Factors Impacting Iron Fortification of Rice Using Parboiling
Kate Wilkes
Advised by Dr. T. Siebenmorgen and Dr. Y. Wang
University of Arkansas
May 24th, 2017

Introduction

Micronutrient Deficiencies
• 3 billion people worldwide suffer from micronutrient deficiencies
• Iron deficiency is the most prevalent nutrient deficiency worldwide
• Endemic in developing countries
• Caused by low dietary diversity, reliance on staple crops

Anemia in preschool-aged children, WHO (2008)

Global Impact of Rice
• 11% of the world’s arable land—154 million hectares (Khush, 2005)
• Represents 20% of the world’s daily energy
• Top producers are China and India
• Global Production: 740.2 million tons (FAOSTAT 2015)
• U.S. Production: 9,026,469 tons (FAOSTAT 2015)

Fortification of Rice

Dusting Method
• Rice is coated with minerals immediately following dehulling, milling, or during packaging
• Most inexpensive method
• Traditional rinsing and excess water boiling practices reduce delivery of micronutrients

Coating Method
• Rice is sprayed with highly concentrated mineral solutions, then sprayed with an edible polymer
• Ineffective when boiled in excess water

Hot Extrusion
• Highly fortified “kernels” are extruded at high temperatures (70°C-110°C) and blended with conventional rice
• “Kernels” are hard, translucent, and most closely resemble rice grains
• Requires specialized equipment, high capital costs

Cold Extrusion
• Highly fortified “kernels” are cold extruded (<70°C) in a process similar to pasta production
• Kernels are more opaque and identifiable
• Lower capital costs, but higher cost of operation than hot extrusion
Fortification in the News

Parboiling

- Soaking reaches moisture contents >30%
- Steaming gelatinizes rice starch, inactivates enzymes
- When parboiling is complete, rice is dried back down to ~12.5% MC
- Increased hardness
- Increased milling yields
- Golden color

Parboiling Fortification

- No patented or commercialized method for fortifying rice via parboiling
- Recent work via collaborative efforts between Australian and Thai scientists
- Our work may help optimize the process by expand the knowledge base by quantifying the impact of factors that impede iron transfer into the endosperm

Objectives

- To establish the influence of various processing factors (soaking and steaming conditions, iron fortificant level, feedstock, milling duration) upon rice color and total iron content.
- To determine the role of rice kernel components in the uptake of iron into the kernel.

Materials and Methods
What is a Therapeutic Level of Iron?

Recommended Dietary Allowances (RDAs):

- Children (1-3): 7 mg/day
- Children (4-8): 10 mg/day
- Women (19-50): 18 mg/day
- Men (19-50): 8 mg/day

WHO recommends between 5-10 mg/day of iron via fortification. Other sources of iron include seafood, chickpeas, lentils, peas, spinach, tomatoes.

Incoming Rice

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Harvest Year</th>
<th>Protein Content (%)</th>
<th>Total Lipid Content (%)</th>
<th>Amylose Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL XL745</td>
<td>2015</td>
<td>5.1</td>
<td>2.2</td>
<td>16.5</td>
</tr>
<tr>
<td>Diamond</td>
<td>2016</td>
<td>6.1</td>
<td>2.3</td>
<td>16.5</td>
</tr>
</tbody>
</table>

Fortification via Parboiling

- Iron concentrations in Millipore water at: 0, 250, 500, and 750 mg NaFeEDTA/L H₂O
- Rice was soaked for 3 hours at three temperatures: 4°C below onset temperature, at onset, and 4°C above onset)
- Steaming for 10 minutes at 115°C (239°F)

Determination of Parboiling Conditions

- Differential Scanning Calorimetry (DSC) to determine the onset gelatinization temperature for each cultivar
Color Assessments

- Color is a critical concern with iron-fortified rice—needs to resemble conventionally-parboiled rice
- Parboiling may mitigate some of the color change associated with iron fortification (golden color already)
- L*a*b* color system

Total Iron Content

- Altheimer Labs, University of Arkansas
- Total iron content measured via Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES)

Results

- Total Iron Content of White and Control CL XL745 Parboiled with 0-750 mg/L NaFeEDTA Solution
Summary and Conclusions

- Parboiling with fortification has been shown to produce rice with therapeutic levels of iron.
- Processing parameters can be modified to increase the level of iron taken up by the kernel.
- Feasibility for world food aid efforts.
- New fortification method for Arkansas processors.
- Could be expanded to other nutrients.

Significance

- Fortified rice for humanitarian efforts.
- Parboiling fortification—no additional equipment purchases.
- Easily produced in developing countries.
- Opportunity for production in Arkansas.

Thank You!
Hypotheses

Based on preliminary studies, it is hypothesized that:

- White and brown rice feedstocks will experience greater iron uptake into the kernel endosperm than rough rice.
- Parboiling conditions will result in greater total iron content.

References


Fortifying Agent

- NaFeEDTA used as the fortifying agent in this study
- 2-3x more bioavailable than Ferrous fumarate (Hurrell 2000)
- Reported to have fewer organoleptic changes than other fortifying agents
- EDTA = ethylenediaminetetraacetic acid
- EDTA is a chelating agent, and in low concentrations prevents iron from binding to phytic acid and phenolics that prevent absorption
- EDTA concentration held constant at a molar ratio of 1:1. (Allen et al. 2006) (MacPhail et al. 1994).

Whiteness Value (L*) of CL XL745 Parboiled with 0-750 mg/L NaFeEDTA Solution

Blue-Gold Value (b*) of CL XL745 Parboiled with 0-750 mg/L NaFeEDTA Solution