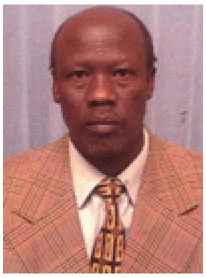
AJFAND ONLINE
African Journal of Food, Agriculture, Nutrition and Development
Scholarly, Peer Reviewed
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

ROLE OF ZINC IN HUMAN HEALTH WITH REFERENCE TO AFRICAN ELDERLY: A REVIEW

Lokuruka MNI[1*]



Michael Lokuruka

[*]Corresponding author email: mlokuruka@gmail.com

[1]Associate Professor of Food Science, Department of Food Science and Nutrition, Karatina University College, P.O. Box 1957-10101, Karatina, Kenya

AJFAND ONLINE African Journal of Food, Agriculture, Nutrition and Development
Scholarly, Peer Reviewed
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

ABSTRACT

This review of the literature was conducted to assess dietary zinc intake among the African elderly, discuss the potential impact of current levels of zinc intake on their health, and to recommend strategies for improving their dietary zinc intake. As zinc plays an ubiquitous role in human metabolism, determination of its dietary intake among African elderly is important from a health standpoint, if the consequences of widely reported deficiency are to be mitigated. Animal meats and seafood are rich sources of zinc, with nuts and legumes being relatively good plant sources. Zinc bioavailability is relatively higher in animal foods due to absence of inhibitors of zinc absorption and the presence of cysteine and methionine, which improve its absorption. Zinc in plant-based foods is less bioavailable for human metabolism due to presence of chelators, phytates and dietary fibre, which inhibit absorption. Individuals at the greatest risk of zinc deficiency include infants and children, pregnant and lactating women, patients being fed intravenously, malnourished individuals including those with protein-energy malnutrition and anorexia nervosa; others are individuals with chronic or persistent diarrhoea, malabsorption syndromes, those with alcoholic liver disease, sickle cell anemia, strict vegetarians, and the elderly aged 60 years and over. A reduced capacity to absorb zinc, increases the likelihood of disease states that may adversely alter zinc utilization, and increased use of drugs that increase zinc excretion, may all contribute to increased risk of mild to moderate zinc deficiency in the elderly. Also, in situations of diminished access to adequate and balanced diets, health care and good sanitation, the likelihood of developing mild to moderate zinc deficiency is high among poor African elderly. Due to the consequences of impaired immune system function in zinc deficiency in the elderly, it is critical to maintain an adequate zinc intake by this group. Despite mild zinc deficiency being unlikely to lead to severe zinc deficiency in individuals without a genetic disorder, zinc malabsorption or conditions of increased zinc loss such as severe burns can also result in mild to severe zinc deficiency. Diets for poor African children, pregnant and lactating women, and the elderly, are deficient in zinc. This is mainly due to low food intake, relatively lower intake of animal foods and high phytate and fibre content of the staple plant-based foods. Fortification of staples and inclusion of inexpensive and available animal protein sources, in plant-based diets for the elderly can increase their dietary zinc intake.

Key words: Zinc, diets, health, Africa, elderly

Published by African Scholarly Science Communications Trust
Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

AJFAND ONLINE Scholarly, Peer Reviewed
African Journal of Food, Agriculture, Nutrition and Development
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

INTRODUCTION

Zinc is an important micronutrient in human nutrition, health and disease states. Despite being until recently one of the neglected trace elements, its critical role in human metabolism is quickly gaining prominence. However, in Africa, its central role in human metabolism is only beginning to be recognized. This review of the available literature is intended to begin to fill this gap in awareness and provide current knowledge with respect to zinc status in African diets and health, and, more so in the diets of the African elderly.

Being an ubiquitous micronutrient in human metabolism, zinc is an essential component of at least one enzyme in every enzyme classification [1]. It is a major component of zinc metallo-enzymes, and plays a central role in gene expression, cellular growth and differentiation [2]. Due to its ubiquity and versatility in subcellular metabolism, zinc deficiency may result in generalized impairment of many metabolic functions [3]. Its importance in cellular growth and differentiation [4], alerts us to the special vulnerability to an inadequate supply of zinc of the rapidly growing embryo, foetus, infant, child or the patient mounting an immune response or requiring tissue repair [5]. In addition to the important roles it plays in growth and development [6], it also has functions related to the immune response [7, 8], neurological function [6] and reproduction [2].

At the cellular level, its functions can be divided into catalytic, structural and regulatory [1, 9]. Zinc guards cell membranes against oxidative damage, which can impair their function [9], and plays a role in hormone regulation and release, specifically of the pituitary growth hormone (GH) and insulin-like growth factor (IGF-1) [10]. As zinc plays a role in gene-directed cell death (apoptosis) [11], it influences growth and development, as well as a number of chronic diseases [12]. It plays a role in the storage, release and function of insulin [13]. Feeding rats with zinc-deficient diets resulted in greater IGF-1 serum concentration as well as impaired glucose sensitivity. These observations were postulated to be related to impaired serum leptin concentration and the insulin signaling pathway [13]. Therefore, long-term suboptimal zinc status may induce abnormal glucose intolerance and insulin release and function impairment. Due to the important role of zinc in protein formation in the body, it is involved in wound healing, and the general growth and maintenance of all body tissues through its involvement in nucleic acid metabolism, DNA and RNA metabolism [14]. Its involvement in most fundamental metabolic activities probably accounts for the essentiality of zinc for all forms of life.

Zinc absorption is concentration-dependent and occurs throughout the small intestine. Zinc absorption from solid diets is less efficient and varies with zinc content and diet composition [15]. This is related to the content, nature and chemical form of dietary constituents that either enhance or inhibit absorption of zinc.

It has been shown that the body has no zinc stores in the conventional sense because in conditions of bone resorption and tissue catabolism, it is released and may be re-utilized to some extent [16]. As zinc is located almost evenly throughout the human

Published by African Scholarly Science Communications Trust
Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

body, as a component of hundreds of metallo-proteins or zinc binding proteins and nucleic acid, it is not easily detectable; this, therefore, presents a challenge in the detection and diagnosis of zinc deficiency by estimating zinc concentration in plasma or serum and other tissues [17]. However, on a community basis, reduced plasma levels are reported to be a fairly reliable marker for zinc-responsive growth reductions [18]. Although it has been shown that changes in immune response occur before reductions in plasma zinc concentrations are apparent, specific and sensitive enzyme markers for zinc status remain elusive [19]. Nevertheless, the concentration of zinc in plasma or serum still remains the best available biomarker of zinc status in populations [20], but tends to be insensitive in conditions of mild zinc deficiency [21]. The status of zinc in the general public can also be estimated by quantitative dietary intake surveys and by gauging the adequacy of zinc intake in populations using the height-for-age estimate, a measure of stunting among children of less than 5 years of age [20, 22]. Zinc deficiency is currently estimated to be of public concern when the prevalence of low serum zinc concentration is >20% or the prevalence of inadequate intake is >25% or a stunting prevalence of >25% [22].

African diets for the poor elderly, children and women, especially the pregnant and lactating mothers are generally deficient in zinc [6, 23, 24, 25, 26]. However, the research literature on dietary zinc intake among African elderly and the effects on their health is limited. Nevertheless as a consequence of the low intake of zinc in diets of most African elderly, impairment of the many functions mediated by zinc may result. This review of the literature explores the role of zinc in human health, the dietary zinc intake among African elderly, and discusses potential impacts of zinc deficiency on their health and suggests remedies to increase their dietary zinc intake.

SOURCES OF ZINC IN HUMAN DIETS

Shellfish, beef, pork, and lamb are rich sources of zinc [27]. Turkey and chicken are good animal sources of zinc among the white meats, while nuts and legumes are relatively good plant sources of zinc [27]. Lean red meats, whole grain cereals, whole wheat bread, brown rice, pulses and legumes provide 25-50 mg/kg of food (wet weight basis) [27]. Processed cereals with low extraction rates, white bread, polished rice and lean meat or meat with high fat content provide a moderate zinc content of 10-25 mg/kg of food [27]. Fish, roots and tubers, green leafy vegetables and fruits, are only modest sources of zinc, providing <10 mg/kg of these foods [28]. Separated fats and oils, sugar and alcohol have very low zinc content [27].

Zinc bioavailability is relatively high in meats, eggs and seafood due to the relative absence of zinc absorption inhibitor compounds and the presence of the amino acids cysteine and methionine, which improve its absorption in the gastrointestinal tract [6], by combining with zinc. It has been suggested that the zinc from eating meat is four times more bio-available than that from grain foods [9]. It has also been reported that increasing the vitamin C, E and B6, and minerals such as magnesium can increase zinc absorption in the body [6], probably through the interaction of these nutrients with zinc, increasing its solubility, bio-availability and utilization. So that, for those who take vitamin C, E and B6 supplements, the daily intake of recommended amounts of these micronutrients is beneficial.

The zinc in plant foods is less bioavailable for human metabolism due to their content of chelators such as phytic acid and dietary fibre, which inhibit its absorption [29]. The phytates react with the divalent zinc and form strong and insoluble complexes that are excreted in stool [30]. Zinc picolinate has been promoted as readily absorbable [28], but data from human experiments to support this assertion is scanty. Limited work in animals suggests that increased intestinal absorption of zinc picolinate is offset by increased elimination [31]. This points to the need to rely on diets as a better way to meet any shortfalls rather than relying on supplementation to improve zinc intake. However, where food intake is inadequate or the reliance is on poor zinc sources, some form of supplementation or fortification of staple foods with zinc is beneficial [32]. Other zinc-providing supplements include zinc oxide, zinc sulphate, zinc gluconate and zinc acetate. Zinc oxide and zinc sulphate do not seem to differ in terms of bioavailability [33], so that zinc oxide which is the cheaper of the two is the current preferred fortificant for mass fortification of foods.

In South Africa, some staple foods are fortified with zinc oxide in order to reduce the shortfall from dietary intake [24]. However, no national surveys are scheduled on a regular basis to ascertain the effectiveness of the program, which was recently found ineffective with respect to nutrient density, particularly for women and adults in the rural areas [24]. Member countries of the East African Community (Kenya, Tanzania, Uganda, Rwanda, Burundi and soon to be admitted South Sudan) are in the process of legislating for mass fortification of some staple foods including granulated sugar (with retinyl palmitate), wheat flours (with retinyl palmitate, thiamine mononitrate, riboflavin, niacinamide, pyridoxine, folic acid, water soluble vitamin B12, zinc oxide and ferrous fumarate or NaFeEDTA),and maize flours with the similar fortificants as described above for wheat flours [34]. Edible oils and fats will be fortified with retinyl palmitate [34]. This is prudent practice in view of the general deficiency of the above nutrients in diets of the general public in the East African Community [6, 23].

Zinc in African Diets and Implications for Health

Some foods that contribute to zinc in African diets include milk and dairy products, beef and other red meats, shellfish (oysters, crabs and clams), legumes and nuts (peanuts, macadamia and cashew nuts) [23, 24, 28]. Other major African food crops that can contribute considerable amounts of zinc in diets include chick peas, beans, and Irish potatoes [23, 24]. Sweet potatoes, maize, macadamia nuts, peanuts, cashew nuts, and sunflower seeds contain significant amounts of zinc [28].

In a study among the elderly in a care centre in South Africa, it was evident that the elderly were prone to zinc deficiency due to nutritional and physiological vulnerabilities associated with aging. A low socio-economic status was associated with increased risk of zinc deficiency [25]. The subjects consumed a mean of 11.0±6.1 mg/day of zinc, with more than 50% not reaching two thirds of the recommended daily dietary allowance. From results of the serum zinc levels, more than 72% of these elderly subjects had zinc values less than the recommended 10.7

AJFAND ONLINE Scholarly, Peer Reviewed
African Journal of Food, Agriculture, Nutrition and Development
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

micromoles of zinc per litre of blood [25]. Therefore, zinc deficiency existed in these elderly black African people, more than 50% of whom consumed maize meal as the staple food. In a study among the elderly 60-99 years old in Botswana, Maruapula and Novakofski [26] concluded that the diet of the elderly in Botswana had poor nutrient content and the intake especially of energy and micronutrients was low. Zinc intake among the Botswana elderly males was 9.0 mg/day, while in the diet of the female elderly it was about 12.8 mg/day as estimated through a 24-hr recall. Although these findings refer to the situation among the elderly in South Africa and Botswana, they can be postulated to apply to the elderly in other African countries under similar socio-economic conditions.

Zinc is important in the elderly for behavioural and mental function [9], the immune and antioxidant system functioning [35], and bone metabolism [32]. It is necessary for protection against oxidative cell damage, enhances DNA repair, and controls cell proliferation in diseased states [9].

As the sense of smell and taste are necessary for food acceptance and enjoyment, inadequate zinc in the body especially of the elderly, can impair nutrient intake, thus weakening their ability to overcome opportunistic infections common in diseased states in old age [36]. Low zinc levels have been implicated in increased incidence of infections [36], and in pneumonia in the elderly [37].

ZINC DEFICIENCY

Generally, zinc deficiency is associated with the slowing or cessation of growth and cellular development, delayed sexual maturation, characteristic skin rashes, chronic and severe diarrhoea, immune system deficiencies; others symptoms are impaired wound healing, diminished appetite, impaired taste sensation, night blindness, white spots on fingernails, swelling and clouding of the corneas, and behavioural disturbances [9]. Oral zinc therapy seems to result in the remission of most of these symptoms; however, adequate serum zinc levels must be maintained in individuals with the genetic disorder known as *acrodermatitis enteropathica* [5]. This condition seems to be due to autosomal recessive mutation of the gene that codes for ZIP-4, disrupting transport and impairing zinc absorption [38]. The ZIP-4 transporter protein has been identified as a key importer of zinc into the intestinal cell [38]. Patients with this disorder need daily supplements of zinc throughout life.

In poor elderly subjects with diminished access to adequate and balanced diets, the likelihood of an inadequate intake of zinc is high. Where inadequate dietary intake is combined with diarrhoea exacerbated by poor sanitation, lack of access to good health care, or some physical impairment due to old age, the likelihood of mild or severe zinc deficiency is real [39]. Excessive excretion of already inadequate dietary zinc, the use of drugs that alter utilization or increase excretion are likely explanations for this observation [39]. However, despite dietary zinc deficiency being unlikely to lead to severe zinc deficiency in individuals without a genetic disorder, zinc malabsorption or conditions of increased zinc loss such as severe burns, or prolonged diarrhoea can also result in severe zinc deficiency, through increased excretion through the skin and in stools, respectively.

It is also known that excessive zinc intake (50 mg/day or more) over a period of several weeks can interfere with copper bioavailability by the induction of the intestinal synthesis of a copper-binding protein called metallothionein, which traps copper within intestinal cells and prevents its systemic absorption [9]. Also, it was evident that supplemental levels (38-65 mg/day of elemental iron) but not similar dietary levels of iron may also decrease zinc absorption [40]. It seems that iron and zinc can interfere with the absorption of the other when they are taken in aqueous solution and in less than equimolar amounts, but no evidence of interference when they are taken in foods [41]; however, nutritional status is enhanced overall despite any nutrient-nutrient interactions [42]. Nevertheless, it seems that there is no effect of zinc supplementation on changes in hemoglobin concentration and neither was the effect of zinc supplementation on the level of serum ferritin concentration of notable significance [22]. As for copper, some studies have shown a negative effect of large dose zinc supplementation on indicators of zinc status in adults [43, 44]. However, overall, the daily zinc supplementary dose had no effect on changes in serum copper concentration [22]. However, it should be noted that serum copper concentration is reported to be an insensitive biomarker of copper status [45], so that subtle changes in copper metabolism could occur without being noticed through changes in serum copper concentration.

Vulnerability of the elderly to Zinc Deficiency

From the perspective of human physiology, the running down of organs and body systems begins after the age of 20 years [46].

The elderly are vulnerable to poor nutrition and need special care by virtue of their age; further, the reduced mobility to shop on their own, and where education is limited and the income for appropriate and adequate food purchase is limiting, problems emanating from inadequate nutrient intakes are inevitable [29]. Also, the inability by the elderly to meet their social and dietary needs because they are unable to do gainful employment can often translate to poverty. In a study among the elderly with an average age of 72 years in a care centre in South Africa, it was evident that the elderly were prone to zinc deficiency due to nutritional and physiological vulnerabilities associated with aging. It was evident that a low socio-economic status could further increase the risk of zinc deficiency [25]. This was related to the inability to afford adequate food of appropriate nutritional quality, which is likely to be low in the relatively more expensive animal foods, such as meat, thereby leading to potential micronutrient deficiency, including that due to zinc.

Where the elderly live alone, the allocation of inadequate quality time to prepare balanced meals can lead to malnutrition and the associated micronutrient deficiencies [47]; chronic disease conditions in some situations make it difficult for the elderly to cook decent meals for themselves. For those who have lost teeth, the chewing and enjoyment of foods is difficult, so that liquid foods often of poor nutritional quality may be preferred; loneliness and neglect by relatives in the event of the death of a partner who used to cook meals, or choosing to live alone can compound nutritional problems faced by surviving elderly people [47].

Generally, total energy needs decrease with age. Factors that contribute to the declining metabolic energy needs with age include: a decreased basal metabolic rate and reduced physical activity. It also seems that a change in body composition and changes in the functioning of the body organs may influence energy requirements for metabolic activities. Also, as people grow older, they tend to eat less and thus compensate to some extent for the reduced energy needs [46]. Decreased food intake may, however, lead to lower nutrient intake of some food components, especially the micronutrients, including zinc [48]. It is, also recognized that the nutrient needs of the elderly for certain nutrients (such as vitamins, minerals and protein) are higher than for young adults [48]. These higher requirements may be related to tissue turnover rate and the lower requirements for growth but higher requirements of these nutrients for disease prevention in the elderly.

Nevertheless, if the food intake is not restricted, there is also the potential for well fed elderly people to become obese, due in part to reduced physical activity arising either from immobility or other physical or chronic health condition (for example, being bed ridden or lacking limbs) that restricts movement.

As energy intake reduces with age, an accompanying decrease in protein intake may result. Due to the role zinc plays in protein formation and the synergistic role of some of the essential amino acids in zinc absorption, such a dietary pattern may lead to zinc deficiency unless care is taken to forestall it. Although endogenous zinc losses in the elderly are reported to be lower, the absorptive capacity reduces with age [9], so that the body compensates by reducing zinc excretion.

To provide an adequate level of zinc in diets of the elderly living sedentary lives, an adequate provision of milk, meat, eggs, fruit, and vegetables, and less fat and sugar than present in normal diets is necessary [46]. Where vitamin and mineral deficiencies are noted or are likely, the use of supplements by the aging may be recommended [32]. However, for the aging in most countries of Africa, the level of supplemental vitamin or mineral intake is partly determined by the availability of the supplements and the ability of the individual to afford them. The capability to afford supplements is often a limitation for many aging persons in African societies due to the widespread poverty in many African countries.

The food habits, the food dislikes and likes, the notions about unfamiliar foods and diets are long standing and will not be readily amenable to change for many aging persons. Consequently, the fixed food habits of the aging demand some respect and such respect can make it easier for the aging to access adequate nutrition in the hands of those with some knowledge of nutrient content of foods and nutrient requirements of the aging. It may be easier to provide for the social and nutrient needs of the elderly when they are living in familiar surroundings and with relatives, rather than in old people's homes among strangers, unless no such option exists.

AJFAND ONLINE Scholarly, Peer Reviewed
African Journal of Food, Agriculture, Nutrition and Development
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

The physical character and the nutrient content of diet often affect the periodontal tissues-the bone, connective tissue, and the epithelium that holds teeth in the jaws. These tissues are particularly susceptible to poor nutrition [46]. The loss of teeth unless replaced by dentures can complicate the enjoyment of food by the elderly, and thus lead to loss of appetite and eventually to potential malnutrition.

In the absence of a sensitive indicator currently for gauging the serum status of zinc, the scientific study of the health implications of zinc deficiency in the elderly still faces challenges.

The RDA for zinc is based on gender and age, and varies over a wide range of these two factors. The RDA for zinc generally varies between 2 and 11 mg/day for males aged 6 months to adolescence, but for the same age groups in females, the RDA is 2-13 mg/day [9].

Although the requirement for zinc by the elderly is not known to be higher than the 11 mg/day generally recommended for adult men, their average zinc intake tends to be considerably less than the US RDA of 15 mg/day [9]. A reduced capacity to absorb zinc, increased likelihood of disease states that may adversely alter zinc utilization, and the increased use of drugs that increase zinc excretion may all contribute to an increased risk of mild zinc deficiency in the elderly. Due to the consequences of mild zinc deficiency, such as impaired immune system function, that are especially relevant to the elderly, particular attention should be paid to maintain an adequate zinc intake by this group [35]. Also due to the lower absorptive capacity in the elderly, a higher dietary requirement could be justified for them, although endogenous losses in the elderly are reported to be lower [9], probably due to altered and better utilization.

Consequences of Zinc Deficiency in the Elderly

Despite the generally acknowledged vulnerability of the poor elderly to zinc deficiency, results of zinc supplementation trials on immune function in the elderly are mixed. One study found that some immunity aspects in the elderly responded positively to zinc supplementation [8]. The level of CD4 T cells and cytotoxic T-lymphocytes increased compared to the placebo in one study [7].

Zinc is hypothesized to play a role in the development of age-related macular degeneration (AMD), a disease of the macula or the retina portion in the back of the eye involved with central vision. The hypothesis is supported by the fact that zinc is found in high concentration in the part of the retina affected by AMD; retinal zinc content has also been found to decline with increasing age, while the activity of some zinc-dependent retinal enzymes also declines with age. However, some observational studies have not demonstrated clear association between dietary zinc intake and the incidence of AMD [49, 50]. However, a large randomized controlled trial of daily supplementation with antioxidants (500 mg of vitamin C, 400 IU of vitamin E, and 15 mg of beta carotene) and high dose zinc (80 mg of zinc and 2 mg of copper) found that the antioxidant combination and the high dose zinc, and the high dose alone, both significantly reduced the risk of advanced AMD compared to the placebo in individuals with signs of moderate to severe AMD at least in one eye [51]. There is also little evidence that zinc supplementation would be beneficial to people with early signs of macular degeneration, and therefore further randomized trials are needed [52].

In a poor elderly population in South Africa, the findings of a study indicated poor dietary intake and high prevalence of vitamins A and E deficiency [53]. Zinc and vitamin A and E deficiency seemed from a study by Boron *et al.* [54] likely to lead to AMD in the elderly. One major consequence of long term consumption of excessive zinc is copper deficiency, which has been shown with zinc intakes of 60 mg/day (50 mg supplemental and 10 mg dietary zinc). Copper is involved in the absorption, storage and metabolism of iron and the formation of erythrocytes and also helps with the supply of oxygen to the human body. The symptoms of copper deficiency are similar to those of iron-deficiency anaemia [28]. To avert copper deficiency, the US Food and Nutrition Board has set 40 mg/day of zinc as the upper tolerable limit for adults (including dietary and supplemental zinc) [31].

Prostate cancer is the second leading cause of cancer deaths in American men, and most elderly men have some abnormal prostate cells. The normal prostates accumulate the highest zinc level of any soft tissue in the body, but the reasons for this observation remain unclear. However, cancerous prostates have much less zinc than normal prostates, and one study has implicated impaired zinc status in the development and progression of prostate malignancy [55]. Also, a recent study has shown that high cellular levels of zinc inhibit prostate cancer cell growth and reduce prostate cancer-specific mortality in men with localized disease [56]. However, an epidemiological study showed an increased risk for prostate cancer in men who took high-dose zinc supplements (over 100 mg/day or long term, more than 10 yrs zinc supplement use) [55]. Yan *et al.* [57] using human prostatic cultured cells suggest that zinc supplementation may be more helpful in the early stages of cancer development rather than as a cancer treatment. This implies that zinc supplementation may not prevent already cancerous prostate cells from growing. So in the elderly, who are likely candidates for prostate cancer, some supplementation may be beneficial to prevent cancerous cells growing, but how much would be appropriate needs to be determined. Also, the stage at which zinc supplementation in relation to zinc deficiency would be beneficial for prostate cancer sufferers needs to be confirmed by more studies.

MAXIMIZING DIETARY ZINC INTAKE AND SYSTEMIC ABSORPTION

As red meats, seafood and poultry contain the highest and most readily available form of zinc, it is nutritionally beneficial to maximize their consumption [6, 9]. However, the cost of meat and animal products often tends to be high, thereby restricting the availability of this commodity to the poor; government and non-governmental agency programmes aimed at making animal products accessible to the relatively poor and the elderly would assist achieve higher intake of zinc and other micronutrients by the poor and elderly.

Although other food categories such as grains are relatively poorer zinc sources and may contain inhibitory factors, frequent consumption of these foods and their consumption in large amounts can contribute significantly to dietary zinc intake. Also, the choice of cereals and other foods that are fortified with zinc is a prudent way of ensuring that dietary zinc intake is maximized. Healthy individuals who eat balanced diets rarely need supplements. Nevertheless, it is important to take special care to ensure adequate zinc intake, especially if one does not consume animal products. As plant foods contain smaller amounts of zinc than animal products which also tend to be absorbed better, vegetarians need greater amounts of zinc in their diets than meat eaters [21]. Normally, protein rich foods tend to be rich in zinc as well [29]. Zinc is lost during cooking and the general preparation of foods, even under the best conditions designed to minimize losses. To reduce losses of zinc in food preparation, cooking foods in minimal amounts of water and for the shortest time possible are prudent practices. The cooking water or broth should also be consumed to obtain the thermostable micronutrients leached out into the cook-water.

There is need to devise nutrition education programmes to assist in improving micronutrient intakes among populations of developing countries, who are at the most risk of zinc deficiency. The acceptance and adoption of simple, culturally acceptable interventions that are economically feasible, and are designed to improve micronutrient intakes, can have positive impacts. In one such programme among rural Malawian families, the adoption rates for 4 practices ranged from 25% for the preparation of enriched porridges, to 10% for preparing soaked, pounded maize [15]. The results indicated that intakes of energy, animal protein, niacin, riboflavin, calcium, iron, and zinc were significantly greater in the intervention group compared to the control group [15]. However, hygiene in handling (although heating is likely to destroy most pathogens) and the likelihood of aflatoxin formation in cereal-based foods should always be kept in mind. When fortified foods were substituted for similar but unfortified foods in another study, there was an improved mean intake of zinc, as well as the overall mean adequacy ratio of the diet [24].

The utilization of zinc depends on the overall composition of the diet, with experimental studies identifying a number of dietary factors as potential promoters or antagonists of zinc absorption [15]. Soluble, low molecular weight organic compounds such as amino acids and hydroxyl acids, facilitate zinc absorption, whereas organic compounds forming stable and poorly soluble complexes with zinc, can impair absorption [15].

Despite the potential interaction with copper and iron, the levels of these minerals as present in normal diets appear not to affect zinc absorption, although high doses as supplements or in aqueous solutions can impair zinc absorption [15, 42].

The total zinc content of a diet, the content of inositol hexaphosphate (phytate) and the level and dietary source of protein are major determinants of absorption and level of utilization of zinc. Phytates are found in whole grain cereals and legumes and in smaller amounts in vegetables. Their strong potential for binding divalent cations and their depressive effect on zinc absorption in humans has been demonstrated [15]. The effect of phytate is, however, modified by the source and the amount of dietary proteins consumed. Animal proteins improve zinc absorption from a phytate-containing diet. Zinc absorption from some legume diets containing soybeans, and lupin is comparable with that from animal protein- based diets despite a higher phytate content in legumes [58].

High dietary calcium potentiates the antagonistic effect of phytates on zinc absorption in experimental animals, but results from animal studies are less consistent and any effects depend on the source of calcium and diet composition [58].

Results of zinc absorption from tropical diets, which normally have high phytate content are generally lacking. Generally, the availability of zinc from diet can be improved by reductions in phytate content and inclusion of animal protein sources. Lower extraction rates in cereal grains will result in lower phytate content, but the reduced zinc means that the net effect on zinc supply is limited. Phytate content can be reduced by activating the phytases present in phytate-containing foods or by the addition of microbial or fungal phytases, which hydrolyze the phytate to lower inositol phosphates, resulting in improved zinc absorption [59]. However, it is reported that the activity of phytases from tropical cereals such as maize and sorghum, is lower than that in rye and wheat [60]. Clearly a plausible explanation for this assertion is not available.

Germination of cereals and legumes increases phytase activity and the addition of some germinated flour to ungerminated maize or sorghum followed by soaking at ambient temperature for 12-24 hr reduced phytate content substantially [60]. Additionally, phytate reduction can be achieved by fermentation of porridge for weaning foods or doughs for bread making. Although commercial phytases can be used, they may not be readily available in developing countries, and even then, they would have to be cost-effective to be useful in regard to making dietary zinc more bio-available. It is generally advised that improvements in zinc intake from supplementary food intake cannot be achieved without inclusion of meat or liver in plant-based diets [60], but not fish, milk or dairy products for unclear reasons.

CONCLUSIONS AND RECOMMENDATIONS

Due to zinc ubiquity and versatility in sub-cellular metabolism, zinc deficiency may result in generalized impairment of many metabolic functions. The poor elderly all over the world are generally at the risk of zinc deficiency in part due to the various physiological and socio-economic factors associated with aging, which may impair zinc intake and therefore the content absorbed. Although supplementation may be an easier, but expensive way to achieve the RDA for zinc, dietary intake is advised, especially among sickly, illiterate elderly, as the likelihood of consuming toxic levels is less likely to occur. Limited studies on zinc dietary intake among the African elderly exist, but very few have been conducted on the effects of low dietary zinc intake on their health. The potential effects of low dietary zinc intake on the health of African elderly in this review are therefore based on studies conducted elsewhere on the elderly. From studies conducted so far, it is beneficial to fortify staples and explore the possibilities of inclusion of inexpensive and available animal protein sources in plant-based diets for the elderly. This approach to solving the potential zinc deficiency problems among poor African elderly, needs to be effected as a matter of nutritional policy, in most African countries. Despite the use of depletion-repletion studies to establish zinc status, specific and sensitive enzyme markers for zinc status in humans remain elusive, especially in conditions of mild zinc deficiency. Also, the effects of high calcium and iron supplementation in humans on zinc absorption need further study so as to clarify the mechanisms, conditions and the reasons for the depressed zinc and copper absorption. Further, the relationship between prostate cancer and zinc status in the elderly needs further investigation, with the possibility to extend the studies to cover other cancers that afflict the elderly. More controlled and clinical studies to ascertain the effects and mechanisms of zinc on human immune function parameters appear necessary in view of the necessity to minimize infections in the elderly.

AJFAND ONLINE Scholarly, Peer Reviewed
African Journal of Food, Agriculture, Nutrition and Development
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

REFERENCES

1. **Fierke C** Function and mechanism of zinc. *Journal of Nutrition* 2000; **130**: 1437S-1446S.

2. **Cousins RJ** A role of zinc in gene expression. *Proceedings of the Nutrition Society* 1998; **57**: 307-311.

3. **Williams RJP** An introduction to the biochemistry of zinc. In: Mills CF (Eds.). Zinc in Human Biology. Springer-Verlag, Berlin, Germany, 1989: 15-31.

4. **McDonald RS** The role of zinc in growth and cell proliferation. *Journal of Nutrition* 2000; **130**(5S Suppl): 1500S-1508S.

5. **Hambridge M** Human zinc deficiency. *Journal of Nutrition* 2000; **130**(5S Suppl): 1344S-1349S.

6. **Neumann CG, Bwibo NO, Murphy SP, Cigman M, Whaley S, Allen LH, Guthrie D, Weiss RE** and **MW Demment** Animal source foods improve dietary quality, micronutrient status, growth and cognitive function in Kenyan school children: Background study design and baseline findings. *Journal of Nutrition* 2003; **133**: 3941S-3949S.

7. **Fortes C, Forastiere F** and **N Agabiti** The effect of zinc and vitamin A supplementation on immune response in an older population. *Journal of American Geriatric Association* 1998; **46**(**1**): 19-26.

8. **Salguiero MJ, Zubillaga M** and **A Lysionek** Zinc status and immune system relationship: a review. *Biological* and *Trace Element Research* 2000; **76**(**3**): 193-205.

9. **Linus Pauling Institute** Zinc. Linus Pauling Institute, University of Oregon, Corvallis, Oregon, 2008. Found at: http://www.lpi.oregonstate.edu/infocenter/htm. Accessed on 10th December, 2009.

10. **Larsson JC, Wolk K, Brismar K** and **C Wolk** Association of diet with insulin-like growth factor in middle-aged and elderly men. *American Journal of Clinical Nutrition* 2005; **81(5)**: 1163-1167.

11. **Kiedasch V, Akel A, Niemoller OM, Wieder T** and **F Lang** Zinc-induced suicidal death. *Journal of Nutrition* 2008; **87**(**5**): 1530-34.

12. **Truong-Tran AQ, Ho LH, Chai F** and **PD Zalewski** Cellular zinc fluxes and the regulation of apoptosis/gene-directed cell death. *Journal of Nutrition* 2000; **130**(5S Suppl): 1459S-1466S.

AJFAND ONLINE Scholarly, Peer Reviewed
African Journal of Food, Agriculture, Nutrition and Development
Volume 12 No. 6
October 2012
ISSN 1684 5374
Published by African Scholarly Science Communications Trust

13. **Jou Ming-Hu, Phillips AF** and **Bo Lönnerdal** Maternal zinc deficiency in rats affects growth and glucose metabolism in the offspring by inducing insulin resistance postnatally. *Journal of Nutrition* 2010; **140**(**9**): 1621-27.

14. **Chester WK** Biochemistry of zinc in animals. *World Review of Nutrition and Diet* 1978; **32:** 135-164.

15. **Sandström B** and **Bo Lönnerdal** Promoters and antagonists of zinc absorption. In: Zinc in Human Biology, Mills CF (Ed.). Springer-Verlag, Devon, UK, 1989: 57-78.

16. **Johnson PE, Hunt CD, Milne DB** and **LK Mullen** Homeostatic control of zinc metabolism in man: zinc excretion and balance in men fed diets low in zinc. American Journal of Clinical Nutrition 1993; **57**: 557-65.

17. **Hambridge KM** and **NF Krebs** Zinc deficiency: a special challenge. *Journal of Nutrition* 2007; **137**: 1101-1105.

18. **Brown K, Peerson JM** and **LH Allen** Effects of zinc supplementation on children's growth. In: Role of Trace Elements for Health Promotion and Disease Prevention. Sandström B and P Walter (Eds.). Bibliotheca Nutritio et Dieta. Karger Publishers, Berlin, Germany, 1998; **54**: 76-83.

19. **Beck FWJ, Prasad AS** and **J Kaplan** Changes in cytokine production and T cell subpopulations in experimentally induced zinc-deficient humans. *American Journal of Physiology* 1997; **272**: E1002-7.

20. **de Benoist B, Darnton-Hill I, Davidsson L** and **O Fontaine** (Eds.) Report of a WHO/UNICEF/IAEA/IZinCG-intragency meeting on zinc status indicators. *Food & Nutrition Bulletin* 2007; **28**: S399-S486.

21. **Hunt JR** Bioavailability of iron, zinc and other trace minerals from vegetarian diets. *American Journal of Clinical Nutrition* 2003; **78**(**3**): 633S-639S.

22. **Hess SY** and **KH Brown** Impact of zinc fortification on zinc nutrition. In: InZINCG Technical Document 2-Systematic reviews of zinc intervention strategies. Brown KH & SH Hess (Eds.). Food & Nutrition Bulletin 2009; **28**: 81-110.

23. **Sehmi JK** National Food Composition Tables and the Planning of Satisfactory Diets in Kenya. Government Printer, Nairobi, 1993.

24. **Steyn NP, Wolmarans P, Nel JH** and **LT Bourne** National fortification of staple foods can make a significant contribution to micronutrient intake of South African adults. *Public Health Nutrition* 2008; **11**(**3**): 307-313.

25. **Oldewage-Theron WH, Samuel FO** and **CS Venter** Zinc deficiency among the elderly attending a care centre in Sharpeville, South Africa. *Journal of Human Nutrition and Dietetics* 2008; **26**(**1**): 566-74.

26. **Maruapula SD and CK Novakofski** Nutrient intake and adequacy of Botswana Elderly. *African Journal of Food, Agriculture, Nutrition and Development* 2010; **10**(**7**): 1-20.

27. **Holland B, Welch AA, Unwin ID, Buss AA, Paul AA and DAT Southgate** McCance and Widdowson's-The Composition of Foods, 5th Revised and extended Edition. Royal Society of Chemistry & Ministry of Agriculture, Fisheries & Food, Cambridge UK, 1991

28. **USDA** USDA Nutrient Database for Standard Reference, Release No. 17. Adapted from the 2002 Revision of Home and Garden Bulletin, No.72, Nutritive Value of Foods, USDHHS, Washington DC, 2002. Found at http://www.nal.usda.gov. Accessed on 6th December 2009.

29. **Wardlaw GM** and **M Kessel** Perspectives in Nutrition. McGraw Hill, New York, 2002.

30. **Fredlund K, Isakson M, Rossander-Hulthen L, Almgren A and AS Sandberg** Absorption of zinc and retention of calcium. Dose-dependent inhibition by phytate. *Journal of Trace Elements in Medicine and Biology* 2006; **20**: 49-57.

31. **Food and Nutrition Board (Institute of Medicine)** Zinc reference intakes and reference intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc. National Academies Press, Washington D.C., 2001; 442-501.

32. **WHO.** Trace elements in human nutrition and health. WHO, Geneva, 1996.

33. **Lopez De Romana D, Lönnerdal B and KH Brown** Absorption of zinc from wheat flours fortified with iron and either zinc sulfate or zinc oxide. *American Journal of Clinical Nutrition* 2003; **78**: 279-83.

34. **East African Community** Draft East African Standard-fortified wheat flour specification (CD-U-38-2011), fortified sugar specification (CD-U-41-2011), fortified edible oils and fats specification (CD-U-40-2011), Arusha, Tanzania, 2011.

35. **Shankar AH and AS Prasad** Zinc and immune function: the biological basis for altered resistance to infection. *American Journal of Clinical Nutrition* 1998; **68(2 Suppl)**: 447S-464S.

36. **Prasad AS, Beck FWJ, Bao B, Fitzgerald JT, Snell DC, Steinberg JD** and **LJ Cardozo** Zinc supplementation decreases risk of infection in the elderly:

effect of zinc on generation of cytokines and oxidative stress. *American Journal of Clinical Nutrition* 2007; **85**(**3**): 837-44.

37. **Meydani SN, Barnett JB, Dallal GE, Fine BC, Jacques PF, Lella L** and **DH Hammert** Serum zinc and pneumonia in nursing home elderly. *American Journal of Clinical Nutrition* 2007; **86**: 1167-1173.

38. **Hess SH, Lönnerdal Bo, Hotz C, Rivera JA** and **KH Brown** Recent advances in knowledge of zinc nutrition and human health. In: InZINCG Technical Document 2-Systematic reviews of zinc intervention strategies. Brown KH & SH Hess (Eds.). *Food & Nutrition Bulletin* 2009; **28**: S1-S188.

39. **Bhatta ZH, Black RE, Brown KH, Cardner JM, Gore S, Hidayat A, Khatun F, Martorell R** and **NX Ninh** Prevention of diarrhea and pneumonia in developing countries: pooled analysis of randomized controlled trials. "Zinc Investigators" Collaborative group. *Journal of Pediatrics* 1999; **135**: 689-97.

40. **O'Brien KO, Zavaleta N, Caulfield LE, Wen J** and **SA Abrams** Prenatal iron supplements impair zinc absorption in pregnant Peruvian women. *Journal of Nutrition* 2000; **130**(**9**): 2251-2255.

41. **Rossander-Hulten L, Brune M, Sandström B, Lönnerdal B** and **L Hallberg** Competitive inhibition of iron absorption by manganese and zinc in humans. *American Journal of Clinical Nutrition* 1991; **54**: 152-6.

42. **Fischer Walker C, Kordas K, Stoltzfus RJ** and **RE Black** Interactive effects of iron and zinc on biochemical and functional outcomes on supplementation trials. *American Journal Clinical Nutrition* 2005; **82**: 5-12.

43. **Yadrick MK, Kenney MA** and **EA Winterfeldt** Iron, copper and zinc status. Response to supplementation with zinc or zinc and iron in adult females. *American Journal of Clinical Nutrition* 1989; **49**: 145-50.

44. **Davis CD, Milne DB** and **FH Nielsen** Changes in dietary zinc and copper affect zinc status indicators of postmenopausal women, notably, extracellular superoxide dismutase and amyloid precursor proteins. American Journal of Clinical Nutrition 2000; **71**: 781-8.

45. **Milne DB** Copper intake and assessment of copper status. *American Journal of Clinical Nutrition* 1998; **67**: 1041S-5S.

46. **Passmore R** and **MA Eastwood** Davidson and Passmore's Human Nutrition and Dietetics, 8th edn. Churchill Livingstone, Edinburgh, 1986.

47. **Davis MA, Murphy SP, Neuhaus JM, Gee L** and **SS Quiroga** Living arrangements affect dietary quality for US adults aged 50 years & older. NHAES III 1988-1994. *Journal of Nutrition* 2000; **130(9)**: 2256-64.

48. **Meunier N, O'Connor J, Maiani G, Cashman KD, Secker DL, Ferry M, Roussel AM** and **C Coudray** Importance of zinc in the elderly: the Zenith Study. *European Journal of Clinical Nutrition* 2005; **59**: S1-S4.

49. **VandelLangenberg GM, Mares-Perlman JA, Klein R, Klein BE, Brady WE** and **M Palta** Association between antioxidant and zinc intake and the 5-year incidence of early age-related maculopathy in the Beaver Dam Eye Study. *American Journal of Epidemiology* 1998; **148**(**2**): 204-214.

50. **Cho E, Stampfer MJ** and **JM Seddon** Prospective study of zinc intake and the risk of age-related macular degeneration. *Annals of Epidemiology* 2001; **11**(**5**): 328-336.

51. **AREDS** (Age-related Eye Disease Study Group) A randomized, placebo controlled, clinical trial of high dose supplementation with vitamin C and E, beta carotene, and zinc for age-related macular degeneration and vision loss. ARES Report No.8. *Archives in Opthalmology* 2001; **119**(**10**): 1417-1436.

52. **Evans JR** Antioxidant vitamin and mineral supplements for age-related macular degeneration. (Cochrane Review)-Cochrane Data System Rev. 2002; **1**: CD000254.

53. **Oldewage-Theron WH, Samuel FO** and **RD Djoulde** Serum concentration and dietary intake of vitamins A and E in low-income South African elderly. *Clinical Nutrition* 2009; **29(1**): 119-123.

54. **Boron H, Hupert J** and **DH Barch** Effect of zinc deficiency on hepatic enzymes regulating vitamin A status. *Journal of Nutrition* 1988; **118**(**8**): 995-1001.

55. **Leslie C, Franklin RB, Feng P** and **M Tan** Zinc supplement use and risk of prostate cancer. *Journal of National Cancer Institute* 2004; **96**(**3**): 239-240.

56. **Epstein MM, Kasperzky JL, Abdrten O, Giovannucci EL, Wolk A, Hakansson N, Andersen S-O, Johansson J-E, Fall K and LA Mucci** Dietary zinc and prostate cancer survival in a Swedish Cohort. *American journal of Clinical Nutrition* 2011; **93**(**3**): 586-93.

57. **Yan M, Hardin K** and **E Ho** Differential response to zinc-induced apoptosis in benign prostate hyperplasia and prostate cancer. *Journal of Nutritional Biochemistry*. 2009; **21**(**8**): 687-694.

58. **Petterson D, Sandström B** and **Å Cederblad** Absorption of zinc from Lupin (*Lupinus angustifolius*)-based foods. *British Journal of Nutrition* 1994; **72**: 865-71.

59. **Sandström B** and **AS Sandberg** Inhibitory effects of isolated inositol phosphates on zinc absorption in humans. *Journal of Trace Elements and Electrolytes in Health and Disease* 1991; **6**: 99-103.

60. **Gibson RS and VP Anderson** A review of interventions based on dietary diversification or modification strategies with the potential to enhance intakes of total and absorbable zinc. In: InZINCG Technical Document 2-Systematic Reviews of Zinc Intervention Strategies. Brown KH & SH Hess (Eds.). *Food & Nutrition Bulletin* 2009; **28**: 111-145.