Improving nutritional status

Deficiencies in many vitamins and minerals affect more than a third of the world’s population. To fight the consequences of such deficiencies, relevant staple foods are chosen to be enriched with micronutrients. Rice is one of them.

Rice is the staple for 3 billion people, most of them in developing countries. In such populations, a high percentage of their daily energy intake comes from rice. The latter should therefore cover a high percentage of the required micronutrient intake. However, this can only be achieved through rice fortification, taking into account the type and amount of nutrients required, how they are added and how they are delivered to the consumer.

Micronutrient selection and suitability

In its unmilled form, rice is a natural source of macronutrients and micronutrients. However, during processing to white rice / polished rice, nutritious parts of the rice kernels – hull, bran layer, and germ – are removed. Consequently, the polished rice grains contain far less B-vitamins and minerals, including iron and zinc.
Adequate nutrient levels in fortified rice are usually defined by the population’s needs and eating habits. Nutrients often added to rice to cover major nutritional gaps are vitamin A, vitamin B1, vitamin B6, niacin, iron, and zinc. The fortification levels aim at providing the EAR (estimated average requirement) by the particular food, which is in line with the WHO/FAO guidelines for micronutrient fortification. Table 2 illustrates an example.

The selection of micronutrient forms used depends on criteria such as sensory properties and stability. The micronutrients must also withstand the fortification process, the shelf-life, and the preparation at the end consumer.

**Technology**

Only fortification offers the possibility to add several micronutrients at once, and to reach the recommended levels of micronutrient intake more easily. Many types of rice can be fortified.

Several techniques exist to fortify rice; dusting, coating and extrusion. DSM and Bühler jointly developed and improved extrusion technology, and there have been several recent advances in extrusion technology. One of which is a recent DSM patent where iron can be added in such a way that it is bioavailable but does not negatively impact the sensory properties of the fortified rice kernel.

The technology of rice fortification and the micronutrient forms used strongly impact the acceptance and bioavailability of the nutrients. Extruded fortified rice kernels have successfully mitigated those challenges, and so has the recent development of adding iron such that bioavailability and consumer acceptance score highest.
Embedding micronutrients by extrusion

Cold, warm or hot extrusion can be applied to produce reconstituted fortified rice kernels. Rice flour, a vitamin / mineral premix, optional additives like binders, moisture barrier agents or emulsifiers, water and steam are mixed to form a dough. This is extruded through a die where kernels are shaped and cut before being dried. As a last step, kernels are dried.

Via extrusion, the added nutrients are embedded in the reconstituted kernel matrix and are largely unaffected by post-processing treatments like transport, storage and washing.

Hot extruded fortified rice kernels can easily be blended with natural rice and have shown a high degree of consumer acceptance – a key criterion for the success of a fortification program.

Hot extruded kernels mimic regular rice kernels to such an extent that up to 10% of extruded fortified rice kernels can be added to non-fortified rice kernels without a perceivable change in product properties. For reconstituted rice kernels produced by cold extrusion this percentage is lower.

Fortifying rice with highly bioavailable iron

Fortifying rice – and food in general – with iron has been an important challenge for decades. There is often a trade-off between iron bioavailability and its sensory impact on the food being fortified. DSM has found a unique way to combine both. Details of the concept can be found in DSM’s patent application (WO2013167506A1). It is about creating an iron complex in the rice. During digestion, the iron is made highly available for absorption. Studies show that the bioavailability of iron in such a system is comparable to that of ferrous sulphate.

Vitamin stability

While iron is challenging mainly for its sensory impact, vitamins bring the challenge of stability across the food fortification process and cooking. Each vitamin, and vitamin form, has its own degradation kinetics. The selection of the product form, and its addition rate, are therefore key.

Figure 6: Main factors contributing to vitamin A losses in extruded fortified rice kernels

Figure 4: Two-step rice fortification manufacturing process

Figure 5: Rice is cut as it comes out of the die during hot extrusion

Figure 3: Basic extrusion steps
Fortification basics: Rice

Process & Storage stability

When producing fortified rice, one needs to consider process losses, and their key parameters: heat, humidity, light, oxygen, metals. In general the process losses are between 0-20% in coating or extrusion technologies. In dusting, the process losses are considered to be the smallest, but segregation is an issue.

Storage stability depends on many factors. The most sensitive nutrients are vitamin A and vitamin B1. Vitamin A is sensitive to oxidation, especially in the presence of humidity, light, and at elevated temperatures. The presence of iron, even as non-water-soluble forms such as iron phosphates or pyrophosphates, enhances the storage losses of vitamin A.

In extruded kernels stored at 30°C, the monthly losses for vitamin A can be at about 4-10%. Technical antioxidants can help delay the oxidation. Further influencing factors are the packaging material, exposure to light and the cooking process. Vitamin B1, known to be heat sensitive, also shows some losses. Typically an average of 30% is added, to compensate on storage losses at 30°C, 1 year, in polyethylene bags.

Washing stability

Dusting is not suitable when rice is rinsed, or soaked and rinsed, before cooking because the added nutrients get washed away. To a certain extent, this is also valid for coated rice. Most of the coated rice show substantial washing losses, but for a few exceptions, such as ethyl cellulose coating.

On the contrary, washing losses in extruded fortified kernels can vary. For hot extruded fortified kernels, washing losses are very low. For cold extruded fortified kernels, the losses mainly depend on the intensity of the washing and on the binder matrix.

Cooking stability

Cooking in excess water that is removed after cooking leads to higher losses mainly in highly water soluble vitamins, e.g. vitamin B12 (50-60%). Soaking overnight and cooking of the rice for two hours, without excess cooking water, can also lead to very high losses including for vitamin A (up to 50%) and for vitamin B12.

Quality control considerations

The nutrient content of the vitamin and mineral premix, and of the rice can be determined with various methods such as HPLC and microbiological methods. Simpler, more cost-effective and faster methods exist and continue to be established.

A key factor is the good extraction of the active substance (vitamin). It separates the active out of its surrounding components, and out of its protecting matrix. Enzymatic digestion is often used.

The concentration of nutrients in the matrix that is to be analysed, will define the methods of preparation and the method of analysis.

Legislation & successful implementation

A successful fortification program requires the collaborative participation between various government sectors, food producers, private organizations, and international agencies. It is about defining the targeted amount of nutrients, their product forms, and the foods to be enriched. Nutritional considerations are key and should focus on the needs of the target population, its deficiencies and its energy intake via the preferred staple food.

Fortification programs are being run in many countries. In some, they are run as a mandatory programs, and in others rice fortification is run on a voluntary basis e.g. Brazil, Bangladesh, Indonesia, Cambodia, India and more (status 2015).

References:
4 Bühler
5 Bühler

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