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Pearl Millet: boon in mineral deficiency: A review

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ABSTARCT

Mineral deficiency can be defined as a condition that caused due to reduced level of any of the minerals essential to human health. Low mineral concentration may impair a function dependent on that mineral in a body. Minerals support normal growth and development through various biochemical reactions. Its deficiencies can lead to a variety of health problems, such as fatigue, weak bones or a low immunity and other disorders. A large section of today's population is suffering from micronutrient deficiencies caused largely by deficiency of vitamins and minerals. Iron and Zinc deficiency is the most common and widespread nutritional disorder in the world, and is a public health problem in both developed and developing countries. Widespread malnutrition specially among children is of great concern as it affects child growth, cognitive development and resistance to infection. Malnutrition due to mineral deficiency is a great concern in India as large number of children are suffering mineral deficiency due to insufficient mineral rich diet. Pearl Millets is important cereal crop and provides various minerals which are required for the wellbeing of a human body. It is enriched with Iron, Zinc and other minerals and its inclusion in diet through various food products could be useful in battling mineral deficiency.

Key words: Malnutrition, Millet products, Pearl millet, Zinc deficiency.

In India, around 63 per cent i.e. 75 million of the children less than five years of age are malnourished, which is one of the worst levels in the world (Rhode, 1994). According to registrar general of India, in 2010, under five mortalities in India were 59 per 1000 live births, one of the highest in the world. According to a report by a British non-profit Save the Children, 1.83 million Indian children die every year before they turn five and stated that malnutrition is the main reason for the deaths (Singh, 2018). Major causes of childhood malnutrition are nutritionally inferior diets and improper feeding practices (Huffman and Martin, 1994). About 2 billion people suffer from a chronic deficiency of micronutrients over the world which is a serious concern for human health in today's society (Tulchinsky, 2010). The malnutrition can affect the growth, physical and cognitive development of infants, toddlers and school children, work performance and productivity of adults as well as productive functions in women (Muthayya *et al*, 2013). Incorporation of pearl millet in diet could solve the problem of minerals deficiency and reduce malnutrition.

Role of minerals in human health: Minerals are not manufactured by the human body and must be obtained through diet or supplementation. The human body requires minerals for biological function and health. Minerals are essential elements required for human life, and typically exclude the organic building blocks of carbon, hydrogen, nitrogen and oxygen (Institute of Medicine, 2001). Minerals are distinct from vitamins in that they are not organic molecules comprised of multiple atoms. The human body requires 17 different minerals, as indicated in Table 1, and these comprise 4% of the total body mass (McDowell, 2003; Gropper *et al*, 2009). They are classified as major minerals (daily requirement of at least 100 mg), trace minerals (daily requirement of less than 100 mg), and ultra-trace minerals (typically 1 µg or less per day) (Offenbacher *et al*, 1997). Minerals are naturally present in food or may be added through food fortification or dietary supplements. Minerals play a variety of crucial biological roles, including maintenance of proper electrolyte balance and conductivity functions for muscle and nerve excitation, acid-base balance, as cofactors in enzymes required for metabolism, in forming and stabilizing proteins, and in the crystalline structure of bones and teeth, as well as other functions (O'Dell and Sunde, 1997).

Mineral deficiency: Mineral deficiencies negatively affect billions of individuals worldwide, imposing a heavy burden on wellbeing and economic productivity. Most prominently, deficiencies in iron, zinc and iodine have the largest negative impact on public health; however, other minerals, including calcium, magnesium, selenium and fluoride, contribute

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significantly to the health burden (Allen *et al*, 2006). It is crucial to note that many minerals interact with each other and with vitamins; for example, healthy bones require a balance between vitamin D, calcium, phosphorus, magnesium, zinc, fluoride, chloride, manganese, copper and sulfur. Deficiency in any of these would inûuence skeletal health. Interactions in absorption may also be important; for example, high intakes of iron may decrease zinc absorption, or high intake of zinc may result in copper deficiency. While the causes of mineral malnutrition are complex, the primary determinant is insufficient dietary intakes. Efforts aimed at fortifying foods or providing supplements to reduce mineral deficiencies have had some success, but substantial efforts are still needed to get effective programming at scale (Allen *et al*, 2006). A balanced diet provides all required minerals and in the proper quantities and ratios. From a public health perspective deficiencies of the trace minerals iron, zinc and calcium have the greatest burden on health and are reviewed below.

Zinc deficiency: Zinc is the second most abundant trace mineral in the body following iron. Sources of zinc and iron coexist, which means deficiency of either one of it may tend to have another one. Body does not retain zinc reserves and when daily intake falls below requirements, the onset of the adverse effects is relatively rapid. Currently, it is estimated that 1 billion persons worldwide suffer from zinc deficiency, and it is associated with 780,000 annual deaths and 29 million disability-adjusted live years (DALYs) (Ezzati *et al*, 2004). Often, zinc deficiency is associated with improper growth, impaired immunity and decreased resistance to infection.

Zinc is an essential nutrient which is important in proper growth, tissue repair, reproduction and better cellular immunity. It also plays a vital role in regulating the metabolism, as a component of metallo-protease enzymes fulfilling catalytic, structural, and regulatory functions, for the stabilization of membranes, and for various ionic cell functions (Milner, 1990). Deficiency of Zinc leads to the risk of a number of infections, restricts physical growth, and affects pregnancy (Hess *et al*, 2009).

Iron deficiency: Iron, which is essential part of haemoglobin is vital micronutrient is required for the transport of oxygen and CO_2 in the blood. It is an important component of tissue enzymes like cytochromes and enzymes involved in the immune system (Martınez *et al*,1999). Iron deficiency is the most common nutritional disorder in the world (Cook and Reusser, 1983; Fairweather-Tait, 1995). When absorbed iron content falls below the particular level, iron deficiency predominates. This situation becomes more alarmed in the cases of during pregnancy, growth, menstrual loss, parasitic infections which needs more haemoglobin or iron in the body. The marked decrease in haemoglobin concentration reduces job performance in adults (Finch and Cook, 1984). Effects on behavioural abnormalities and cognitive and motor development is found in infants (Andraca *et al*, 1997).

Table 1: Essential Minerals in descending order by recommended daily intake level and key biological functions.

Dietary mineral	RDA/AI	Functional Significance
Potassium	4700 mg	Systematic electrolyte needed to maintain membrane action potentials; essentials for ATP regulation
Chlorine	2300mg	Production of hydrochloric acid in the stomach and in cellular pump functions
Sodium	1500 mg	Systematic electrolyte needed to maintain membrane potential and action potential; essential in co-regulating ATP with potassium
Calcium	1000 mg	Needed for muscle contractility, heart and digestive system health, builds bone, supports synthesis and function of blood cells
Sulfur	850	Critical in tertiary protein structure including connective tissue and skin, needed for several enzymes and antioxidant molecules
Phosphorus	700	Key component of bones and energy processing via ATP and related molecules
Magnesium	420 mg	Required for processing ATP and for bones
Zinc	11 mg	Required for production of immune cells and their function, is an antioxidant
Iron	8 mg	Required for oxygen carrying capacity of hemoglobin and myoglobin, and as a cofactor for several other enzymes
fluorine	3.8 mg	Forms compounds with calcium and phosphorus that are stronger and less soluble than other calcium salts, leading to stronger teeth and bones
Manganese	2.3 mg	Required cofactor for enzymes of energy production and synthesis of DNA and RNA
Copper	900 µg	Need for connective tissues formation and release of iron from storage sites and maturation of red blood cells
Chromium	200 µg	Needed for normal sugar metabolism via GTF that enhance glucose utilization
Iodine	150 µg	Required for synthesis of thyroid hormones,
Selenium	55 µg	A cofactor essential to activity of antioxidant enzymes
Molybdenum	45 µg	Key component of oxidase
Cobalt	1 µg	Critical component of vit. B_{12}

AI- adequate intake, GTF- glucose tolerance factor, RDA- recommended daily allowanceFrom *NHS Direct Online (2017): Vitamins and Minerals.* Available from:www.nhs.uk/Conditions/vitamins-minerals/Pages/vitamins-minerals.aspx. (Accesed on 01/11/2017).

Table 2: Mineral and vitamin content of pearl millet.

Mineral Content		Vitamin Content	
Ca, (%)	0.01	Thiamine,mg/g	0.38
P, (%)	0.35	Riboflavin,mg/g	0.22
K, (%)	0.44	Niacin, mg/g	2.70
Na, (%)	0.01	Pantothenic acid, mg/g	1.09
Mg, (%)	0.13	Folacin, mg/g	—-
Fe, ppm	74.9	Carotenes, mg/kg	5.4
Co, ppm	0.50	Vit. E, mg/kg	19.0
Cu, ppm	6.2		
Mn, ppm	18.0		
Zn, ppm	29.5		

Source: Léder, (2004).

The iron content of food is variable, both in terms of quantity and chemical forms. For example, in meat iron content ranges between 2 and 4 mg/100 g, Fish, poultry, and seafood contain less than 2 mg/100 g, eggs contain 0.3 mg/ 100 g, and milk contains less than 0.1 mg/100 g. In vegetables, the highest concentration of iron can be found in legumes (710 mg/100 g). Cereals have a content of 24/ 100 g mg, whereas fruits and vegetables show small and variables amounts of iron.

Calcium and magnesium: Calcium is the most abundant mineral inside the body. More than 99% is found in bones where it plays an important role in their structure and strength. There are significant health impacts of calcium and magnesium deficiencies. Both calcium and magnesium play important roles in bone structure, muscle contraction, nerve impulse transmission, blood clotting and cell signaling (FAO, 2002). Inadequate intake of calcium results in rickets and a risk of osteoporosis, as well as hypertension and stroke. Magnesium deficiency affects neurologic and neuromuscular function, resulting in anorexia, muscular weakness and lethargy. Calcium and magnesium deficiencies for both adults and children are widespread, especially in developing countries (Combs and Nielsen, 2009). For women, both calcium and magnesium are known to play an important role in the prevention and treatment of pre-eclampsia and eclampsia during pregnancy (ACOG, 2002). Calcium plays an important role in muscle contraction and regulation of water balance in cells, as modification of plasma calcium concentration can lead to the alteration of blood pressure (Hofmeyr *et al*, 2007). Magnesium is an essential cofactor for many enzyme systems and plays an important role in neurochemical transmission and peripheral vasodilatation (Norwitz *et al*, 1999).

Nutritional Profile of Pearl Millet

Pearl millet (Pennisetum glaucum), also known as bajra, is one of the four most important cereals (rice, maize, sorghum and millets) grown in marginal agricultural areas where annual rainfall is variable, unpredictable and very low (200–500 mm) and where daily temperature reaches 30 °C (FAO, 2012). Pearl millet is a nutritious cereal grown on about 10 million hectares in India. India is also one of the largest producers of pearl millet crop in the world. Besides providing food for human, millet stems are used for a wide range of purposes, including: the construction of hut walls, fences and thatches, and the production of brooms, mats, baskets, sunshades, etc (IFAD, 1999).

Pearl millet is the sixth most important drought tolerant crops of the tropical and subtropical regions of the world (Abdullahi *et al*, 1998). According to ICRISAT (2012) pearl millet is annually grown on more than 29 million hectare in the arid and semi-arid tropical regions of Asia, Africa and Latin America. India is the largest producer of pearl millet in Asia, both in terms of area (about 9 million hactre) and production (8.3 million tons) with an average productivity of 930 kg/hactre. In India, pearl millet or bajra is grown on almost 10 per cent of India's food-grain area (Nampoothiry, 2004) and it yields about 5 per cent of the country's cereal food.

In developing countries, pearl millet is recognized as an important crop, which helps with food shortages and meeting the nutritional demands of an increasing population. It constitutes an important source of dietary calories and protein in the daily diet of a large segment of the poor population (Simwemba *et al*., 1984). Pearl millet was found significantly rich in resistant starch, soluble and insoluble dietary fibers, minerals, and antioxidants (Ragaee *et al*., 2006). It contains about 92.5% dry matter, 2.1% ash, 2.8% crude fiber, 7.8% crude fat, 13.6% crude protein, and 63.2% starch (Ali *et al*., 2003). In pearl millet the percentage of crude protein varied in the range of 7.02 to 13.67, fat from 4.0 to 7.8, crude fibre from 0.5 to 4.0 and ash content from 0.25 to 2.54 as reported in various papers. Bran fraction which represents about 8 per cent of grain in pearl millet is rich in non-protein nitrogen, non-protein nitrogen ranges from 39.02 to 73.0 mg/100 g and true protein content from 9.9 to 12.2 per cent (Aggarwal, 1992).

Pearl millet is a rich source of energy (361 Kcal/ 100g) which is comparable with commonly consumed cereals such as wheat (346 Kcal/100g), rice (345Kcal/100g) maize (125 Kcal/100g) and sorghum (349Kcal/100g) as per the Nutritive value of Indian foods (NIN, 2007).

Mineral profile of pearl millet: Pearl Millet is cheap and abundant source of minerals which are necessary for proper health and growth of the human health. The type minerals and their importance is discussed in the subsequent paragraph.

Minerals: The mineral contents of pearl millet depend on the cultivation practices, soil and climatic conditions. Mineral content expresses as ash matter of the pearl millet is usually higher than that of other millets and cereals. Pearl millet varieties were also contained appreciable amount of mineral content i.e., potassium, magnesium, calcium, iron, zinc and copper varied from 171.6 to 215.3, 64.1 to 72.0, 27.2 to 37.3, 2.7 to 6.4, 1.3 to 1.9 and 0.1 to 0.5 mg/100 g, respectively. Different treatments such as soaking, fermentation, blanching and roasting can enhance the bio-availability of these minerals by decreasing the level of antinutrients. Therefore, knowledge of nutrient content of these locally grown pearl millet varieties may help in the commercial processing of these grains into value-added food and beverage products which can be an important driver for economy and to curb malnutrition in developing countries (Kaushik *et al*, 2017). Millets are rich in minerals like iron, magnesium, phosphorous and potassium. Finger millet is the richest in calcium content, about 10 times that of rice or wheat. In this fashion, nutrient to nutrient, every single millet is extraordinarily superior to rice and wheat and therefore is the solution for the malnutrition that affects a vast majority of the Indian population (Malathi *et al*., 2016).

Mac Masters *et al* (1971) determined the locations of minerals in pearl mille kernels by X-ray energy dispersive analysis. High levels of Si and K were present in the covering layers (including aleurone), and a major portion of the phopshourous was located in the germ. High levels of iron were found in both germ and covering layers. Low mineral concentrations were observed in the hard and soft endosperms; the predominant minerals detected in those areas were S, K, and Fe. The greater concentration of minerals in the covering layers and the germ than in the endosperm portions is typical of most cereal grains.

Iron: Iron content of pearl millet in various studies varies from 3.0 to 18.0 mg/100g which is higher in comparison to other food grains. Calcium content in pearl millet varieties ranges from 10 to 80 mg/100g and phosphorus from 185 to 990mg/100g. However, presence of anti-nutritional components may adversely affect their bio-availability. Iron biofortification of pearl millet (Pennisetum glaucum) is a promising approach to combat iron deficiency in the millet-consuming communities of developing countries. Caramondi (2013) evaluated the potential of iron-biofortified millet to provide additional bioavailable iron compared with regular millet and post-harvest iron-fortified millet and an iron absorption study was conducted in 20 Beninese women with marginal iron status. Composite test meals consisting of millet paste based on regular-iron, iron-biofortified, or post-harvest iron-fortified pearl millet flour accompanied by a leafy vegetable sauce or an okra sauce were fed as multiple meals for 5 days. Results indicate that consumption of iron-biofortified millet would double the amount of iron absorbed and, although fractional absorption of iron from biofortification is less than that from fortification, iron-biofortified millet should be highly effective in combatting Iron deficiency in millet-consuming populations.

Iron and zinc rich variety of pearl millet: Biofortified high iron and zinc pearl millet has been developed by ICRISAT using conventional breeding. It has a 2.5–3.5-fold increase in iron content and double the zinc content with the highest contents up to 12.4 and 8.4 mg/100 g, respectively. While the increased levels of iron were still within levels previously reported for normal pearl millet and other millets, the zinc contents are substantially increased. The biofortified pearl millet has also been found to have improved iron and zinc bioavailability and iron absorption (Caballero, 2015).

Lonnerdal, (2000) studied that pearl millet bred to contain more iron can provide young children with their full daily iron needs. These new varieties of pearl millet are being conventionally bred to provide more dietary iron to rural farming communities in arid drought-prone regions where few other crops thrive. In the study, iron-deficient Indian children under the age of three who ate traditionally prepared porridges (sheera, uppama) and flat bread (roti) made from iron-rich pearl millet flour absorbed substantially more iron than from ordinary pearl millet flour, enough to meet their physiological requirements. As an added bonus, this iron-rich pearl millet also contained more zinc, which was similarly absorbed in sufficient amounts meet the children's full daily zinc needs. Lack of zinc in children can lead to stunting and impaired immune response against common infections.

In another study, Lonnerdal, (2000) observed that marginally iron-deficient Beninese women who ate a traditionally prepared iron-rich pearl millet paste were found to absorb twice the amount of iron than paste made from ordinary pearl millet with lower iron content. The results indicate that less than 160 grams of iron-rich pearl millet flour daily is enough to provide Beninese women aged 18-45 with more than 70 percent of their daily iron needs. The equivalent amount of the ordinary pearl millet used in the study provided only 20 percent of their iron needs. Women, generally, have higher iron needs than children. The first iron-rich pearl millet variety (ICTP-8203Fe) was commercialized in 2012 in Maharashtra, India. It also provides more zinc, is high yielding and is disease and drought tolerant. Results from this study indicate that children could get their full daily iron needs from just 100 grams of this pearl millet flour. Children aged under two, who might eat less, would still benefit substantially from eating iron-rich pearl millet (Anon, 2013).

Phosphorus: Millet's high phosphorous (P) content may be an important factor in determining the total nutritional value of this grain, particularly if phosphorous is present in the grain as phytin, which may reduce the absorption of trace minerals from the gastrointestinal tract. Phytin phosphorous has been reported to constitute from 33 to 90% of the total phosphorous in cereal grains (Hamdy, 1971). Pearl millet is a rich source of phosphorus, which plays an important part in the structure of body cells. Phosphorus, found in pearl millets, is a significant component of several necessary compounds including adenosine triphosphate (ATP). This element is also a crucial component of nucleic acids, which are the building blocks of the genetic code. Phosphorus is a constituent of lipid-containing structures such as cell membranes and nervous system structures.

Vitamins: The vitamin content of pearl millet is not much different from sorghum. Dried, matured kernels do not contain vitamin C and the B vitamins are concentrated in the aleurone layer and germ. Removing the hull by decortication reduces the levels of thiamine, riboflavin and niacin by about 50 per cent in the flour. Niacin in pearl millet is found in free and bound forms and can be synthesized from tryptophan. This is why the vitamin B3 insufficiency disease, pellagra, is not found in areas where millet is consumed in great quantities. Malting and fermentation increase the amount of B vitamins and their availability.

FOOD PRODUCTS FROM PEARL MILLET

In Africa and Asia, pearl millet is consumed, primarily in the form of thick and thin porridges (fermented and unfermented), flat bread (fermented and unfermented), steamed and boiled cooked products, snacks alcoholic beverages and in composite flour for bread, cookies noodles etc. Next is the flat bread either fermented or unfermented. Idli is steamed product made in India, usually for breakfast. Different types of food products can be prepared from pearl millet flour such as roti, porridge from grits, non-fatty, crisp noodles and puffs etc. Various types of traditional health foods can be prepared from pearl millet like Bhakar, Chakli, Dashmi, Kharvadi, Khichadi, Kurdaya, Nagdive, Papadi, Shankarpali, Shev, Thalipeeth and Usal (Deshmukh *et al*, 2010).

CONCLUSION

Pearl millet is a nutritious cereal and widely available in India. It has tremendous potential to combat the mineral deficiency vis-à-vis malnutrition in India. It provides key minerals like iron and zinc and incorporation of pearl millet into convenience food products would provide the balanced food to the consumer. Various varieties of pearl millet which are richer in zinc and iron are developed and continuous work is going on to improve the varieties of pearl millet in respect to mineral enhancement. The incorporation of pearl millet in diet can be an effective and most economical way of dealing with micronutrient and mineral deficiencies.

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