Iron Contents of Malawian Foods when Prepared in Iron Cooking Pots

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Abstract: The aim of this study was to determine the iron content of Malawian foods prepared in iron pots and to examine the effects of continuous cooking time and added oil on the iron content of the food prepared. Foods prepared, which included a staple (Nsima), relish vegetables, and beans, had an increased iron content when prepared in an iron compared to a glass pot. For these three foods, iron content per gram increased by 3.15 μg, 35.8 μg, and 147.32 μg, respectively. Continuous use of the iron pot for cooking could have a positive effect on the amount of iron added to the food, as the three foods' iron content increased by a further 2.9 μg iron/g, 7.6 μg iron/g and 20.1 μg iron/g, respectively. This effect needs more study. Food pH was significantly negatively correlated with food iron content. The use of oil reduced the amount of iron added to stir-fried vegetables by 52.37 μg/g and increased iron added to Nsima (1.2 μg/g). Malawian foods increased their iron content when cooked in iron pots. This method of food preparation potentially provides a low-cost sustainable means of improving the iron intakes of families and communities where this traditional method of food preparation is acceptable.

Introduction

Iron deficiency and iron deficiency anemia are major public health problems, with more than two billion people affected worldwide [1]. Prevalence estimates of iron deficiency, with or without anemia, have increased substantially in recent years due to multiple contributory factors [2]. Despite intensive research, the understanding of iron absorption is still not complete, hindering the development and implementation of dietary interventions [3].

A non-food source of iron, which is a potentially low-cost sustainable intervention, is the use of cast iron utensils for cooking. A number of studies have shown their utility for increasing the iron content of food [4–10]. Martinez and Vannucchi reported, using a rodent model, that iron added in this manner was bioavailable [11], and three randomized controlled trials in humans have demonstrated beneficial effects of consumption of food prepared in iron pots [9, 12, 13].

Field research is needed to assess the value of this type of intervention under different settings. Laboratory studies are also needed to see if and to what extent the increase in iron content occurs in foods used in areas with a high prevalence of iron deficiency. Until now only one laboratory study has been conducted on African foods [9]. Further work on the variables, which influence the amount of iron that is added to food, is also required. Factors already known to be important include: cooking time, food moisture content, and pH [14]. Other factors may be important but have not been systematically studied, for example, the

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effect of continuous use of iron utensils and the effect of the addition of oil in food preparation.

The aim of the current study was to determine the iron content of Malawian foods when prepared in iron pots and to examine the effects of continuous use of an iron cooking pot and of added oil on the iron content of the food prepared.

Methods

Cast iron and glass pots were used. The cast iron pots were 10 liters in volume (Falkirk size 4, Zimcast, Zimbabwe) and weighed 12 kg. They had a round base and three legs for stability, and had two side handles and a lid with a handle. These were not insulated. The glass pot was made of Pyrex with a 2.5-liter volume, a flat bottom, and a lid. Two identical unused cast iron pots were used, one for studying the effects of continuous cooking (referred to as "continuous use pot") and one for individual experiments (referred to as "normal use pot"). The iron pots were prepared for use by "burning". This was done by heating them for 1.5 hours on a charcoal fire; afterwards they were cleaned with a nylon pan scourer and water.

All meals were prepared with non-metal utensils on charcoal fires. After each meal the cooking pots were cleaned with water and a scourer and dried with a paper towel. The pots were rinsed with distilled water and dried with a clean cloth. From each meal prepared in a pot the sequence number was recorded, with number one being given to the first meal prepared in the pot, two for the second etc., to make it possible to study the effect of continuous cooking on iron content of the different meals.

The ingredients for the meals were bought at the same time; only the Chinese cabbage for the relish vegetables prepared in the continuous cooking pot was bought on a separate date. All maize flour needed for the continuous experiment was placed in a container and thoroughly mixed. If necessary, ingredients were washed with distilled water before preparation.

The three most commonly consumed meals in southern Malawi were separately prepared in both an iron and a glass cooking pot. The three meals were Nsima (a maize porridge), relish beans (a bean stew), and relish vegetables (a vegetable stew). Recipes used were taken from a Malawian cookbook [15]. The three meals studied were each prepared twice and two food samples were collected and weighed from each meal from the center of the food in the cooking pot, after thorough mixing of the meal. Food sample weights varied between 96 g and 284 g.

The effect of continuous cooking was assessed by preparing Nsima fifty times in the same new cast iron pot (continuous use pot). Total cooking time was kept constant for each meal prepared. Three meals were prepared daily to simulate normal village use. Pots were cleaned between meals as described above. From each meal in the continuous cooking experiment two samples were taken from the center of the pot after thorough mixing. These varied in weight between 146 g and 269 g. To reduce costs only the iron content of every fifth meal was measured. Following the preparation of these fifty meals, a further meal of relish beans and relish vegetables was prepared.

The effect of oil was assessed first by preparing Nsima in an unseasoned iron pot and then, after seasoning, with 40 mL of oil. Excess oil was removed with a paper towel. Two samples were obtained from the center of the food in the pot after thorough mixing. In a second experiment, vegetables were stir-fried with varying amounts of oil, first 40 mL and then 160 mL. Samples of the stir-fried meals were collected and were immediately frozen.

Non-vegetable samples were dried in an oven at 100–110°C for 48 hours to determine moisture content. Vegetable samples were dried for 16 hours at 105°C, after defrosting and thorough mixing. Dried, well-mixed samples were placed in a furnace programmed to increase in temperature by 10°C per minute until 150°C was reached for 2 hours, then to increase further by 2°C per minute until 275°C was reached for 4 hours, and then to increase by 5°C per minute until 450°C was reached for 24 hours. Samples were cooled and 2 mL 50% nitric acid was added. They were dried on a hot plate and placed back in the oven programmed to increase in temperature by 10°C per minute until a 450°C hold was reached for 12 hours. Samples were cooled, dissolved in 5 mL 50% hydrochloric acid, and diluted to 50 mL with distilled water. Further dilutions with 5% HCl were undertaken if iron concentrations were above the 6 ppm range of the standards used, measured by atomic absorption spectrophotometry.

For food iron determination, a Perkin-Elmer 3300 atomic absorption spectrophotometer was used with a wavelength of 248.3 nm and slit width of 0.2 nm. Samples were read against 1, 3, and 6 μg/L standards and an average value taken using three two-second readings taken at one-second intervals. Iron content was calculated as μg iron/g of wet sample. One sample was used as an internal standard for quality control purposes and was included with each analysis batch. Data were analyzed with Epi Info 6 version 6.04. The effect of continuous cooking was analyzed by linear regression analysis.

Results

All meals prepared in the iron pots had an increased iron content compared with meals prepared in the control glass pot (Table I). Nsima, relish vegetables, and relish beans contained 3.1 µg, 34.5 µg, and 147.3 µg more iron per gram, respectively, when prepared in the iron compared to the glass pot. The cast iron pot that was used for continuous cooking added an extra 2.9 µg iron/g to Nsima compared to the normal use iron, an extra 7.6 µg iron/g for relish vegetables, and an extra 20.1 µg iron/g for relish beans (Table II).

There was an increase in the amount of iron added to Nsima between the first and fiftieth meal cooked of 6.5

Table I: Iron content of Malawian foods prepared in iron or glass cooking pots

Meal	Iron pot	Glass pot
Nsima		
Number of meals	1	2
Sequence number of meals	10	1 and 2
Number of samples	2	4
Iron µg/g wet sample (SD)	5.8	2.7 (0.6)
Cooking time (min)	30	30
pH (SD)	6.20	6.18 (0.06)
% water (SD)	80.5	79.6 (0.5)
Relish vegetables		
Number of meals	2	2
Sequence number of meals	8 and 9	7 and 8
Number of samples	4	4
Iron µg/g wet sample (SD)	37.1 (7.9)	2.6 (0.02)
Cooking time (min)	13	16
pH (SD)	5.34 (0.11)	5.03 (0.06)
% water (SD)	93.5 (2.3)	94.8 (1.0)
Relish beans		
Number of meals	2	2
Sequence number of meals	4 and 5	3.4
Number of samples	4	4
Iron µg/g wet sample (SD)	167.3 (12.6)	20.0 (2.2)
Cooking time (min)	112.5	111
pH (SD)	5.47*	5.58 (0.05)
% water (SD)	62.4 (7.4)	70.0 (4.9)

* One pH measurement was not possible to obtain, due to lack of liquid in the meal after preparation.

Table II: Food iron content of foods prepared in normal or continuous use iron cooking pots

Meal	Normal use	Continuous use
Nsima		
Number of meals	1	1
Sequence number of meals	10	10
Number of samples	2	2
Iron µg/g wet sample (SD)	5.8	8.7
Cooking time (min)	30	30
pH (SD)	6.20	6.13
% water (SD)	80.5	80.5
Relish vegetables		
Number of meals	2	1
Sequence number of meals	8 and 9	52
Number of samples	4	2
Iron µg/g wet sample (SD)	37.9 (7.9)	45.5
Cooking time (min)	13	15
pH (SD)	5.34 (0.11)	5.70
% water (SD)	94.5 (2.3)	95.4
Relish beans		
Number of meals	2	1
Sequence number of meals	4 and 5	51
Number of samples	4	2
Iron µg/g wet sample (SD)	167.3 (12.6)	187.4
Cooking time (min)	112.5	114
pH (SD)	5.47*	5.66
% water (SD)	62.4 (7.4)	72.8

* One pH measurement was not possible to obtain, due to lack of liquid in the meal after preparation.

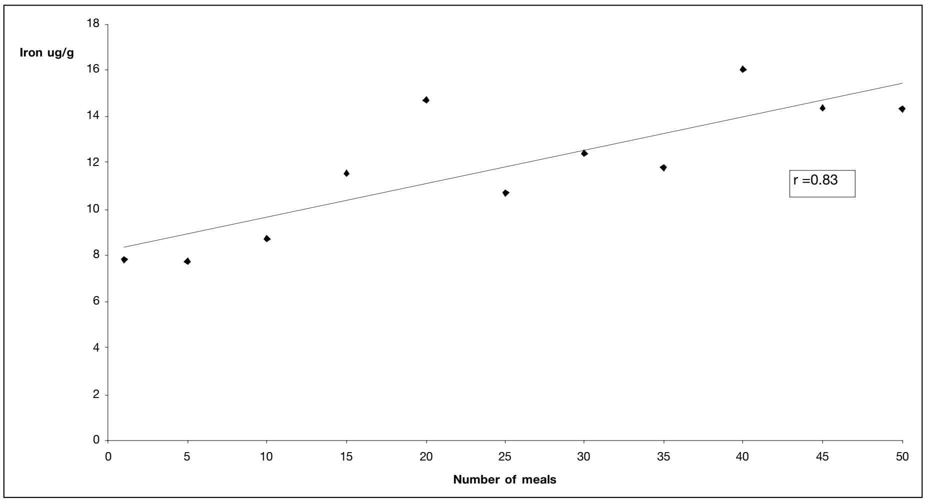

Figure 1: Iron content of Nsima (wet basis); effect of continuous use of iron cooking pot.

μg iron/g wet sample, an increase of 83.5%. Linear regression of the number of times an iron pot was used and meal iron content showed a significant correlation coefficient of 0.83 (CI 0.39 to 0.95) (Fig. 1). There was no significant difference between meals with regard to cooking time or moisture content but there was a significant difference in pH. If iron content of food was corrected for food pH, assuming a pH of 6.10, by means of the formula given by the linear regression analysis ($y = 120.7 - 17.9\times$, where y = iron content and x equals pH) the correlation coefficient was reduced to 0.16 (CI-0.06 to 0.09) (Fig. 2). The differences in pH were due to changes in the pH of the distilled water obtained from the still.

Table III: Effect of cooking oil on food iron content

Meal	No or little oil	Moderate oil
Vegetables stir-fried		
Number of meals	1	1
Sequence number of meals	11	12
Number of samples	2	2
Iron content μg/g wet sample (SD)	70.01	17.6
Amount of oil (mL)	40	160
Cooking time (min)	12	12
pH	4.84	4.86
% water	86.1	71.8
Nsima		
Number of meals	1	2
Sequence number of meals	10	13 and 14
Number of samples	2	4
Iron content μg/g wet sample (SD)	5.8	7.0 (1.2)
Amount of oil (mL)	0	40
Cooking time (min)	30	30
pH (SD)	6.20	5.99 (0.04)%
water (SD)	80.5	80.1 (0.4)

* One pH measurement was not possible to obtain, due to lack of liquid in the meal after preparation.

The use of oil resulted in a decreased amount of iron added to stir-fried vegetables of 52.4 μg/g and an increased amount of iron added to Nsima of 1.2 μg/g (Table III).

Discussion

Malawian meals when prepared in cast iron pots have an increased iron content, ranging from 3.1 to 147.3 μg per gram (Table I), which could make a significant contribution to the iron intake of rural villagers who use the pots on a regular basis. Due to the small number of meals prepared it is not possible to determine if this difference is of statistical significance. The prevalence of iron deficiency and anemia in the Shire Valley in Southern Malawi in the age group < 12 years is reported to be 96.1% and 83.0%, respectively, and in the age group over 12 years, 85.5% and 57.2% [13]. These findings highlight the potential impact of this intervention in reducing iron deficiency and iron-deficiency anemia in Malawi. It is important to take also into account the acceptability of this intervention for the Malawian community since traditionally, clay pots were used for cooking, and the use of aluminum cooking pots is now predominant [16].

Several factors could have been responsible for the observed difference in the amount of iron added to these foods; for example the kind of meal, cooking time, food moisture content, and pH. But other, still unknown, factors could have affected iron content. It is unclear what form of iron is added to the food during preparation and how it binds to components of the diet such as phytate and polyphenols. Ferric oxide and hydroxide are the most common forms of iron that contaminate food, but both are very poorly absorbed [3]. Iron that is solubilized from iron cooking pots and utensils will enter the common non-heme

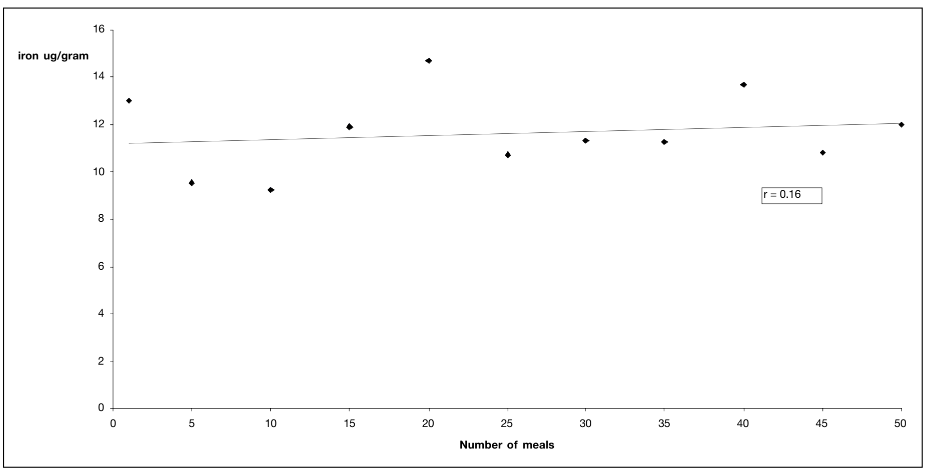

Figure 2: Iron content of Nsima (wet basis); effect of continuous use of iron cooking pot corrected for pH = 6.1.

iron pool, and its availability for absorption (potential bioavailability) will be determined by the composition of the meal and physiological factors primarily relating to the lumenal conditions of the gastrointestinal tract [17].

The effect of continuous cooking on the amount of iron added to relish vegetables and relish beans could not be determined with statistical certainty due to the small number of meals prepared. There seems to be a difference between the two iron pots with regard to the amount of iron that was added to the Nsima. For both iron pots this meal was prepared as the tenth meal in the pot, so any difference observed could not have been caused by an effect of continuous cooking on the amount of iron added to the food. If this difference were to be shown to be statistically significant, this would imply that individual iron pots add different amounts of iron to a meal. The difference found in the amount of iron added to relish beans and relish vegetables meals could be caused by such factors.

Others studies have shown no difference between iron pots with regard to the amount of iron added to the food [4, 8], which may relate to the kinds of foods prepared and their pH. Brittin and Nossaman reported that there was a significant difference between iron pots in the amount of iron added to the food in certain foods [14]. This was also observed by Cheng and Brittin, who reported a significant effect of continuous cooking on the iron content of spaghetti sauce but not apple sauce [18]. We initially found a significant effect of continuous cooking on the amount of iron that was added to Nsima. However when adjusted for pH variation by recalculating iron content, assuming a pH of 6.10, there was no significant difference in the amount of iron added over time. Cheng and Brittin, who reported a significant positive effect of continuous cooking on the iron content of spaghetti sauce, do not state if there was variation in pH in their experiment. These differences highlight the need for a better understanding of the iron solubilization process.

Oil seems to have a substantial negative effect on the amount of iron added to stir-fried vegetable meals (Table III). At first glance it looks as if oil has a positive effect on the amount of iron added to Nsima. However this difference is most likely due to natural variation in the amount of iron added to the food by the iron pots and/or the difference in pH that existed between the meals of Nsima (6.20 vs. 5.99). A more important observation is that no negative effect on the amount of iron added to Nsima was present. This indicates that the negative effect of oil on the amount of iron added, as suggested by the results of stir-fried vegetables prepared in different amounts of oil, is not present if there is an abundance of water used for preparing the food (like Nsima), or after the pot is washed. This seems to remove so much oil that the negative effect of oil on the amount of iron that is added to the food disappears (Table III). However the amount of oil that remained on the surface of the iron pot was sufficient to reduce the amount of pot rusting substantially. Since rusting of the iron pots is one of the most important factors that negatively influence their acceptability [16], then regular use of small amounts of oil could improve acceptability without diminishing the positive benefits of iron pots on iron content of food.

Malawian foods increased their iron content when cooked in iron pots. The amount of iron seems to be sufficient to improve the iron intake of Malawian families using these cooking pots on a regular basis for the preparation of the family meal. This assumes that a sufficient quantity of the additional iron is bioavailable.

A systematic approach is required to clarify the relative importance of variables that determine iron solubility from cooking pots and how it binds to the food. More research is needed to study the effect of continuous use of iron cooking pots on the amount of iron added to the food. Also the health risks of long-term use and of preparing acidic foods in cast iron pots, especially with regard to iron overload, should be assessed by long-term follow-up studies. Preparing food in iron pots could provide a low-cost sustainable means of improving iron intakes of whole families, and should be evaluated as a strategy for reducing iron deficiency anemia.

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