Indigenous Food Processing Methods that Improve Nutrient Bioavailability in Plant-based Diets of the Kenyan Population: the Example of Zinc

Mary Khakoni Walingo BEd MSc PhD
School of Public Health and Community Development, Maseno University, P.O Box 333, Maseno, Kenya
E-mail: marywalingo@yahoo.com & maelo@maseno.ac.com

ABSTRACT

Most Kenyan diets are composed of cereals and legumes that have a high content of zinc inhibitors, whose levels may be reduced through appropriate food processing technologies at the household level. Indigenous food processing methods like soaking, germination, drying, fermentation, boiling, and roasting, and diet combinations usually reduce the levels of zinc antagonists in the plant diets, thus increasing zinc absorption and bioavailability. These methods are used in combination to both enhance organoleptic properties of food, increasing acceptability and also promoting complementation of nutrients. There are food combination patterns that enhance nutrient bioavailability and complementation that were known to most traditional households and are quickly being forgotten due to lack of proper knowledge transfer. There is a need for profiling the indigenous knowledge in food processing, preparation and diet combinations to identify processes that promote nutrient content and bioavailability for improved health and nutrient situation of rural populations whose diets are basically plant based. The identification of suitable sources of absorbable zinc and possible suitable dietary combinations can contribute towards the reduction of zinc deficiency. This chapter discusses the indigenous food processing methods that enhance zinc absorption and bioavailability of zinc in local dietary combinations that could reduce zinc deficiency.

INTRODUCTION

The genetic make-up of a plant or animal, the type of soils in which plants are grown or in which animals subsist, the type of fertilizer used, and the agro-ecological conditions of the area will determine the nutrient content of a plant or animal food material. At the pre-and post-harvest handling level the state of maturity at harvest, food processing and preparation methods, packaging, and storage conditions determine the nutrient content of a food. The effect of processing on the nutrient content of food depends on the sensitivity of the nutrient to various conditions prevailing during the processing, some of which include pH, light and oxygen. Sensitivity of nutrients to processing methods vary with the type of nutrient, with some nutrients increasing and others decreasing with different processing methods. The concentration of the nutrients in the food and its characteristics determine the level of nutrient retention. Most processes are heat-related and improve the digestibility of foods, making nutrients more available by sometimes inactivating the anti-nutrients found in food and thus increasing their bioavailability. This chapter discusses indigenous food processing methods and their effect on nutrients, with emphasis on zinc nutrition.

PROCESSING AND ZINC RETENTION

In many low-income countries diets are primarily composed of cereals and legumes which contain phytate (myo-inositol hexaphosphate), a compound known to inhibit zinc absorption [Calhoun et al., 1974]. These diets contain few animal-sourced foods which are rich in zinc and are free of phytates [Wallwork & Sandstead, 1990]. Dietary combinations of foods that have high levels of phytates are consumed mostly by rural populations and may have complexities regarding bioavailability and utilization of zinc. This calls for serious consideration of the assessment of the indigenous food preparation methods and diet combinations with implications
Zinc inhibitors like phytates and fiber are present in higher amounts in plant foods, especially cereals and legumes, and influence zinc absorption. Although phytates have been singled out as the most potent dietary inhibitor of zinc bioavailability [Herzberg et al., 1990; Saha et al., 1994], other known inhibitors include oxalate, fiber, EDTA, and polyphenols such as tannins [Larsson et al., 1996].

Most Kenyan diets are composed of cereals and legumes that have a high content of zinc inhibitors whose levels may be reduced through appropriate food processing technologies adopted by households. Maize as a cereal grain is a common staple in most Kenyan diets, and has very high phytate content [Fordyce et al., 1987; Gibson, 1994]. When these staples are fermented, phytases are produced which break down phytates increasing the amount of available zinc. Figures 1-4 show some of the cereals, nuts and legumes consumed in local diets.

Figure 1. A Variety of Sorghum in the Market

Figure 2. A variety of beans sold in the market
Animal sources of food provide higher levels of zinc than plant foods, which are also high in phytic acid and other constituents that reduce the bioavailability of dietary zinc. Consumption of beef protein increases zinc absorption [Sadstead, 1991]. Plant foods that are rich in zinc include legumes, nuts, seeds and whole grains but they are also high in phytic acid, an inhibitor of zinc bioavailability. Unrefined cereal grains, classified as low-zinc bioavailability diets, have a high phytate-zinc ratio, a high level of energy in these high-phytate foods and low amounts of proteins [Etcheverry et al., 2006] and compose the daily diets of many people.

**ZINC ABSORPTION AND BIOAVAILABILITY**

The balance between absorption facilitators and inhibitors, and the individual’s zinc nutrition status determines the bioavailability of zinc from individual foods or from a meal [Cheryan, 1990; Cousins 1996; Kelsay, 1988]. Promoters of zinc absorption include amino acids such as histidine and cysteine [Kies et al., 1983]. Diets have been classified into high, medium and low-zinc availability based on the absorption of energy from animal sources, the phytate-zinc molar ratio, the amounts of inorganic calcium salts and the methodologies of processing of cereals. Phytate-zinc molar ratio is used to estimate the likely absorption of zinc from a mixed diet. Diets with a phytate/zinc molar ratio greater than 15 have relatively low zinc bioavailability, those with phytate/zinc molar ratio between 5 and 15 have medium zinc bioavailability and those with a phytate/zinc molar ratio less than 5 have relatively good zinc bioavailability [Sandstrom, 1997]. Phytate/zinc molar ratio and calcium/phytate/zinc molar ratios play a major role in inhibiting zinc absorption such that zinc absorption is typically less than 15% in high phytate meals [WHO, 1996].

Several studies have reported on the fractional and net absorption of zinc under different dietary conditions [Sandstrom, 1980; Sandstrom & Cederblad, 1987; Flanagan, 1998]. Although fractional absorption decreases with higher intakes of zinc, the net absorption was greater when total consumption of zinc was increased. This increase was less dramatic in foods that had low phytate levels than in foods with higher phytate levels. Fractional absorption of zinc was further reduced when other minerals were included in the aqueous supplement. Absorption of zinc tripled when white bread was enriched with 3.1 mg zinc chloride to produce a total meal content of 3.5 mg zinc, but not when sufficient zinc was added to the same amount of phytate-containing wholemeal bread to produce a similar final zinc content. When meals containing chicken meat were enriched with 3.3 mg zinc per meal, fractional absorption fell by only a quarter and net absorption increased by 30-50%. Incubation of dough with yeast for 16 hours before baking reduced the phytate/zinc molar ratio of bread containing wheat bran from 17 to 4 and doubled the absorption of zinc. Zinc was absorbed most efficiently from aqueous solutions and from meals...
containing animal products. Absorption was considerably less from phytate-containing meals. Fortification of foods with exogenous zinc generally produced a small reduction in fractional absorption, but a positive impact on net absorption. However, fortification of foods with a high phytate/zinc molar ratio had only a small effect on net zinc absorption [Sandstrom, 1987].

High fiber foods are often associated with diminished zinc absorption. However, refined foods that are low in fiber have substantially lower levels of zinc, so that while relative zinc absorption from low fiber foods is improved, the overall zinc absorption is greater from high fiber foods. For example, almost 40% of the zinc in white bread (refined) is absorbed, while only 17% of the zinc in whole grain bread is absorbed [Kannan, www.vegetariannutrition.net/articles/iron-zinc-Bioavailability-in-vegetarian-N.]. However, the total amount of zinc absorbed from whole grain bread is almost 50% more than that absorbed from white bread because whole grain bread contains more than three times the level of zinc found in white bread [Sandstrom, 1980]. These technologies are unavailable to the local communities.

INDIGENOUS KNOWLEDGE IN FOOD PROCESSING

Increased food production, availability of food supply and access are crucial to achieving major nutritional improvements. Wide application of proper technologies and approaches, and development of new concepts that should be transmitted to households and stakeholders, are necessary for promotion of dietary interventions in zinc deficiency states. Transfer of indigenous knowledge and skill in food processing, presentation and meal combinations from the older population to the younger, and building on their knowledge for production, processing and preservation of food is necessary for the control of zinc deficiency. There have been notable changes in food selection patterns and traditional methods for preparing and processing of indigenous foods with implications for nutrient retention and bioavailability. The traditional methods are a cheaper, acceptable, economically feasible and sustainable means for improved zinc status.

Use of traditional methods requires an understanding of the local dietary patterns, food beliefs, and food consumption patterns of the population to consider the general dietary compositions and combinations, and interactions between the diverse food constituents that antagonize zinc absorption and bioavailability. Such development must consider the cost of foods in terms of accessibility by the general population. Challenges in changing dietary habits, attitudes and practices must be appreciated. There are a range of dietary diversification and modification strategies that increase zinc content and bioavailability of plant-derived foods. Dietary approaches are based on promotion of increased consumption of zinc-rich diets and reduction in the intake of inhibitors of zinc absorption. Strategies to increase the zinc content of the diet are necessary in Kenya where diets are based on cereal staples.

Dietary diversification includes consumption of zinc rich foods, animal foods and local plants that have high zinc content and indigenous insects. However, zinc and phytate contents of local Kenyan plant foods have not been clearly assessed to identify suitable sources of absorbable zinc. Indigenous food processing methods and diet combinations usually reduce the levels of anti-nutrients in the plant diets, thus increasing nutrient bioavailability. Such methods include soaking, drying, fermentation, boiling and roasting. These methods are used in combination to both enhance organoleptic properties of food (thus increasing acceptability) and also promote nutrient complementation. Soaking of cereals and legumes has been used to reduce the phytate content of plant foods. For example, sprouting of beans can dephytinize food products and thus improve zinc bioavailability and also increase the vitamin C content [Yadav, 1994]. Drying has been used to preserve meat, fish, cereals, roots and tubers, fruits and green leafy vegetables. Meat and fish are dried over smoke which adds flavor besides increasing shelf life. Such dried fish has readily available zinc [Gibson and Hotz, 2001]. Amino-acid and cystein-containing peptides are released during digestion of cellular animal proteins, enhancing zinc absorption.

Soaking and germination have been used to process foods, reducing levels of anti-nutrients and increasing the nutrient quality of foods. Soaking oats followed by sprouting the oats reduces
phytate content and doubles the amount of absorbed zinc in comparison with untreated oats. Zinc content is improved when leavened products are used [Gibson, 1994]. Sorghum, for example, is soaked, germinated and eaten or ground to flour and added to ungerminated cereal flour, reducing the cereal viscosity and activating endogenous cereal phytases that break down phytate into lower inositol phosphates. Soaking and germination enhance enzymic hydrolysis of phytates. Cereal porridges have been prepared by combining germination and fermentation to improve flavor, digestibility of the products and increase the content of vitamin and minerals. The initial enzymic changes which precede germination result in both transfer and increase of the B-complex vitamins. It also breaks down the higher carbohydrates and other storage molecules such as calcium, magnesium and phytate [Akpapunam & Sefa-Dedeh, 1997].

Fermentation and drying have been used in combination. For example, cassava roots are peeled and grated into pulp, put into cloth bags and set in the sun to drain and ferment. Weights are added onto the bags to press out the moisture for 3-4 days. There is a degree of fermentation and souring. After complete draining, the material is sieved and put in shallow metal pots over a wood fire and is continuously stirred and turned, beating humpy sections to disintegrate them. The other example is maize flour which is soaked as a thick paste for 3-4 days at ambient temperatures to promote fermentation. The paste is roasted over low heat until golden-brown. It is then sun-dried to reduce the moisture content and to increase the peeping quality. Fermented products are low in soluble fiber and high in insoluble fiber. Organic acids such as acetic, lactic, citric, formic and butyric acids produced during fermentation potentiate zinc absorption by forming ligands with zinc. Microbial fermentation enhances zinc bioavailability through hydrolysis induced by microbial phytase enzymes. Reduction of phytates in the diet could also favor enhanced absorption of other minerals like calcium and iron. Fermentation reduces the phytate content by releasing endogenous phytases and incorporates yeast during the process [Kavas & Sedef, 1991].

**Figure 5. Germinating Soya Beans**

**Figure 6. Germinating Sorghum in the Market**
Figure 7. Flours from two sorghum varieties

Figure 8. Flours from different cassava varieties

Figure 9. Dried cassava varieties
IMPLICATIONS FOR RESEARCH AND PRACTICE

Diets in Kenya and other low-income countries are composed primarily of cereals and legumes that are high in phytates that inhibit zinc absorption. The high level of zinc inhibitors can be reduced through appropriate traditional food processing technologies adopted in households. The zinc and phytate content of local Kenyan plant foods has not been clearly assessed so as to identify suitable sources of absorbable zinc and possible suitable dietary combinations that can contribute towards the reduction of zinc deficiency. The adoption of non-Kenyan cultures, changing tastes, diets and lifestyles have negatively influenced the consumption of indigenous foods and contributed to the loss of indigenous knowledge and skills in food preparation, food combinations of nutritional value and food conservation. Time has also become a major constraint in food preparation with populations resorting to convenience and easy to prepare foods that are generally of low nutritional quality, monotonous and lack variety. Social networks have changed the traditional mode of knowledge transmission. There is also failure of knowledge transmission from generation to generation because of attitude formation relegating these methods into categories of primitive technologies. There is potential for creating awareness of the value of indigenous foods, and preparation and conservation methods. Recipe development offers the potential for increased product variety for the changing tastes and for improved marketability of the products. Indigenous food processing methods and diet combinations usually reduce the levels of zinc antagonists in the plant diets, thus increasing zinc bioavailability. Transfer of indigenous knowledge in food processing, preparation and diet combinations to communities needs to be profiled to identify processes that promote nutrient content and bioavailability for improved health and nutrient situation of rural populations whose diets are basically plant-based with high phytic contents that reduce the bioavailability of zinc. There is need for extensive study of dietary patterns of a population to initiate changes that seek to enhance nutrient content of food and bioavailability.

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