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Fermentation and Lactic Acid Addition Enhance Iron Bioavailability of Maize

Abstract

Maize is one of the most important cereal crops for human consumption but the iron bioavailability (FeBA) from maize foods is very low due to the high phytate content. The objective of this study was to determine the effect of common maize food processing on FeBA for identifying better processing techniques to improve FeBA. Maize foods were prepared to represent different processing techniques: heating (porridge), fermentation (ogi), nixtamalization (tortillas) and decortication (arepas). The effect of processing on iron and phytate contents was evaluated using a mass balance methodology. FeBA was assessed using in vitro digestion coupled with caco-2 cell model and using ferritin as an index of bioavailability. Phytate content of maize foods was significantly reduced only by nixtamalization (15%, $p = 0.03$), while iron content was not affected by any processes. Processing, irrespective of type of fortificant had a significant effect on FeBA ($p = 0.02$). Relative Bioavailability (RBA compared to 100% bioavailability of Porridge with FeSO4), was significantly higher with ogi fortified with FeSO4 (141% ± 16 RBA, $p < 0.001$), and RedFe (42% ± 6 RBA, $p < 0.001$). To determine whether the high FeBA from ogi was due to acidification, we added lactic acid (6mg/g) to unfermented maize foods. Addition of lactic acid significantly increased iron solubility as well as FeBA in maize foods by an average about 2-fold ($p < 0.01$), with the most pronounced effect observed in tortillas. Our findings of minimal reduction of phytic acid with ogi preparation suggest that acidification but not phytate hydrolysis is responsible for improving iron solubility and FeBA during fermentation. Improvement of FeBA with lactic acid addition to unfermented foods further confirms our results. Adapting processing methods to improve FeBA could have a significant impact on the effectiveness of fortification schemes. Lactic acid addition is another alternate and inexpensive approach to improve FeBA, and may be more feasible than adding expensive fortificants with high bioavailability.

Introduction

- Iron deficiency is the most prevalent nutritional deficiency worldwide, affecting over two billion people.
- Iron fortification of maize has a minimum impact on improving iron status because of the high level of phytate in maize significantly inhibiting FeBA.
- Many studies focus on food fortification but not on processing or formulation practices to improve FeBA of maize foods.
- Many traditional maize processing techniques may have an effect on reducing phytate levels and those can be broadly categorized by four main techniques: *heating, nixtamalization, decortication, and fermentation.*
- No studies have systematically compared the effect of traditional processing on phytate levels as well as FeBA.

Objectives

- Evaluate the effect of traditional processing techniques for maize (heating, nixtamalization, fermentation and decortication) on phytate and Fe contents, iron solubility, and FeBA.
- Enhance the FeBA of maize foods by modifying the formulation and incorporating LA during processing.
- Evaluate sensory differences between products with or without LA

Results

Table 1. Soluble iron (%) in digested maize foods

Fe Solubility				
	Tort	Arp	Ogi	Por
No fort	-0.7 ± 0.9	6.7 ± 2.6a	14.9 ± 2.4	7.1 ± 4.3
+ LA	18.4 ± 0.5**	26.8 ± 2.0**	Not applicable	24.7 ± 0.5*
+ $FeSO_4$	-0.6 ± 0.2	30.6 ± 0.6	21.2 ± 1.5	28.4 ± 1.5
+ $FeSO_4$ + LA	3.9 ± 0.1**	27.4 ± 2.2	Not applicable	25.6 ± 1.3
+ RedFe	-0.6 ± 0.2	14.6 ± 0.6	13.8 ± 2.0	14.3 ± 0.4
+ RedFe + LA	6.5 ± 0.9**	13.6 ± 1.5	Not applicable	12.7 ± 0.6
Phytate:Iron Molar Ratio				
	Tort	Arp	Ogi	Por
No fort	17.1 ± 1.3	20.7 ± 3.0	21.9 ± 2.6	30.0 ± 6.9
+ fortification	4.9 ± 0.3	5.1 ± 0.6	5.6 ± 0.4	6.8 ± 0.7

-Treatments with stars are significantly different (* p <0.01; ** p <0.001) as determined using Student's t test, n=3-8

Table 2. Triangle Testing for sensory differences in products with or without LA

Sample	# of panelists correctly identified	p value
Arepa	14 / 44	0.831
Tortilla	19 / 44	0.166
Porridge	32 / 43	<0.0001

-p value determined by binomial distribution, $p > 0.05$, no sensory difference

Abbreviations

Processing Treatments	Fortification Treatments	Products	Parameters
Heating - Heat	No fortification - No fort	Porridge - Por	Iron – Fe
Nixtamalization - Nixt	Ferrous sulphate - FeSO4	Tortillas - Tort	Relative bioavailabilty – RBA
Fermentation - Ferm	Reduced iron - RedFe	Arepas - Arp	Iron Bioavailability – FeBA
Decortication – Decort	Lactic acid - LA	Ogi - Ogi	
Uncooked – No Cook			

Methods

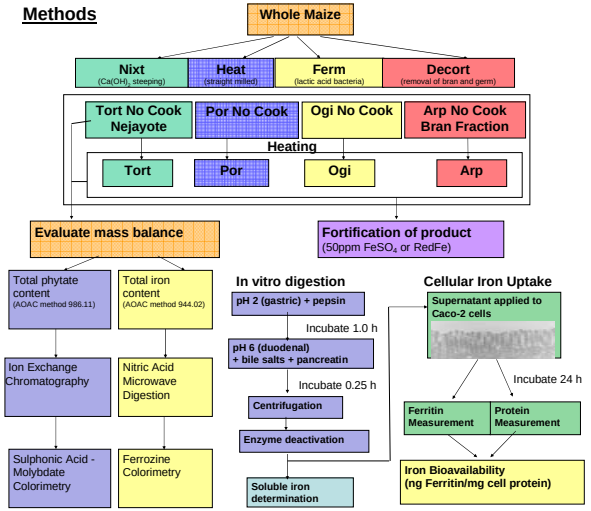
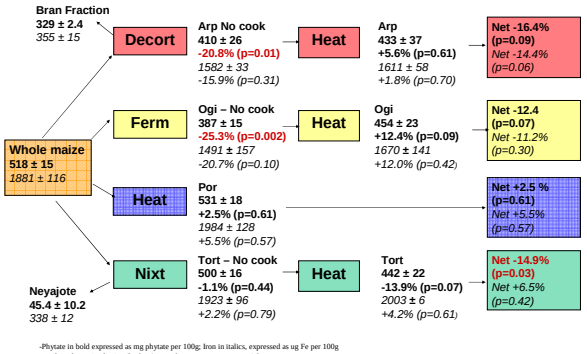
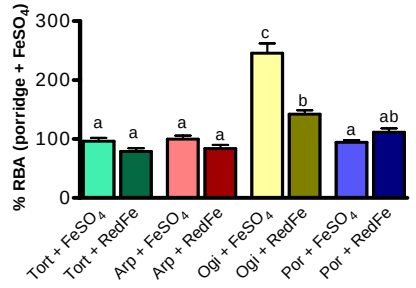


Figure 1. Changes in phytate and iron content during processing.



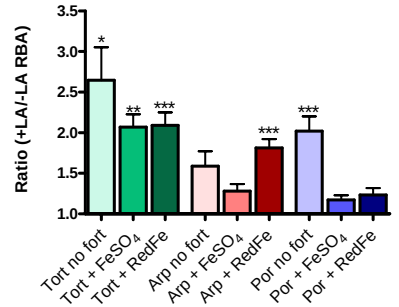
-Phytate in bold expressed as mg phytate per 100g; Iron in italics, expressed as ug Fe per 100g
-p values determined using Student's t test between treatments, n=4-8.

Figure 2. Relative Bioavailability (RBA) for processed and fortified maize food products.



n = 9-14. Columns with similar letters are not significantly different based on ANOVA with Tukey's Multiple Comparison test.. RBA value relative to Por + $FeSO_4$ treatment

Figure 3. Relative Bioavailability (RBA) for processed maize with or without added lactic acid.



Effect of lactic acid was compared by Student's t test for each product. * $p < 0.01$; ** $p < 0.001$; *** $p < 0.0001$; n = 5-14.

Discussion

- Phytate content was significantly reduced by decortication and fermentation, while Fe content was not affected.
- While iron solubility is generally low in maize foods, the solubility of intrinsic Fe is significantly increased with addition of LA, however fortification Fe solubility was not enhanced, except in high pH maize products (tortillas).
- FeBA of fermented maize (ogi) is higher than other treatments when fortified with $FeSO_4$ or RedFe.
- FeBA increased with addition of LA to unfermented products, and is most pronounced in low solubility product (tortilla).
- The higher FeBA of fermented maize may be primarily due to acidification and its effects on iron solubility.
- Tortillas and arepas with 6mg/g added LA were not distinguishable from their unacidified counterparts

Conclusion

Fermentation or lactic acid addition increases iron bioavailability of maize without affecting sensory characteristics in most products and may provide a low cost means of improving bioavailability of maize products.

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