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Abstract

In Africa, indigenous vegetables are a common food source and rich source of micronutrients such as carotenoids, vitamin C, calcium and iron. However, food preparation and processing operations affect contents and bioavailability of micronutrients in vegetables. Several studies have been carried out to investigate the influence of local food preparation and processing methods on iron and carotenoid accessibility of vegetables including African indigenous vegetables (AIV) such as African nightshade (*Solanum scabrum*), amaranth (*Amaranthus blitum*), slenderleaf (*Crotalaria ochroleuca*), sweetpotato leaves (*Ipomea batata*) and cowpea leaves (*Vigna unguiculata*). Different experiments showed that cooking vegetable mixtures from either two of these AIV together increased iron accessibility when compared to cooking one vegetable. Fried recipes had significantly higher iron content compared to boiled ones and raw vegetables. Improved recipe formulation may increase AIV acceptability and consumption and thus increase iron intake. An additional study on cooking and drying effects on carotenoid and flavonoid retention in two nightshade species (*Solanum scabrum* and *Solanum villosum*), showed that oven drying retained carotenoids while drying in direct sun and under shade cause a significant decrease in the carotenoid contents in both nightshade species. Cooking (boiling in water for 10 min) did not affect the levels of lutein and β-carotene but caused total loss of violaxanthin and neoxanthin. Cooking also reduced flavonoid content while oven drying, drying in direct sun and under shade did not affect the flavonoid content of *Solanum scabrum* sp. In vitro simulated gastro intestinal digestion caused a loss of approximately 80% in the carotenoid contents of the two nightshade species, and also revealed that the accessibilities of iron, carotenoids and flavonoids are improved more in the cooked leafy vegetables than in the raw, oven dried and sun dried samples. Another study investigated feasible food preparation methods to increase carotenoid retention and iron bioavailability of leafy vegetable dishes traditionally prepared by Tanzanian households. Results showed that modified traditional preparation methods with appropriate ingredients improve the retention of lutein and β-carotene; and iron accessibility in sweetpotato leaves. Specific cooking, preparation and preservation practices of AIV that are compatible with local experience can be encouraged as an alternative or adjunct to other methods of increasing the availability of micronutrients in foods.

INTRODUCTION

Micronutrients deficiency, also known as hidden hunger, is a public health problem that is affecting a huge proportion of human population especially in developing countries. Most physiological disorders, poor health, reduced productivity, reduced intellectual potential and increased mortality are associated with it (Maberly et al., 1994; Friis, 2005). Vitamin A and iron are among the two nutrient deficiencies of public interest as they affect over 2 billion people worldwide. It is estimated that 25% of preschool children and 18% of women are vitamin A deficient; whereas 37% of the world's total population is iron deficient (Borwankar et al., 2007). Data for developing countries show that about 40% of the population suffers from iron deficiency and 40% of children are growing up with insufficient vitamin A (UNICEF, 2004). In Tanzania, 65% of children under 5 years of age suffer from iron deficiency while 37% are estimated to have sub-clinical vitamin A deficiencies (UNICEF, 2004). The prevailing situation calls for urgent and effective measures to overcome micronutrient deficiency, which is precondition for ensuring rapid and appropriate development.

Strategies to combat micronutrient deficiencies include fortification, biofortification, supplementation and other food based approaches. Fortification involves addition of nutrients in foods and other consumable products. However, fortification has been associated with increased price of fortified foods and difficulties in enforcement of fortification regulations (FAO, 1997). Biofortification is the process of breeding crops that are richer in nutrients. It has the advantages of targeting rural areas, being cost-effective and it is sustainable. Supplementation provides nutrients other than those taken in the normal diets (SCN, 1993). However, the routine provision of single micronutrient supplementation has not been effective in combating the coexisting micronutrient deficiencies in developing countries (Gibson, 2004). Supplements and fortified foods are also often not widely available in rural areas. Among all the strategies, food based strategies seem to be a sustainable solution to micronutrients deficiencies especially in developing countries (WHO, 2001; FAO/WHO, 2003). The strategies involve intake of micronutrients rich foods such as fruits and vegetables and optimizing processing methods (Tontisirin et al., 2002).

African indigenous vegetables (AIV) such as nightshade (*Solanum scabrum* and *Solanum villosum*), amaranth (*Amaranthus blitum*), cowpea (*Vigna unguiculata*), jute mallow (*Corchorus olitorius*), and spiderplant (*Cleome gynandra*), play a highly significant role in the food security of underprivileged both in rural and urban settings in Africa. They act as valuable sources of micronutrients, fiber, and bioactive compounds such as iron, carotenoids and antioxidants in the diets of most communities. They are sometimes better nutritional sources than the modern vegetables (Sato et al., 2002; Rensburg et al., 2004; Yang and Keding, 2009). They also require less capital investments, less-labor intensive management and are better adapted to local conditions. A study in Tanzania showed that most of the indigenous vegetables were preferred by 50 to 90% of the people surveyed (Lyimo et al., 2003; Keding et al., 2008). Since the vegetables are affordable they provide a sustainable source of micronutrients to rural and urban families (Sato et al., 2002).

In spite of the proven potential of indigenous vegetables in alleviating micronutrient deficiency in sub-Saharan Africa, they are often neglected in research (Rensburg et al., 2004; Madisa and Tshamekang, 2006). A number of studies in Africa (Mwajumwa et al., 1991; Raja et al., 1997; Kinabo et al., 2004) have focused on nutritive value of the uncooked vegetables (Msuya et al., 2008). Therefore, information about nutrients in cooked vegetables is insufficient (Marcela and Rodriguez-Amaya, 2004). Studies on traditional vegetable processing methods in Tanzania found significant nutrient losses (Mosha et al., 1997; Lyimo et al., 2003; Mulokozi et al., 2004; Msuya et al., 2008). Other studies elsewhere reported changes in physical and chemical composition in vegetables due to cooking and other processing methods (Severi et al., 1998; Reddy and Love, 1999; Turkmen et al., 2005).

Indigenous vegetables play an important role in food security of most African populations in both rural and urban settings. Although the consumption and use of AIV are still rooted in the practices and knowledge systems of Africa's rural people, the current neglect and loss of processing knowledge may soon translate into disuse and eventual loss of these vital nutritional and economic resources. AIV are a valuable source of nutrition in rural areas and they contribute substantially to protein, mineral and vitamin intake. They are compatible in use with starchy staples and represent a cheap but quality nutrition to the poor sector of the population in both urban and rural areas where malnutrition is widespread (Maundu, 1997; Weinberger and Msuya, 2004). AIV can also play a significant role in addressing three major factors of low income, malnutrition and loss of biodiversity that greatly affect the quality of life of resource-poor households in Africa. AIV can be used as cash crops in peri-urban systems, source of new crops, source of vegetables for daily sustenance in home gardens; and as source of variation for diversification of production systems and diet. However, this has been hindered by lack of variety in recipe formulation in AIV.

HIGH IRON RECIPES

AIV production can compensate for low vegetable supply during the off-season, potentially helping to alleviate nutrition deficiency during this period (Engle and Altoveros, 2000). While most AIV are nutritious if well cooked, surveys carried out showed that preparation and cooking procedures used in households could lead to a decrease of the nutritive value of cooked vegetables (Waudo et al., 2007; Ngegba, 2007). This therefore emphasizes the need to develop recipes so that people become informed on the best methods of food preparation, which can help minimize nutrient loss and at the same time increase acceptability and thus increase consumption.

Formulation of high iron recipes from AIV could enhance the acceptability and consumption of iron rich indigenous vegetables that can complement insufficient iron supply of current exotic vegetable consumption. It will also help eliminate economic implications of anemia in terms of reduced work capacity and food insecurity, which create the vicious cycle of malnutrition. Studies on recipe formulation in AIV encourage consumption, which could lead to the AIV being used more as a source of vegetables for daily sustenance of home gardens, and as a source of diet diversification and production systems; which could result in nutrient and food security. These vegetables are also seasonal and recipe formulation and development of vegetable products promises availability of these vegetables throughout the year, which will also help reduce wastage.

A study carried out in Kenya has shown a positive correlation between taste and appearance. Demographic factors such as age and sex, as well as whether the vegetables are cooked as a single vegetable or in combinations do not have any effect on vegetable acceptability. When raw, boiled and fried indigenous vegetables in different combinations were analysed for vitamin C, iron and copper content, it showed increased or reduced accessibility when nutrients are consumed simultaneously. For example a combination of nightshade and cowpea in a recipe increases carotenoids and vitamin C content of the cowpea dish, which is higher than the quantity in single vegetables of nightshade and cowpea. On the other hand a combination of nightshade and sunhemp reduces vitamin C content compared to single combinations and also the rest of the vegetable combinations (Habwe, 2008). When selected AIV were screened for iron content in raw, boiled and fried form, results showed that cooking in fried form significantly increases iron accessibilty of AIV (Habwe et al., 2009). A combination of amaranth and slenderleaf significantly increases iron content while a combination of nightshade and slenderleaf reduces iron content compared to the rest of the vegetable combinations (Habwe et al., 2009). Additionally, cooking in frying form significantly increases copper content of AIV when compared to boiled and raw vegetables. There is no effect on both iron and copper contents when the AIV are cooked as single vegetables or as vegetable combinations (Habwe et al., 2009; Habwe, 2008). In general, to minimize nutrient loss such as vitamin C, copper and iron, frying is the best cooking method.

Dietary change programmes may be more suitable at the family and community levels where AIV are locally available. The change can be accelerated with the availability of nutrient composition data and recipes that show how well to prepare these vegetables so as to ensure minimum loss of nutrients. Availability of these recipes can encourage individuals to consume more nutrient rich AIV.

TRADITIONAL AND MODIFIED PREPARATION METHODS

Most researchers have concentrated on the production aspects of AIV yet lack of recipe formulation and information may contribute to low consumption. These vegetables are also seasonal and recipe development can make available these vegetables throughout the year by helping reduce wastage and increase diet diversification. The increased availability may contribute to nutrient and food security. Food processing has advantages of preserving food and nutrients, tasteful and shelf-stable or better digestibility. It plays a role in increasing digestibility and improving food flavour or quality by destruction of oxidative enzymatic reactions and anti-nutrient components.

AIV constitute part of the traditional legume and cereal based diets and provide dietary carotenoids and iron. However, the legume and cereal based diets are characterized by a high level of nutrient inhibitors such as phytic acid, which reduces the bioavailability of minerals (Ruel, 2001). The contents and bioavailability of some key micronutrients in foods can be enhanced by right food combinations and appropriate food processing methods (Gibson, 2007; Tontisirin et al., 2002).

Indigenous vegetables were widely consumed in Tanzania before exotic species were introduced. The vegetables are more available and consumed in rural areas where exotic species are limited due to high cost and other factors (Lyimo et al., 1991). Households consume vegetables on the basis of taste, availability and affordability (Sato et al., 2002). Most indigenous vegetables are available during the rainy season. They are cultivated in farms, gathered from the wild or grown in home gardens (Keller et al., 2005). In semi-arid areas, where their availability is seasonal, they are dried traditionally and preserved for consumption during dry season (Mosha et al., 1995; Keller, 2004; Mulokozi et al., 2004).

Vegetables in Tanzania are prepared in different ways and with varying cooking methods. Different ingredients are added at varying proportions and therefore it is difficult to obtain standard recipes from the communities (Weinberger and Msuya, 2004). Hence, there is a gap in knowledge regarding carotenoids and iron bioavailability of vegetables under varying cooking methods and the enhancement of these micronutrients. A study has been carried out to investigate feasible food preparation methods to increase carotenoid retention and iron accessibility in leafy vegetable dishes traditionally prepared by rural households in Tanzania (Ngegba, 2007). The study was carried out to generate information that could help guide households in identifying and utilizing indigenous vegetable recipes that are of high nutritional quality, locally available, low cost, and could ultimately help in improving their food security and nutritional status.

The study of Ngegba (2007) and Ngegba et al. (2008) showed that the five most cooked vegetables in Kongwa, Singida and Arumeru districts in Tanzania are amaranth, jute mallow, sweet potato leaves, nightshade and African eggplant. Boiling, stir-frying and open-sun drying are some of the most used methods for cooking and preservation but the preferred method in each district is crop specific (Ngegba, 2007). Improved modified food preparation methods have shown to be better than traditional methods in terms of nutrient retention. Traditional preparation methods retain the carotenoids in a range of only 16-70%, whereas modified methods retain carotenoids in a range of 60-116%. On the other hand, iron accessibility was also improved when vegetables are prepared by modified methods. Pro-long cooking and reheating of cooked indigenous vegetables are mostly responsible for significant reduction of carotenoid retention and iron accessibility in dishes prepared by traditional methods (Ngegba, 2007; Ngegba et al., 2008).

Amongst the modified preparation methods, the use of oil in combination with tomato and lemon helps to improve the lutein, β-carotene retention and iron accessibility in sweet potato leaf dishes. Additionally, vegetable recipes that include soybean as ingredient increase iron accessibility to a comparable level with dishes cooked with oil, probably due to the presence of oil in the soybean (Ngegba, 2007; Ngegba et al., 2008).

It is recommended that improved preparation methods such as boiling for a short time, avoiding coiling and draining vegetables in the sun, washing before cutting and retaining of boiled stocks or soup are highly recommended as best practices for preparation and processing of leafy vegetables. Oven-drying with 50°C is also recommended as a better way of preserving nutrients in vegetables than solar drying. However, availability of ovens is not practically feasible, especially in rural settings where there is no electricity and thus indirect sun-drying methods should be used such as solar cabinet dryers and blanching prior to drying (Ngegba, 2007; Ngegba et al., 2008).

FOOD PREPARATION PROCESSES AND IN VITRO GASTRO-INTESTINAL DIGESTION

Food-derived flavonoids and carotenoids have been reported to play a significant role in health maintenance and prevention of disease (Milner, 1999; Yang et al., 2007, 2008). Some reports have documented the losses of nutrients from vegetables during drying (Yadav and Sehgal, 1997) and cooking (Kachik et al., 1992). Sun-drying in direct sunshine or under shade are the common practices used in most parts of Africa to preserve vegetables for dry season consumption (Lyimo et al., 1991). However, food preparation and preservation techniques may affect significantly the concentration and availability of minerals, vitamins and other essential compounds contained in food. Studies have been undertaken to determine the effects of food processing methods such as cooking, sun-drying and oven-drying on carotenoids and phenolic antioxidants of nightshades (Koskei, 2006). Additional studies on in vitro digestion have also been undertaken to determine the bioavailability and/or accessibility of iron, carotenoids and phenolic antioxidants of nightshade leafy vegetables (Koskei, 2006).

Results have shown that cooking, oven drying, drying in direct sunshine and drying under shade have significant effects on the concentrations of carotenoids and flavonoids of two nighshade species *Solanum scabrum* and *Solanum villosum*. Cooking has little effects on β-carotene and lutein contents but leads to total loss of violaxanthin and neoxanthin contents in both species. Oven drying has little effect on carotenoid content of leafy vegetables such as nighshade but drying in direct sunshine and under shade significantly reduce the levels of carotenoids in nightshade (Koskei, 2006).

Different species respond differently to processing methods and it has been shown that in nightshade, cooking, oven drying, drying in direct sunshine and drying under shade have little effects on the flavonoid content of *Solanum scabrum* but affect the flavonoid content of *Solanum villosum* species (Koskei, 2006). In vitro gastro-intestinal digestion also shows that dialysability of iron and bioaccessibility of carotenoids and flavonoids are improved more in the cooked leafy vegetables than oven dried and sun dried samples. However, the concentrations of iron, carotenoids and flavonoids were higher in *Solanum scabrum* than in *Solanum villosum* while the bioaccessibility of these substances occur more in *Solanum villosum* than in *Solanum scabrum* species (Koskei, 2006).

CONCLUSION

The best practices for vegetable preparation methods that preserve micronutrients should involve: short cooking times, adding vegetables to boiling water rather than cold water before heating, covering of vegetables while cooking, boiling the vegetables in just enough amount of water, and boiling before frying rather than intensive frying. Additionally, modified preparation methods with enhancing ingredients provide better results in improving iron bioavailability in vegetables than traditional preparation methods. Drying in direct sunshine and drying under shade cause greater losses of flavonoids and carotenoids from the leafy vegetables although the effect varies by species.

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