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Research Application Summary

Potent inhibitors of iron bioavailability in germinated maize used for complementary feeding in Tanzania

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Abstract

Plant based foods are the major staples of diets in developing countries including Tanzania. These foods contain high levels of phytates and polyphenols, the potent inhibitors of iron bioavailability. Frequent intake of these foods exposes children to the risk of developing iron deficiency and iron deficiency anemia. The objective of the study was to determine the effects of soaking and germination on reduction of nutrient inhibitors to enhance the availability of iron in maize used for complementary feeding in rural Tanzania. An experimental study design was employed. Maize grains were soaked in distilled water for 24 hours, drained and germinated at 0, 36, 48 and 72 hours then dried and milled to obtain flour. Chemical analysis was carried out using standard methods. For all measures, statistical analysis employed Duncan multiple range test to separate means. On average phytates decreased significantly ($P < 0.05$) with germination time from 39.7 mg/100g at 0 hour to 32.4 mg/100g at 72 hour. Polyphenols increased with germination time. There was a significant ($P < 0.05$) increase at 72 hour germination time for the samples from all locations. Iron content fluctuated with germination time, however a significant ($P < 0.05$) increase was observed at 72 hour. These findings can be utilized to improve the availability of affordable complementary foods used by infants and young children living in resource-poor families.

Key words: Complementary foods, germination, iron, phytates, polyphenols, soaking

Résumé

Les aliments à base de plantes sont les principaux aliments de base des régimes alimentaires dans les pays en développement, y compris la Tanzanie. Ces aliments contiennent des niveaux élevés de phytates et polyphénols, et les inhibiteurs puissants de la biodisponibilité du fer. La consommation fréquente de ces aliments expose les enfants au risque de développer une carence en fer et l'anémie ferriprive. L'objectif de cette étude était de déterminer les effets de trempage et de germination sur la réduction des inhibiteurs de nutriments pour améliorer la disponibilité du fer dans le maïs utilisé dans l'alimentation complémentaire en Tanzanie rurale. Une conception de l'étude expérimentale a été employée. Les grains de maïs ont été trempés dans de l'eau distillée pendant 24 heures, égouttés, et germés pendant 0, 36, 48 et 72 heures, puis séchées et broyées pour obtenir de la farine. L'analyse chimique a été effectuée en utilisant des procédés standards. Pour toutes les mesures, l'analyse statistique a utilisé la méthode Duncan pour la séparation des moyennes. En moyenne, les phytates ont diminué significativement (P < 0,05) avec le temps de germination de 39,7 mg / 100 g à 0 heure à 32,4 mg / 100 g à 72 heure. Les polyphénols ont augmenté avec le temps de germination. Il y avait une augmentation significative (P < 0,05) à 72 heures de germination pour les échantillons venant de tous les endroits. La teneur en fer a fluctué avec le temps de germination, mais une augmentation significative (P < 0,05) a été observée à 72 heures. Ces résultats peuvent être utilisés pour améliorer la disponibilité des aliments complémentaires abordables utilisés par les nourrissons et les jeunes enfants vivant dans des familles pauvres en ressources.

Mot Clés: Les aliments complémentaires, la germination, le fer, les phytates, les polyphénols, le trempage

Background

Complementary foods (CFs) are solids and liquids introduced to a child's diet when milk alone is not sufficient to meet nutritional requirements (Muhimbula and Zacharia, 2010). The CFs are introduced to infants at the age of 6 months as per WHO recommendation (WHO, 2009). Maize is the staple food for most families in many African countries including Tanzania. Maize flour serves as raw material for stiff porridges and weaning gruel (Nuss and Tanumihardjo, 2011). Plant-based complementary foods have been reported by previous researchers to contain high levels of phytates and polyphenols, the potent inhibitors of iron bioavailability (Gibson *et al.,* 2010). Prolonged consumption of maize porridge by infants and young children as their primary food exposes them to high risk of developing iron deficiency (ID) and iron deficiency anemia (IDA) (Hotz and Gibson, 2007). Prevalence of ID is higher in children in developing countries (Diaz, *et al.,* 2003). In Tanzania, it is estimated that 50% of the cases of anemia are due to ID (URT, 2008). Low bioavailability of dietary iron in plant-based CFs is due to inhibitors such as phytic acid and polyphenolic compounds (to mention few) (Gibson *et al.,* 2010). The objective of the present study was to determine the effects of soaking and germination on reduction of nutrient inhibitors to enhance the availability of iron in maize used for complementary feeding in rural Tanzania.

Literature summary

Phytic acid is the storage form of phosphorous in many plant tissues particularly grains and seeds (Frontela, 2008). Phytic acid also known as myo-inositol hexaphosphate or phytate when in the salt form is a naturally occurring compound found in many plant tissues (Egli *et al.,* 2002). The chemical designation of phytic acid is myo-inositol (1, 2, 3, 4, 5, 6) haxakisphosphoric acid (Grainer *et al.,* 2006). Phytic acid is a good chelator of diatomic metals (iron, zinc, magnesium and calcium) hence considered as powerful inhibitor of minerals necessary for good health (Azeke *et al.,* 2010). Chelation of metal ions forms insoluble complexes in the gastrointestinal tract that cannot be absorbed by the body (Gibson *et al.,* 2010). Polyphenols/phenolic compounds are group of natural compounds with phenolic structural features. Polyphenols are the largest group of phytochemicals and are found mainly in plant-based foods (Tsao, 2010). Cereals are major sources of polyphenolic compounds such as anthocyanins. Polyphenols occur in various amounts in plant foods including vegetables, fruits, beverages (coffee, tea) and some cereals and legumes (Hurrell and Egli, 2010). Polyphenols are well known for their inhibitory effect on non-heme iron and hence making it unavailable for absorption in the intestinal tract (Sokrab *et al.,* 2012). According to Hurrell and Egli (2010) polyphenols in cereals and legumes cause inhibitory effect on iron absorption. Iron is an essential mineral as it is needed for a number of highly complex processes such as oxidative metabolism, cellular proliferation, production of red blood cells and it is also part of hemoglobin which transports oxygen throughout the body (Geissler and Singh, 2011).

Although many factors are responsible for iron deficiency and iron deficiency anemia, the main cause of this nutritional problem in developing countries is the poor bioavailability of dietary iron (Hurrell and Egli, 2010). Since accessibility of iron fortified foods by people in rural areas is still low, there is need to promote the use of traditional processing technologies to enhance availability of nutrients in foods used by infants and young children living in resource-poor families.

Study description

Maize grains were collected from five wards in Iringa district, Iringa region, Tanzania. The samples (maize grains) were purchased from the ward selling centers/ware houses. The collected maize grains were packed in bags/sacks and transported to the Food Science Laboratory at Sokoine University of Agriculture (SUA), Morogoro for Laboratory Analysis. Subsquently, maize grains were soaked in distilled water for 24 hours, drained and germinated at 0, 36, 48 and 72 hours then dried and milled to obtain flour. Chemical analysis was carried out using standard methods. Phytates were determined by a modified Wheeler and Ferrel method (1971), Phenolic contents were determined by a method described by Ragazzi and Veronese (Eghdam, 2010), and Iron was determined by a method described by Tee *et al.* (1989). Data were analyzed by SAS 9.1.

Results and Discussion

Phytates

There was a significant ($P< 0.05$) decrease of phytates in soaked and germinated maize from all wards (Table 1). In general, much of the phytates were efficiently removed at 72 h germination time (Table 1). On average phytates decreased significantly ($P< 0.05$)

from 39.7 mg/100g at 0 hour to 32.4 mg/100g at 72 hour. Phytate is water soluble; therefore soaking the grains in water resulted into passive diffusion of water-soluble phytates, which can be removed by decanting the water. Samia *et al.* (2007) and Vadivel *et al.* (2011) revealed that the decrease in the level of phytic acid during soaking may be attributed to leaching out of the acid into water. Therefore soaking and germination can reduce significantly the levels of phytates in maize-based complementary foods hence increasing nutrient bioavailability particularly iron. In the present study phytates were reduced significantly ($P < 0.05$) in soaked and germinated maize from 39.7 mg/100g at 0hour to 32.4 mg/100g at 72 hour.

Phenolic compounds/polyphenols

The phenolic compounds was significantly ($P < 0.05$) increased at 72 h for the maize obtained from all the wards (Table 2). Maize from the KSW and NZW showed significant ($P < 0.05$) decreases in phenolic compounds from 0 to 36 hours and increased slightly at 48 hour (Table 2). Those from LHW and MSW also showed significant ($P < 0.05$) decreases in phenolic compounds from 0 to 36 h germination time. Further the maize obtained from Mseke ward (MSW) produced higher amounts of phenolic compounds (848.17mg/100g) and (1268.38mg/100g) at 48h and 72h, respectively (Table 2).

Table 1: Interactive effect of location and germination on phytates content (mg/100g) of soaked and germinated maize grains.

Location	Germination time (h)				P-value
	0	36	48	72	0.0001
IFW	42.00±1.22[a]	40.60±0.01[b]	39.67±0.45[b]	38.50±0.13[c]	
KSW	41.68±4.54[a]	40.56±4.31[b]	39.04±1.48[b]	27.46±0.49[c]	
LHW	45.28±1.18[a]	41.14±1.63[b]	35.73±2.18[c]	34.55±3.75[d]	
MSW	41.38±6.35[a]	38.06±0.29[b]	37.69±0.02[b]	36.87±0.22[c]	
NZW	27.95±1.65[a]	26.62±0.39[b]	26.28±0.40[b]	24.88±0.87[c]	

Values are means ±SD of duplicate determinations. Means with the same superscripts within the same row are not significantly different ($P < 0.05$). SD Standard deviation.IFW-Ifunda Ward, KSW-Kising'a Ward, LHW-Luhota Ward, MSW-Mseke Ward, NZW- Nzihi Ward

Table 2: Effect of germination on phenolic compound content (mg GAE/100g) of soaked and germinated maize grains

Location	Germination time (h)				SEM	P-value
	0	36	48	72	39.06	0.0001
IFW	143.55[d]	174.52[c]	329.28[b]	789.86[a]		
KSW	178.71[b]	145.40[d]	176.53[c]	827.44[a]		
LHW	155.81[c]	149.06[d]	197.36[b]	839.93[a]		
MSW	174.41[c]	169.26[d]	848.17[b]	1268.38[a]		
NZW	177.43[b]	150.85[d]	163.27[c]	760.51[a]		

Values are means of duplicate determination. Means with the same superscripts within the same row are not significantly different ($P < 0.05$). SEM- Standard error of mean.

The variation in the phenolic compounds between wards might be due to fact that storage conditions, drying methods used by the farmers or households, and stage of maturation differ from place to place. Beneficial function of phenolic compounds has been reported by some studies as anticancer, strong antioxidants, anti-inflammatory anti-allergic, cholesterol lowering and anti-ulcerogenic properties (Tsao, 2010; Yao *et al.,* 2004).

Total iron

Iron content fluctuated with germination time for the maize obtained from all wards (Table 3). However a significant (P< 0.05) increase was observed at 72 hour germination time for all wards (Table 3). This could be due to the hydrolysis of phytates during germination, which enhanced iron solubility.

Table 3: Interactive effect of location and germination on total iron content (mg/100g) of soaked and germinated maize.

Location	Germination time (h)				P-value
	0	36	48	72	0.0001
IFW	1.20 ± 0.15^{b}	1.13 ± 0.01^{c}	1.20 ± 0.4^{b}	1.23 ± 0.7^{a}	
KSW	0.95 ± 0.15^{b}	0.94 ± 0.01^{b}	0.91 ± 0.6^{c}	1.09 ± 0.8^{a}	
LHW	1.23 ± 0.05^{a}	1.11 ± 0.19^{d}	1.14 ± 0.54^{c}	1.18 ± 0.59^{b}	
MSW	1.17 ± 0.05^{c}	1.23 ± 0.1^{b}	1.16 ± 0.83^{c}	1.32 ± 0.54^{a}	
NZW	1.21 ± 0.1^{b}	1.17 ± 0.25^{c}	1.20 ± 0.05^{b}	1.33 ± 0.83^{a}	

Values are means±SD of duplicate determination. Means with the same superscripts within the same row are not significantly different (P< 0.05). SD Standard deviation. IFW-Ifunda Ward, KSW-Kising'a Ward, LHW-Luhota Ward, MSW-Mseke Ward, NZW- Nzihi Ward

It was also observed that the maize obtained from Kising'a ward (KSW) had low iron content (0.91±0.6mg to 1.09±0.8mg) as compared to that obtained from other wards (Table 3). The variation of iron content in the given locations, may be attributed by other factors such as soil and fertilizer, however the mechanism is not well known.

Conclusion

This study has shown that there is a significant decrease of phytates in soaked and germinated maize grains. Such reduction increased availability of iron. On the other hand polyphenol contents increased with germination time which was more significant at 72 hours. Iron content increased significantly at 72 hour germination time. Therefore the findings in this study can be utilized to improve the availability of affordable complementary foods used by infants and young children living in resource-poor families.

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