Technology for Rice Fortification

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Key Messages

- Rice fortification using either extrusion or coating technologies is a two-step process. The first involves the production of fortified kernels; the second, the blending of fortified kernels with non-fortified rice.
- Extrusion and rinse-resistant coating are the best available technologies to produce fortified kernels that remain stable under different storage conditions, preparation methods, and cooking techniques, and that are acceptable to consumers.
- Recommended vitamins and minerals to fortify rice include the micronutrients removed during processing, in addition to micronutrients needed to fill the target population's nutrient gaps. Fortification with multiple micronutrients is recommended, as micronutrient deficiencies often coexist.
- The choice of fortificant used to fortify rice depends on its bioavailability and stability, its impact on consumer acceptability, and the type of technology used.

Rice is the world's second most commonly consumed cereal grain. In recent years, rice fortification technology has evolved. As a result, rice fortification at scale is gaining momentum as a feasible and cost-effective strategy to address micronutrient deficiencies. To date, about 15 countries have introduced rice fortification on either a mandatory or a voluntary basis, embedded in social safety nets, or at limited scale through trials. This article provides an overview of technological challenges for rice fortification and explores rice fortification technologies available to produce fortified rice. It also discusses the use of potential fortificants (vitamins and minerals).

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Technological challenges for fortifying rice

As for food fortification in general, rice should be fortified with fortificants that are available for absorption by the body, and that remain stable during processing, storage, transport, preparation, and cooking methods and practices including discarding excess water.[1] Rice is consumed as a whole kernel, which complicates the fortification process and requires specialized technology. In contrast to flour fortification, where the premix and flour are both in powder form and can be easily blended, this is not an option with rice.

The micronutrients in the fortificant mix should not interact with each other and/or with the rice matrix, as this may influence color, taste and stability, thus lowering consumer acceptability. The fortificants must remain stable during different means of preparation such as washing before cooking, soaking, cooking in different amounts of water, and for varying amounts of time.[2,3]

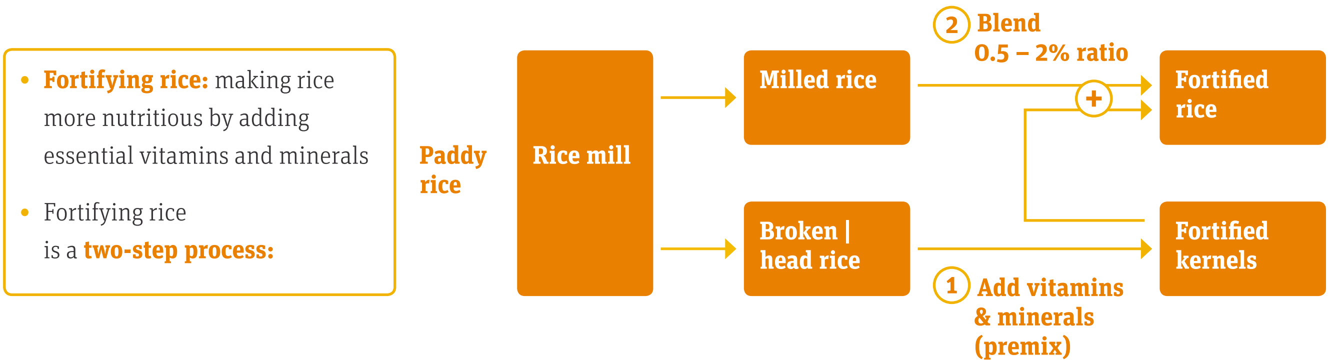
Appropriate quality assurance and quality control, as well as monitoring, are needed throughout the rice fortification process to ensure that standards are met and that the fortified rice effectively improves the nutritional health of the consumer.

Overview of available technologies for rice fortification

Dusting

Dusting is a fortification technology that adds micronutrients onto the surface of the rice grains. Dusting relies on electrostatic force to bind the fortificant in a dry powder form to the surface of the milled rice grains. This technology provides limited nutrient protection when rice is washed, soaked or cooked in excess water, which is then discarded. In the United States, dusting is acceptable since rice is not washed prior to cooking, nor cooked

FIGURE 1: Two-step process of rice fortification through coating or extrusion technology



in excess water. All packaged fortified rice sold in the United States includes a label advising against washing or cooking in excess water.

Coating and extrusion

As illustrated in **Figure 1**, fortifed rice is produced using a two-step process. First, coating or extrusion technology is used to produce fortified kernels. Second, the fortified kernels are blended with non-fortified rice at a ratio of 0.5% to 2% to result in fortified rice.

Option 1: Coating technology for production of fortified kernels

Coated fortified kernels are produced by coating rice grains, typically head rice, with a liquid fortificant mix. Additional ingredients, such as waxes and gums, are used to 'fix' the micronutrient layer or layers on the rice grain. Whole or head rice is evenly spray coated with micronutrients and other ingredients to preserve the coating. This is usually done in large rotational drum or pan coating machines. The coated kernels are then dried to yield fortified kernels. This technology concentrates the micronutrients on the surface of the rice grains. When cooked, the coating dissolves, spreading the micronutrients throughout the cooked rice. Where rice is washed or soaked, coated fortified kernels must be rinse-resistant so as to ensure micronutrient retention.

Option 2: Extrusion technology for production of fortified kernels

Extruded fortified kernels are formed by combining water and a fortificant mix with rice flour which is usually made from grinding lower value and non-contaminated broken rice, to form a dough (**Figure 2**). The dough is passed through an extruder, producing a fortified kernel visually similar to a non-fortified rice grain. Micronutrients are equally distributed inside the fortified kernel, with only a few particles left on the surface. This reduces the exposure to the environment and hence micronutrient degradation. The extruded fortified kernels are dried, reducing the water content to 14% or less, thus increasing stability during storage.

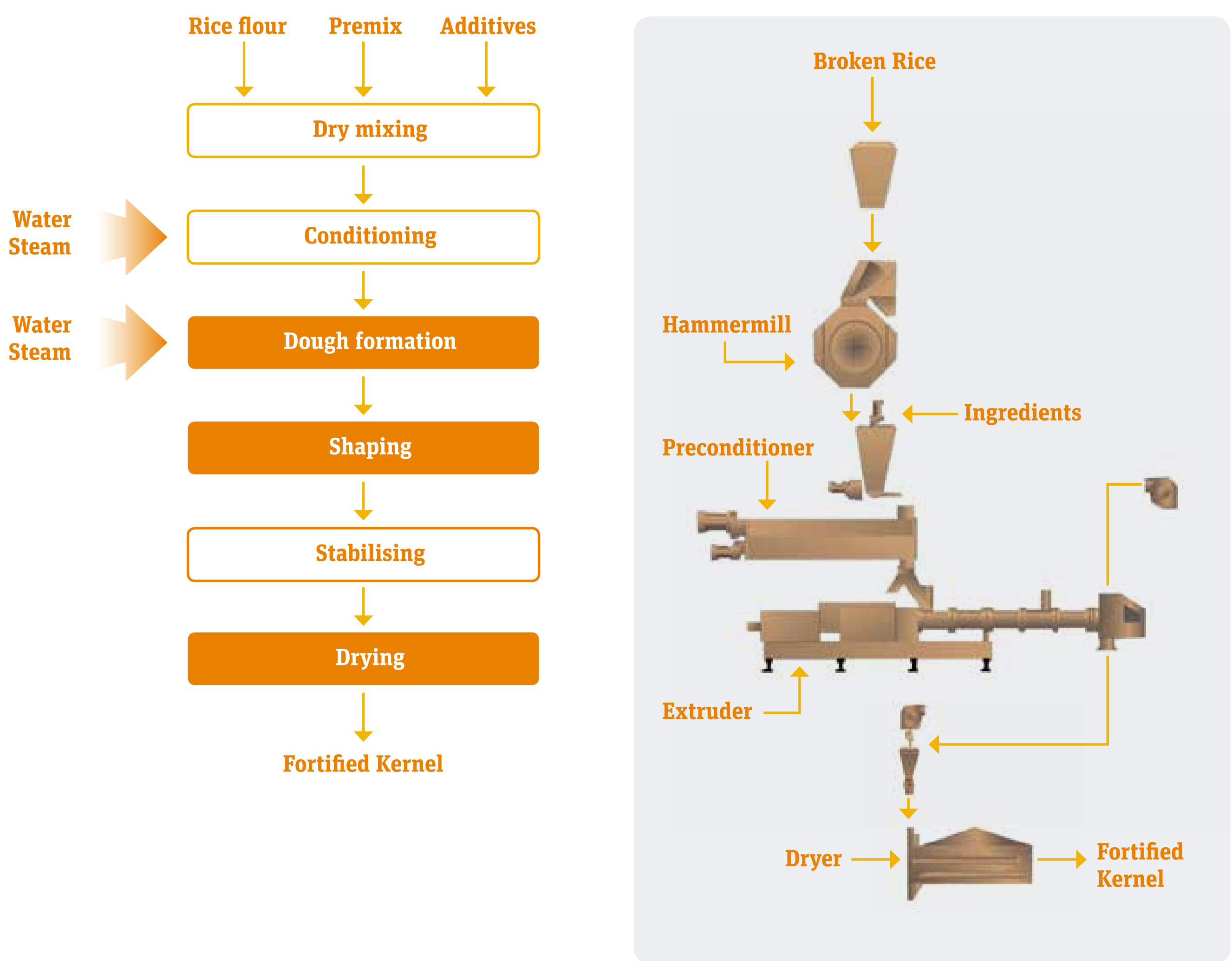
The amount of starch that is gelatinized in the fortified kernel influences color, texture and stability during soaking and cooking. This is affected by the temperature and the amount of water used during extrusion. In Cold extrusion (30°C–50°C), a pasta press is used to "shape" the dough and form opaque fortified kernels. This requires binders to be added or a subsequent boiling step to produce a cohesive product. Warm extrusion (60°C–80°C) also uses a pasta press, but adds a preconditioner with steam, or is equipped with a steam-injection device to produce fortified kernels that appear more translucent and more closely resemble non-fortified rice. An emulsifier can be used, but no additional additives are required. Hot extrusion (80°C–110°C) is more energy-intensive and, although not a requirement, ideally uses more sophisticated equipment. It can include a preconditioner, and can rely on a double screw extruder to produce the fortified kernels. An emulsifier (monoglyceride) can be added to maintain stability during storage of the fortified kernels. The resulting fortified kernels closely resemble different types of rice, with different degrees of translucency and texture.[2]

Fortified kernels made by either warm or hot extrusion are similar to non-fortified rice in their uptake of water during cooking, cooking time, and firmness. Kernels made by cold extrusion have a softer texture. In practice, most fortified kernel production with cold extrusion utilizes additional heat to improve the firmness and appearance, and can therefore be categorized as warm extrusion (see **Figure 3** for the appearance of fortified kernels using extrusion at different temperatures).

Step 2: Blending of fortified kernels and non-fortified rice

The coated or extruded fortified kernels are blended with non-fortified rice through a continuous or batch mixing process

FIGURE 2: Basic extrusion steps



(**Figure 4**). The blending ratio, typically between 0.5% and 2%, depends on the nutrient content of the fortified kernels and the desired level of fortification. Quality assurance and quality control are needed to ensure uniform blending at the correct ratio.

Other approaches to increase micronutrient intake through rice include parboiling, soaking, biofortification and communication for behavior change to increase consumption of brown rice.

Parboiling is not a fortification technology. No micronutrients are added to the rice; rather, parboiling causes the existing nutrients in the outer layers to be transferred and retained in the starchy endosperm of the rice grain. Consequently, parboiling enhances the intrinsic nutrient value of rice. The level of niacin, vitamins B_1 (thiamin) and B_6 (pyridoxine) is around three times as high in parboiled rice as it is in regular milled rice. For niacin and pyridoxine, the level in parboiled rice is similar to brown rice. However, parboiling does not increase the level of minerals, such as iron and zinc, nor is it a source of vitamin A or vitamin B_{12}. Overall, parboiled rice or brown rice is more nutritious than milled white rice, but only covers a limited part of the suggested micronutrients to add to fortified rice. Parboiled rice can be fortified.

For additional information on biofortification, and on consumption of brown rice, please refer to the contribution by Pachón et al (p. 188). Soaking is not discussed in this supplement, as research into this subject is still in initial stages.

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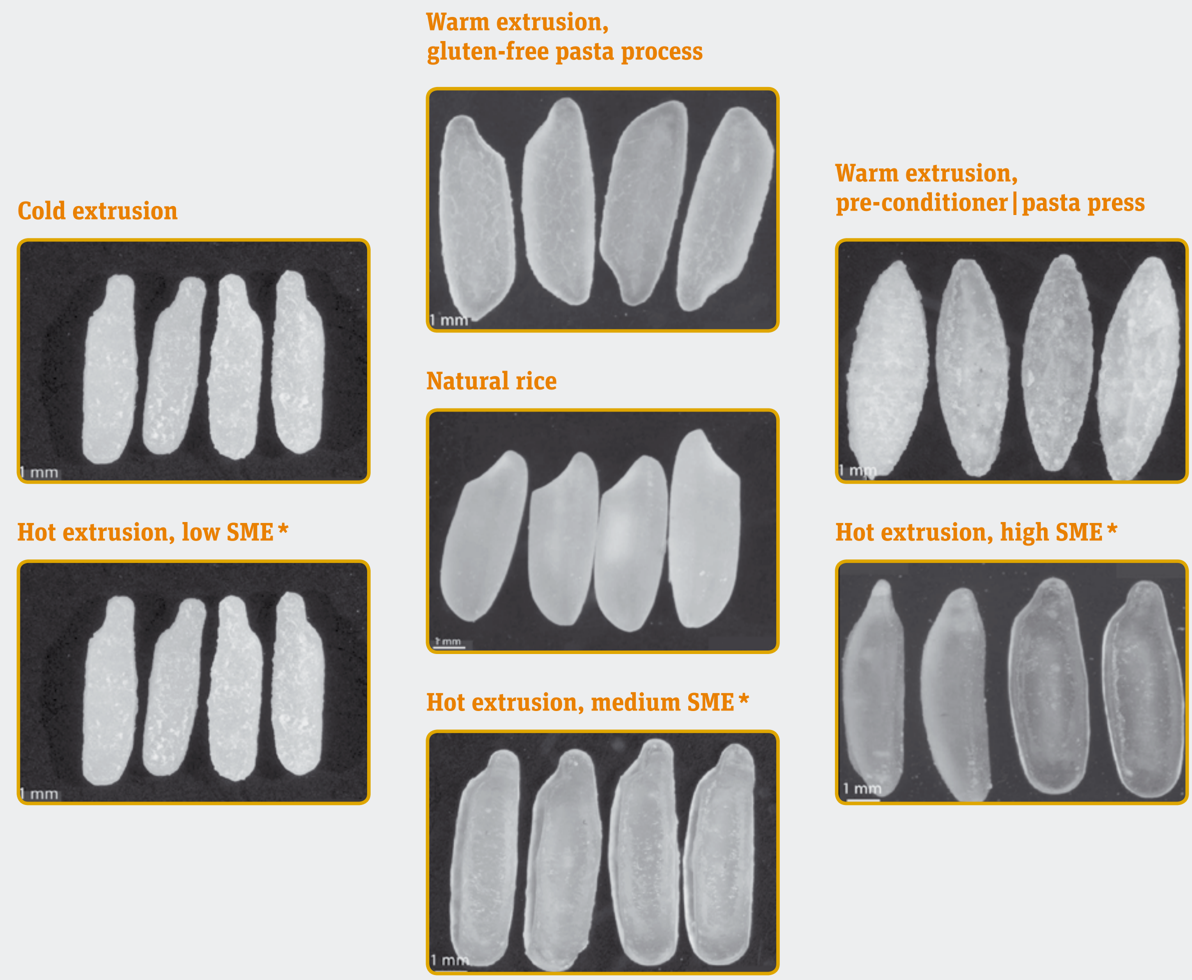
FIGURE 3: Visual appearance of natural rice grains and extruded rice kernels produced with cold, warm and hot extrusion



* Specific Mechanical Energy (SME) is a measure of the mechanical energy required to push material through an extruder.

Overview of commonly used fortificants

Micronutrients recommended for rice fortification are those that address a target population's nutrient gap in addition to those removed during processing. Fortification with multiple micronutrients is recommended, as micronutrient deficiencies often coexist in low- and middle-income countries. The selection of fortificants depends not only on their bioavailability, stability, and sensory acceptability, but also on the fortification technology utilized. For additional information on fortificants, please refer to the contribution by de Pee and Fabrizio (p. 165).

To be effective as a fortificant, the micronutrient form must be bioavailable. In other words, the body must be able to effectively absorb and utilize the micronutrient. In addition, the chosen fortificant must not affect the color or taste of the fortified rice. Different forms of micronutrients have varying degrees of bioavailability and degrees to which they affect the appearance and taste of fortified rice.

The most commonly used micronutrients and their fortificants are discussed below.

Iron

Different forms of iron offer trade-offs between bioavailability and properties impacting consumer acceptance. The iron fortificants recommended for wheat and maize flour fortification (e.g. ferrous sulfate, ferrous fumarate or sodium iron EDTA) are nearly unnoticeable to the consumer because the relevant iron fortificant is equally distributed throughout the fortified flour. However, when concentrated in a fortified kernel, color and taste may be affected. **Figure 5** shows rice that has been fortified with various types of iron, sometimes resulting in fortified kernels that may not be acceptable to consumers.

Ferric pyrophosphate (FePP) is recommended for rice fortification as it does not affect the color of fortified kernels and thus does not negatively influence consumer acceptability. However, the bioavailability of FePP is not as high as of ferrous sulfate, and the total iron that can be added to the fortified kernels is relatively low. A micronized form of FePP can increase bioavailability to some extent. Ferric orthophosphate is sometimes used since it is a nearly white powder; however, bioavailability is below that of FePP.[4,5]

Recent research by the Swiss Federal Institute of Technology (ETH Zurich), confirms that adding a chelating agent can greatly improve the bioavailability of FePP in rice, matching the bioavailability of ferrous sulfate.[6]

Zinc

Adding zinc to rice is relatively easy. Zinc oxide is suitable for the technical needs of fortification and has high bioavailability, with virtually no negative impact on taste, color, or stability for the other micronutrients. Zinc sulfate ($ZnSO_4$) is less suitable, as it may have a negative impact on vitamin A stability.

Selenium

Where selenium deficiencies exist – for example, in Costa Rica – the preferred form for fortification is sodium selenite.

Vitamins

Similar to wheat and maize flour fortification, **the water-soluble vitamins B_1 (thiamin), B_3 (niacin), B_6 (pyridoxine), B_9 (folic acid), and vitamin B_{12} (cobalamin)** are frequently used to fortify rice without affecting acceptability. However, there are some stability concerns with respect to vitamin B_1 when fortified rice is stored at elevated temperatures. Vitamin B_2 (riboflavin) changes the color of the fortified kernels, which reduces consumer acceptability. It is therefore not typically added to rice even when there is a public health need.

Vitamin A is a fat-soluble vitamin commonly used to fortify vegetable oils, but also wheat and maize flour. The preferred form is retinyl palmitate, in combination with a powerful antioxidant, such as butylated hydroxytoluene (BHT). This ensures stability during storage. Among the vitamins used in rice fortification, vitamin A is the most sensitive to the environment and preparation, including such factors as light, heat, and pH.

FIGURE 4: Production methods for batch and continuous blending to produce fortified rice

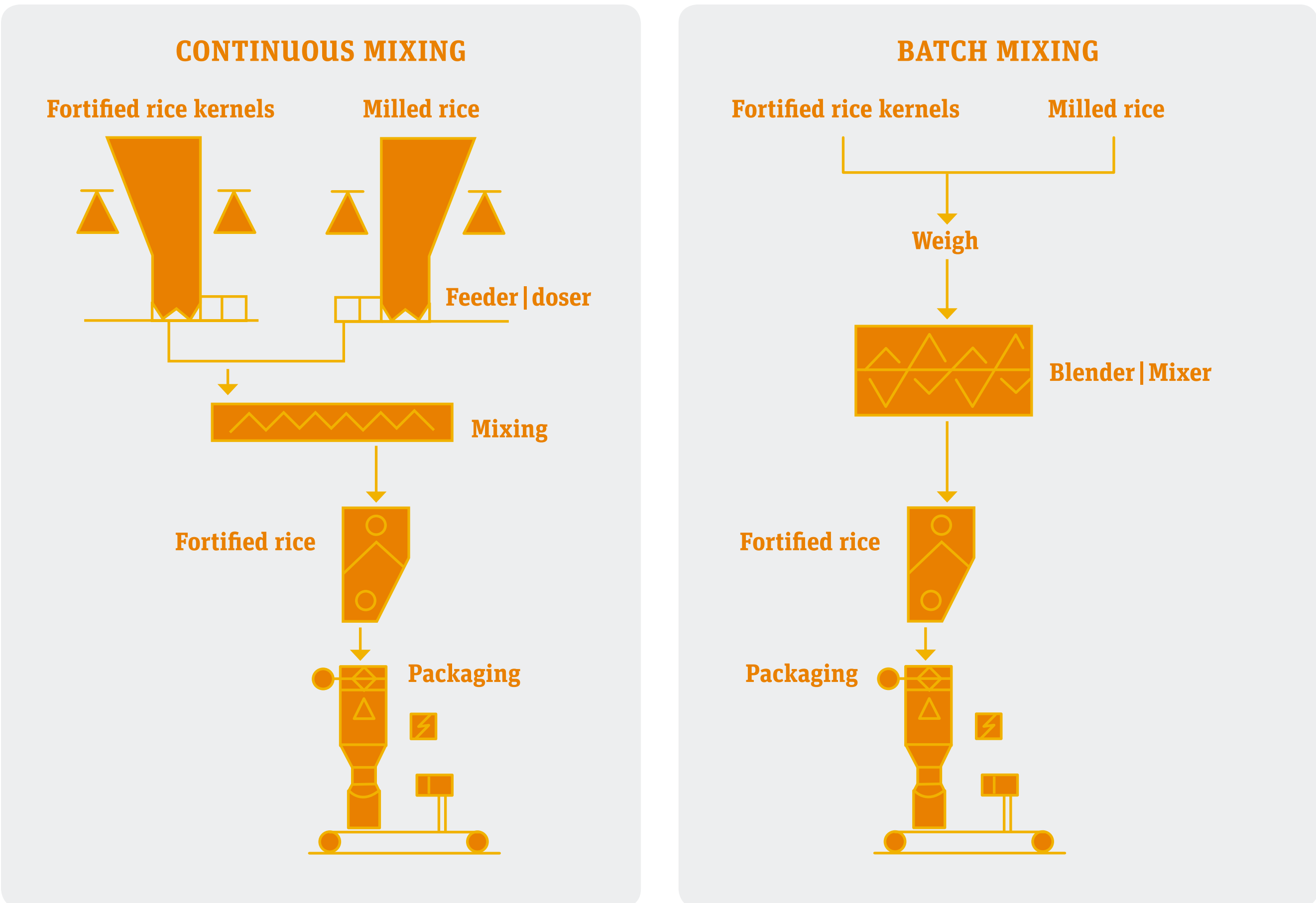


FIGURE 5: Visual appearance of rice fortified with various forms of iron

Some countries also fortify with vitamin E, using a spray-dried α-tocopheryl acetate form. Vitamins D and K are possible in rice fortification; however, they are not yet used in any of the rice fortification programs.

Other

Overall, rice is a good source of amino acids except for lysine; therefore, fortification with lysine can increase the biological value of rice protein. Although the recommended form is highly water-soluble, the majority of lysine in extruded fortified kernels is retained during washing and cooking.[2]

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Conclusion

The technology for effective fortification is now available for rice, the world's second most commonly consumed cereal grain. The choice of technology must take into account retention of nutrients during preparation (soaking, washing and cooking), and consumer acceptability (taste, shape, and color). The use of rinse resistant coating or extrusion (hot or warm) to produce fortified kernels meets nutrient retention and consumer acceptablity requirements. Both technologies involve a two-step process: first, production of the fortified kernel, and second, blending of fortified kernels with non-fortified rice.

The fortificant used is also important as it influences consumer acceptability and the effectiveness of fortified rice for public health.

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