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Iron retention in iron-fortified rice and use of iron-fortified rice to treat women with iron deficiency: A pilot study

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ABSTRACT

Objectives: 1. Evaluate the effect of washing and cooking iron-fortified rice on iron retention and bioavailability. 2. Evaluate the effect of iron-fortified rice on women with iron deficiency anemia

Methods: 1. Iron-fortified rice (18 mg/100 g as $FeSO_4$) was cooked in Baton Rouge, Louisiana (C), rinsed and cooked (RC), fried and cooked (FC), cooked with extra water (CW), or soaked and cooked with extra water (SCW), and iron retention was determined. 2. Rice samples were cooked in Kampala, Uganda in a lab (C-Uganda) and households using traditional cooking method (TC-Uganda) and iron retention were determined. 3. Seventeen women with iron deficiency (low iron and/or low ferritin) anemia were randomized to 100 g/d of rice (two cooked 0.75 cup servings) for two weeks containing 18 mg/d iron (supplemented) or 0.5 mg/d iron (un-supplemented). Hemoglobin and hematocrit were evaluated at baseline and 2 weeks with other measures of iron metabolism.

Results: 1. Iron retention, from highest to lowest, was (C), (RC), (FC), (C-Uganda), (CW), (SCW) and (TC-Uganda). 2. Seventeen women were randomized and 15 completed the study (hemoglobin 10.6 ± 1.6 g, hematocrit 33.7 ± 4.1%), 9 in the iron-fortified rice group and 6 in the un-fortified rice group. The iron-fortified group had a greater increase in hemoglobin (0.82 g, p = 0.0035) and Hematocrit (1.83%, p = 0.0248) with directional differences in other measures of iron metabolism favoring the iron-fortified group.

Conclusions: Iron-fortified rice increased hemoglobin and hematocrit in women with iron-deficient anemia. Iron deficiency and anemia are widespread in Southeast Asia and Africa and undermine development in these regions.

1. Introduction

Micronutrient deficiencies in iron, zinc, vitamins A/B, iodine, and folic acid affect > 2 billion people worldwide [1,2]. Micronutrient malnutrition, a common condition in Southeast Asia and Africa, is a risk factor for several diseases and has profound implications for health, cognitive development, education, economic development, and productivity in these regions [3–9]. Food fortification with micronutrients has been recognized as an important health program for the prevention and treatment of micronutrient deficiencies in many countries around the world. Although staple foods such as rice, maize, wheat flour, or cassava fortification can all address the problem of malnutrition, the focus of our study was on iron fortified rice and predicting its efficacy in prevention/treatment of iron deficiency anemia in regions with a rice based diet.

Iron deficiency is a major public health problem particularly across Sub-Saharan Africa where 67.6% of pre-school children and 57.1% of pregnant women suffer from anemia [10]. For example, in Angola, > 56% of children under 5 years of age are anemic [11]. In Cameroon, the prevalence of iron deficiency in women between the ages of 15 and 49 years and children between the ages of 1 and 5 years has been estimated to be 14% to 68% and 12% to 47%, respectively [12]. Iron deficiency is associated with a higher prevalence of pre-term birth and low birth weight babies with lower Appearance, Pulse, Grimace, Activity and Respiration (APGAR) scores [13]. In this region, where rice is a dietary staple, iron fortified rice may provide the solution for

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prevention of iron deficiency.

There are many advantages associated with the use of polished rice for iron fortification. Rice is the staple for an estimated 3 billion people around the world [7], but the iron content in polished rice is very low. The phytate content of polished rice is low compared to wheat or corn flour, the fortification of which is associated with adverse interactions including sensory effects [14]. A significant share of rice coming from rice mills can be fortified before distribution to the market at a cost that is not > 3% of the current rice retail price. Iron treatment has been shown to improve birth weight in a linear fashion [15], and the use of iron supplementation in food has been demonstrated to be better accepted in developing countries than supplements like iron drops or pills. Foods supplemented with iron are cheaper and result in higher compliance to treatment than medication based supplementation [16].

Although fortification of bread through wheat flour has been a successful strategy in Egypt, other African countries like Nigeria have a rice-based economy [17]. Fortifying rice with iron is challenging because iron leaches easily from the surface of rice during washing, and cooking has been reported to decrease the iron concentration of the iron-fortified rice [18]. Rinse resistant fortified rice kernels have been developed using an advanced coating technology that applies concentrated nutrients (iron or multiple nutrients) to rice kernels which can be added to regular rice to produce micronutrient-fortified rice without altering the taste and with high nutrient retention after washing [19].

The cooking quality of rice is an important attribute that affects consumer acceptance, and cooking methods significantly impact the nutritional values of the cooked rice. There are several ways of cooking rice according to culture and final cooked rice quality preferences. Typical rice cooking methods include (1) rinsing and cooking, (2) frying and cooking without rinsing, (3) cooking with extra water, and (4) soaking and cooking in extra water. The methods commonly used to cook rice include boiling, steaming, and pressure-cooking. Boiling can be performed with a precise volume of water, usually 1.5 to 2 times the weight of rice, and boiling proceeds until all the water is absorbed and some has evaporated. During boiling with extra water, the excess water is discarded when rice has cooked. Each cooking method has a different effect on nutrient retention.

The objective of this study was two-fold, (1) to determine iron retention in iron-fortified rice that was cooked following each one of the cooking methods mentioned above, and (2) to carry out a short-term, double-blind, controlled preliminary evaluation of the Wright Group fortification technology to confirm that it would effectively treat iron deficiency anemia by increasing hemoglobin and hematocrit.

2. Materials and methods

2.1. Rice samples and reagents

Rice samples including control (unfortified rice) and iron-fortified samples were provided by The Wright Group (Crowley, LA). The form of iron used in the fortified rice was food grade ferrous sulfate. Concentrated ferrous sulfate was coated on to the rice kennels to form coated iron fortified rice kernels. Then coated iron fortified rice kernels were added to the regular rice at a 1 to 200 ratio (1 g of coated iron fortified rice kernels was added to 199 g of regular rice). The iron content in the finished iron fortified rice is 18 mg/100 g.

2.2. Rinse test for the analysis of iron retention during rinsing

To assess iron retention during rinsing, a rinse test was performed. Fifteen grams of rice were added to a 250 mL beaker. One hundred mL of deionized water was added. The sample was stirred vigorously for 30 s with a glass rod. The rice was allowed to settle for 30 s. The water was decanted. Two mL of concentrated HCl was added to 98 mL of the rinse water and used for iron analysis by inductively coupled plasma-mass spectrometry (ICP) as described below. All reagents were of analytical grade.

2.3. Rice cooking

Fortified rice cooking was performed at two different locations, in Baton Rouge, LA and in Kampala, Uganda. Rice cooking in Baton Rouge was performed as follows. All cooking methods used 100 g rice samples in triplicates and treated as described below. Sample 1 was used as control uncooked iron-fortified rice. Sample 2 was cooked at boiling temperature (BT) for 20 min in 200 mL water until fully cooked and no water remained (absorption method) without rinsing and referred to as cooked rice (C). Sample 3 was rinsed with 500 mL of water, the rinsing water was saved and the rice cooked at BT for 20 min with 200 mL water with absorption method. This sample was referred to as rinsed and cooked rice (RC). Sample 4 was fried for 1 min in 1 tablespoon of corn oil and cooked at BT for 20 min without rinsing with absorption methods. Sample 4 was referred to as fried and cooked rice (FC). Sample 5 was cooked at BT for 20 min with 500 mL water and referred to as cooked in excess water sample (CW). After 20 min, the remaining water was removed and saved for iron analysis. Sample 6 was soaked for 1 h in 500 mL of water and cooked at BT for 20 min. The excess water was removed and saved for iron analysis. This sample was referred to as soaked and cooked in excess water sample (SWC).

Fortified rice cooking in Kampala, Uganda was also prepared in triplicates and performed in two ways as follows. Approach 1. The rice to water ratio was 1:2. The cooking time of 100 g of rice was about 30 min on low heat after boiling. This was done in the Food Science Department Lab at Makerere University and referred as to rinsed and cooked in Uganda (C-Uganda). Approach 2. Fortified rice samples (500 g triplicates) were given to ten local households. Women in the ten households prepared rice by following their own customs without any control, mainly by boiling in open or covered pans over firewood flame. As the rice boiled, some of the water initially added foamed and poured out of the pan. In many of the cases, more water was added until the rice was fully cooked. The cooking time could be around 30 min or longer. The ratio of rice to water at the beginning of the cooking varied from 1:1 to 1:2.5. The additional amount of water added varied widely and was mainly based on amount required to get the rice well cooked. These various household cooking methods were reported to the researchers of this Uganda study and were referred to as traditional cooking method (TC-Uganda). Cooked rice samples were collected by Makerere University researchers for iron retention analysis.

In both approaches used in Uganda, cooking was mainly done on charcoal stoves, and it was difficult to estimate the cooking temperature. The cooking time varied according to the temperature of the stove in the Approach 2 (see Table 1).

2.4. Iron analysis in cooked rice samples

To assess iron retention, uncooked control and cooked rice samples were lyophilized, ground into powder, passed through a 20 mesh US Standard screen (0.841 mm), mixed well, and 2 g samples were added to 5 mL of 5% nitric acid. The samples were mixed well, allowed to settle and the supernatant was filtered through 0.22 μm filter. The mineral analysis was performed using inductively coupled plasma-optic emission spectroscopy (ARCOS, Spectro, Germany for LSU, Baton Rouge, LA, USA and Perkin Elmer 2380 at Makerere University, Kampala, Uganda). All reagents were of analytical grade.

2.5. Clinical study

Originally 20 women with iron deficiency determined by a serum ferritin (Siemens Immulite 2000) and/or a serum iron value (Beckman Coulter DXC600) below the lower limits of normal for the local laboratory (5 ng/mL and 40 μg/mL, respectively) but otherwise healthy