 min; the fortificant is sprayed onto the grain surface as a solution [8]. In extrusion, the temperature is raised gradually from 70–100 °C to 100–140 °C; because extruders are costly, the price of the product rises by 15–20% [5]. Examples from world practice are given in Table 1.

Table 1. Fortification of rice with vitamins and minerals in practice [1]

No.	Mineral	Vitamin	Fortification method	Country
1	Iron, zinc	A, B1, B12	Hot extrusion	Bangladesh; Nepal
2	–	A, B9	Parboiling (soaking with limited water)	USA
3	Iron, zinc	A, B3, B6, B9, B12	–	Nepal
4	Zinc	–	Parboiling	Bangladesh
5	Iron	B9, beta-carotene	Parboiling	Sydney, Australia
6	Calcium, iron	–	Parboiling (soaking with limited water)	USA
7	Iron, zinc	A, B1, B3, B6, B12	Cold and hot extrusion	South Asia (Cambodia, Vietnam)
8	–	B5	Sonication	Philippines
9	–	B9	Ultrasonication	Philippines

Fortification levels. In experiments rice was fortified with 250–450 mg/kg of iron; the optimum is 250 mg/kg, at which consumer acceptability, pre-cooking appearance, cooking quality and sensory attributes are highest. When whole paddy was fortified with 50–400 mg/kg of zinc, zinc concentration rose 1.3–4.5 times compared with unfortified rice [7]. According to the source, approximately 95.4% of people in South Asia suffer from zinc deficiency.

Quality indicators. The gelatinization temperature of rice starch is 55–79 °C and the amylose content 15–35%. In sensory evaluation a rice sample reached approximately 75% acceptance among consumers, and no considerable difference was found between fortified and unfortified rice [9]. Rice at 12% moisture content has good aromatic attributes.

Discussion

The three technologies differ in cost and limitations. Parboiling has long been used at household and industrial scale; it increases head rice yield and reduces nutritional losses during polishing, but prolonged soaking may lead to mycotoxins in paddy. Dusting requires less investment than extrusion, yet excess washing before

cooking removes micronutrients, and the colour and taste of the rice may change. Extrusion is efficient but expensive; part of this cost can be offset by using broken kernels, which are sold at a considerably lower price [1, 5].

Fortification with several micronutrients at once is more effective than supplementation with a single one. Dietary inhibitors – phytates, drugs and other chemicals – bind minerals and reduce their bioavailability. According to a World Bank report, no alternative technology offers such an opportunity to improve the nutritional status of consumers at so low a cost [4]; food fortification ranks 3rd among international development priorities. For communities that cannot afford a diversified diet and rely on rice as a staple, fortification is a cost-effective strategy [1].

Conclusion

1. Rice is the staple food of more than half of the world population, yet milled rice contains only 4–8 mg of iron per kg, which makes it a promising vehicle for micronutrients.

2. Parboiling, dusting and extrusion all increase the mineral content of rice; their limitations are the risk of mycotoxins, losses during washing and a 15–20% rise in price, respectively.

3. The optimum iron fortification level is 250 mg/kg; fortification with 50–400 mg/kg of zinc raises zinc concentration 1.3–4.5 times; fortified rice does not differ considerably from unfortified rice in sensory terms.

4. It is recommended that rice-consuming countries introduce iron and zinc fortification programmes, strengthen public-private partnerships and government mandates, and raise public awareness of the benefits of fortification.

References

1. Junaid-ur-Rahman S, Chughtai MFJ, Khaliq A, et al. Rice: a potential vehicle for micronutrient fortification. Clinical Phytoscience. 2022;8:14. doi:10.1186/s40816-022-00342-3

2. Muthayya S, Sogimoto JD, Montgomery S, Maberly GF. An overview of global rice production, supply, trade and consumption. Ann N Y Acad Sci. 2014;1324:7–14.

3. WHO. Guidelines on food fortification with micronutrients. The world health report. Geneva: WHO; 2011.

4. World Bank. World Bank enriching lives: overcoming vitamin and mineral malnutrition in developing countries. Washington DC: The World Bank; 1994.

5. Steiger GN, Muller-Fischer H, Cori C-PB. Fortification of rice: technologies and nutrients. Ann N Y Acad Sci. 2014;6:1–11.

6. Prom-u-thai C, Rerkasem B, Fukai S, Haung L. Iron fortification and parboiled rice quality. J Sci Food Agric. 2009;112:982–6.

7. Prom-u-thai C, Rerkasem B, Cakmak I, Haung L. Zinc fortification of whole rice grain through parboiling process. Food Chem. 2010;120:858–63.

8. Kyritsi A, Tzia C, Karathanos VT. Vitamin fortified rice grain using spraying and soaking methods. Food Sci Technol. 2011;44:312–20.

9. Khanh Van T, Burja K, Thuy Nga T, Kong K, Berger J, Gardner M, et al. Organoleptic qualities and acceptability of fortified rice in two southeast Asian countries. Ann N Y Acad Sci. 2014;1324:48–54.