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Vitamin Fortification of Milled Rice: A New Approach to Address Micronutrient Malnutrition*

Policy Recommendation

To address micronutrient deficiencies in the susceptible sector of society, it is recommended to fortify the commercial milled rice with vitamins using the new technique of fortification. The simple approach, which involves rice surface modification and vitamin absorption, is deemed economical compared to traditional fortification processes. Moreover, the susceptibility of losing vitamins due to washing processes is resolved in this improved grain fortification as ~90% of the vitamins are retained. The results shown in this study indicate the successful fortification of vitamins on rice and that fortification is more pronounced when the grain undergoes sonication process. As the staple food for an estimated 3 billion people worldwide, fortification of rice grains through sonication and adsorption allows vitamins to be delivered into the body regularly through the diet, which can be a potential approach towards a massive food fortification programs to address severe nutrient deficiencies in the population.

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Nutrient Fortification

The optimal health of a nation's human resource is critical for economic success. The growth and development of children and the health condition of the adult population are directly correlated to the work productivity of nations. Poor health and disabilities of people are due to deficiencies in a vitamin that retards growth, damages developing brains, impairs learning ability, increases susceptibility to infections, and reduces the productivity of the working class. One of the approaches to address health issues, like vitamin deficiency, is food fortification. It is a process of adding micronutrients to food

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to provide regular amounts of nutrients through the diet. As a public health policy, it is instituted to reduce the number of people with dietary deficiencies in a population by enriching a food vehicle with extra micronutrients (Ashong et al., 2012). The Food and Agriculture Organization (FAO, 2004), the UN World Food Programme (Landis, 2017), and governments (Tsang et al., 2016; Hijar, Aramburu, Hurtado, & Suarez, 2015; Dexter, 1998) promote rice fortification to improve the daily intake of essential nutrients and address the malnutrition and other health issues of vast majority of the human population. Rice, being the staple food in the Philippines, is a potential food vehicle for vitamin fortification.

The regular commercial rice is processed by milling the grain to remove the germ and bran layers and polishing to render the rice white. This process is driven by consumer acceptability. However, very significant amount of natural vitamin contents are lost during the milling process. Thus, to regain the lost vitamins, milled rice needs to be fortified; otherwise, it is devoid of essential vitamins. The rice fortification technologies developed so far involve a) mixing the rice flour with vitamin mix, either by hot or cold process, and reforming to simulate the rice grain; b) combining the vitamins with waxes and gums and spray coating on the rice grain; and c) dusting the polished rice grains with vitamins through electrostatic action (Alavi et al., 2008). The first two approaches require tedious processes, while the third approach is limited. The available commercial fortified rice uses the first approach involving hot extrusion. This process is limited only to mineral fortification like iron because minerals can tolerate the high temperature demand of the process. However, this is not the case for vitamins, which are sensitive to light and temperatures. Hence a new technique is desired to incorporate not only the minerals but also the essential vitamins to commercial rice. This project developed a new and simple approach of fortifying rice with vitamins, which can be instituted to address deficiencies in essential vitamins like the B complexes.

Rice Surface Modification

Any commercial milled rice can be subjected to ultrasonication. Sonication technique, which employs ultrasonic waves, creates an impact on the rice grain modifying the surface morphology. Upon drying the rice grain, the sonication process allowed the formation of porous, polygonal cavities on the rice surface as revealed by scanning electron microscopy (SEM). Morphological analysis revealed that sonication promoted fragmentation and destruction of the surface shell and induced the formation of micropores, exposure of cell walls, and disintegration of starchy endosperm into individual starch granules. This is in stark contrast to the control rice that did not undergo sonication where the surface is observed as smooth with irregular surface humps. The resulting highly porous surface of rice upon sonication is suggestive of possible incorporation of a guest molecule inside the pores. This gives the impetus of the possibility of adhering compounds into the rice surface pores.

Vitamin Adsorption on Rice Surface

The vitamin initially explored in this project is the vitamin B5 complex (pantothenic acid). Rice samples were sonicated for 25 minutes and dried under air. The sonicated and non-sonicated (control) rice were soaked for 1 hour in 1000 ppm vitamin solution with a rice-to-water ratio of 1:2. After soaking, the rice was collected then dried and the vitamin content was analyzed. The degree of vitamin loading was determined quantitatively using high performance liquid chromatography (HPLC). Results show that fortification was achieved on non-sonicated rice as evidenced by pantothenic acid (B5) peak at 5.53 mins (peak area: 95.5) as compared to the raw rice (peak area: 2.17). A dramatic increase in B5 content is very evident on sonicated rice (peak area; 175.4). The increase in peak area can only be attributed to the improved capacity of sonicated rice to absorb/adsorb water including the nutrients in it. The uptake capacity of rice for pantothenic acid showed that the vitamin B5 uptake on rice is very pronounced when the rice was subjected to sonication compared to the non-sonicated sample. Comparison of the uptake concentration of B5 on rice after 60 min soaking using paired sample t-test showed a significant difference ($p < 0.05$) in the uptake concentration of vitamins per gram of sonicated rice (M= 447.59 µg/g, SD= 4.51) and non-sonicated rice (M= 186.16 µg/g, SD= 8.42) (conditions; $t(2)= -110.82$, $p = 0.00004$). These results indicate that the sonication process significantly increased the absorption capacity of rice. The pantothenic acid (B5) uptake of sonicated TH82 rice is 140.0 % higher than the non-sonicated rice. The significant increase in vitamin uptake capacity is attributed to the notable macrostructural changes on the surface as evidenced by the SEM data showing the uniform formation of pores, disintegration of starch granules, and exposure of cell walls. These porous surfaces allow for improved adsorption/absorption of vitamins. The kinetic study indicates that the rate of adsorption in porous sonicated rice is 93.9% higher than the non-sonicated rice. Adsorption investigation showed heterogeneous binding mechanism indicating the critical role of the modified porous surface of rice grain in the fortification process.

The investigation was extended on other vitamin B complexes such as vitamins B1 (thiamine), B2 (riboflavin), and B6 (pyridoxine hydrochloride). By virtue of their differences in structure, different vitamin B compounds would have different degrees of adsorption on rice. Results show the prominent peaks of the spiked vitamins on rice samples confirming the enhancement of vitamin content with comparable uptake concentrations similar to B5. This indicates positive fortification of rice as compared to the untreated rice. The effect of washing and cooking the rice showed ~6-10% losses of vitamins indicating that ~90% of the vitamins are retained even after washing and cooking.

Summary

White milled rice contains reduced nutritional value as a result of milling and polishing processes. This work explored a simple approach of fortifying rice through surface modification and vitamin adsorption. Exposure of white commercial rice to an ultrasonic environment modified the surface from smooth to porous. Soaking the sonicated rice in a solution of vitamins allowed the adsorption of the vitamin into the rice grain. The uptake of vitamin B5 in sonicated rice is 140.0% higher than the non-sonicated rice. The kinetic study indicates the rate of adsorption in porous sonicated rice is 93.9% higher than the non-sonicated rice. Adsorption investigation showed heterogeneous binding mechanism indicating the critical role of the modified porous surface of rice grain in the fortification process. Washing and cooking the rice showed ~90% retention of the vitamins. The results of this study offer a potentially cheaper and effective fortification technique that can be used to address the massive malnutrition problem in the country.

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