Introduction
INTRODUCTION

In many developing countries large chunks of the population are compelled to live below the poverty line. They have a very poor standard of living, poor access to medical facilities and widespread illiteracy. Superstitions, taboos and myths and various types of ignorance are widely prevalent in these communities. In this scenario malnutrition is rampant among the socio-economically backwards communities.

In India, like other developing countries, the poor people have very low purchasing capacity which compels them to pass their days in semi-starved condition. Iron deficiency anaemia is one of the most widespread but neglected problems. “Hidden hunger” or micronutrient deficiency hinders both economic as well as national development and also reduces the individual human potentiality in the form of blindness, mental retardation, poor immunity, low learning ability etc. (1). Micronutrient deficiencies are also widespread in India but the prevalence of different micronutrient deficiencies varies widely across the states. Iron deficiency anaemia, sub-clinical Vitamin-A deficiency and Iodine deficiency are the most common type of malnutrition (2).

Child mortality constitutes more than 34% of total deaths in India (3). Seven out of ten of these deaths are due to respiratory infections, diarrhoea and malnutrition. Under-five morbidity and mortality rates are also high in India (4). Diarrhoea (12%) and pneumonia (15%) are the two major causes of under-five mortality (5). Protein energy malnutrition is a main contributory factor in the majority of these childhood morbidities and mortalities (4). Even globally, undernutrition contributes to more than 1/3rd of child death (5).

Figure-1: In India, among the under-five children, 39% are stunted and 15% are wasted
Based on WHO definition, protein energy malnutrition (PEM) refers to “an imbalance between the supply of protein and energy and the body's demand for them to ensure optimal growth and function”. It is a major public health problem in India. It affects particularly the preschool children (below 6 years). PEM is measured in terms of underweight (low weight for age), stunting (low height for age) and wasting (low weight for height). The majority of such incidence of children suffering from mild to moderate undernutrition remain unnoticed. The sociocultural factors are an important causative factor for developing PEM. The poor nutritional status of the mother comes up as a direct determinant in delivering a low birth weight baby, worse if the child is born to a large and poor family. The condition is worsened by the susceptibility to infections and lack of health care services. Faulty feeding practices, food fads and taboos, ignorance as well as lack of food availability further deteriorate the situation (6).

According to India State Hunger Index (2009), India was the home of the largest number of hungry people in the world with more than 200 million food-insecure citizens. India’s rank on the Global Hunger Index 2008 was 66th; the ranks of the different states in relation to the GHI ranged from 34th for the state of Punjab to 82nd for Madhya Pradesh. Not a single state in India falls in the “low hunger” or “moderate hunger” category defined by the GHI 2008. Instead, most of the states fall into the “alarming” category, with one state, Madhya Pradesh, falling in the “extremely alarming” category. Four states—Punjab, Kerala, Andhra Pradesh, and Assam—fall in the “serious” category (7).
Bharati, P. et al. (2009) conducted a large cross-sectional study on 26,369 preschool (0-35 months) children (13784 boys and 12585 girls), selected from 26 States of India, by measuring their height and weight. The children were lighter and shorter than the International standards irrespective of their age and sex. Boys were heavier and taller than girls. Urban preschool children were comparatively heavier and taller than those from rural areas. Both in urban and rural areas, the prevalence of underweight as well as stunted growth in girls was higher than that of boys. There was a significant rural-urban as well as gender difference in growth and nutritional status of Indian children (0-35 months)\(^8\).

In 2011, the HUNGaMA (Hunger and Malnutrition) Survey was conducted across 112 rural districts of India, covering nearly 20% of Indian children to collect nutrition information. The 112 districts surveyed by HUNGaMA were divided into following 3 categories:

- 100 focus districts selected from the six states: Bihar, Jharkhand, Madhya Pradesh, Orissa, Rajasthan and Uttar Pradesh.
- 6 best districts from focus states, one district per state.
- 6 best districts from ‘best’ states namely Himachal Pradesh, Kerala and Tamil Nadu (two districts per state)

The HUNGaMA Survey captured data regarding the nutritional status of 1,09,093 children under five years of age. Data collection took place between October 2010 and February 2011 in 3,360 villages in 112 rural districts across 9 states. The HUNGaMA survey covered about 1/6\(^{th}\) of India’s population and about 1/5\(^{th}\) of India’s children\(^9\).

**The key focus of the HUNGaMA Survey\(^9\):**

- **Child malnutrition was widespread across the states:** In the 100 Focus Districts, 42% of children under-five were underweight and 5% were stunted. Among the stunted children, about half were severely stunted. In the best district in each of these states, the rates of child underweight and stunting were significantly lower i.e. 33% and 43% respectively.

- **A reduction in the prevalence of child malnutrition was observed:** In the 100 Focus Districts, the prevalence of child underweight decreased from 53% (DLHS, 2004) to
42% (HUNGaMA 2011); representing a 20.3% decrease over a period of 7 years, with an average annual rate of reduction of 2.9%.

**Child malnutrition starts very early in life:** 42% children (aged 24 months) were underweight and 58% were stunted in the 100 Focus Districts. Birth weight was an important risk-factor as the prevalence of underweight in children born with a low birth weight (i.e. below 2.5kg) was 50% while that among children born with a normal weight (i.e. above 2.5 kg) was 34%; the corresponding figures for stunting were 62% and 50% respectively.

**Household socio-economic status had a significant effect on children’s nutrition status:** The prevalence of malnutrition was significantly higher among children from low-income families, but rates of child malnutrition were also significant among middle and high-income families. Children belonging to Muslim or Scheduled Castes or Schedule Tribes families generally had worse nutritional status.

**Mothers’ education level was a determinant of children’s nutrition:** In the 100 Focus Districts, 66% mothers did not attend school; rates of child underweight and stunting were significantly higher among mothers with low levels of education; the prevalence of child underweight among mothers who could not read was 45% while that among mothers with 10 or more years of education was 27%, correspondingly the rates of child stunting were 63% 43% respectively.

**Giving colostrum to the newborn and exclusive breastfeeding for first 6 months of a child’s life were not commonly practiced:** In the 100 Focus Districts, 51% mothers did not give colostrum to the newborn soon after birth and 58% mothers fed water to their infants before 6 months.

**Hand washing with soap was not a common practice:** In the 100 Focus Districts, 11% mothers said they used soap to wash hands before a meal and 19% did so after a visit to the toilet.

Both protein-energy malnutrition and micronutrient deficiencies retard the physical and cognitive growth of children and increase the susceptibility to infection, further increasing the risk of malnutrition. Undernutrition also undermines educational attainment, and productivity, with adverse implications for income and economic growth. PEM weakens immune response and aggravates the effects of infection. So, malnourished
children have a higher risk of severe diarrheal episodes and pneumonia. In addition, malnutrition in early infancy is associated with increased susceptibility to chronic disease in adulthood, including coronary heart disease, diabetes and high blood pressure (2).

Moderate and severe wasting represent acute undernutrition, and those children suffered from it have a markedly increased risk of death. The burden of wasting is highest in India, which has more than 25 million wasted children. In 2011, more than 20 million infants, an estimated 15% globally, were low birthweight babies. India alone accounts for 1/3rd of the global burden. In South Asia, the prevalence of low birth weight babies is highest where one in every four new-borns weighing less than 2,500g at birth (5).

Stunting refers to a child who is too short for his/her age. Stunting is the failure to grow both physically and cognitively and is the result of chronic or recurrent malnutrition. Its effects often last a lifetime. Between 1990 and 2014, global stunting prevalence declined from 39.6% to 23.8% and numbers affected declined from 255 million to 159 million. The rate of stunting in the 29 Indian states (Fig-3) showed that stunting rate declined from 2005-06 to 2013-14 among the children below 5 years of age in every state of India, which is a good sign (10).

**Figure-3: Stunting rates among the children below 5 years of age in 2005–2006 and 2013–2014 in 29 Indian states**

*Source: Global Nutrition Report (2015)*
Wasting refers to a child who is too thin for his / her height. Wasting is the result of sudden or acute malnutrition, where the child is not getting enough calories from food and faces an immediate risk of death. In 2014, Approximately 1 out of every 13 children in the world was wasted. Nearly 1/3rd of all wasted children were severely wasted, with a global prevalence of 2.4%. 50 million under-five children were wasted in the world of which 16 million were severely wasted. In 2014, almost all wasted under-five children lived in Asia (68%) and Africa (28%). Southern Asia is home to more than half of all wasted under 5 children in the world (11).

\[ \text{Source: Global Nutrition Report (2015)} \]

Fig-4 compares the rates of wasting among the children below 5 years of age across the two time periods. Most states except a few show a decline in wasting rates. Arunachal Pradesh, Maharashtra, Andhra Pradesh, Goa, and Mizoram show increases in wasting, although the increases for the first two are marginal (10).

The significant declines in stunting rates from 2006 to 2014, in almost all Indian states, was showed to be positively correlated with the strong increases in exclusive breastfeeding rates over the same period.
The exclusive breastfeeding rates were nearly doubled in the past eight years. Fig-5 showed a positive picture for exclusive breastfeeding rates in India. The exclusive breastfeeding rate in India increased from 46% to 65%. In 2005–2006 only four states had rates of 60% or higher whereas in 2013-2014, 18 states do (10).

In 2011, Infant mortality rate (per 1,000 live births) was 47 and Neonatal mortality rate (per 1,000 live births) was 32 in our country (5). In West Bengal, Infant mortality rate and under five mortality rate (per 1000 live births) are 27 and 32 respectively. Among the adults (15-49 years) 21.3% women and 19.9% men are underweight (BMI< 18.5Kg/m²). 54.2% of under five children, 62.5% women and 30.3% men are anaemic (12).

After childhood, a rapid growth spurt occurs during the adolescent period, when up to 45% of skeletal growth takes place, 15-25% of adult height is achieved and up to 37% of total bone mass may be
accumulated. Calcium intake and bone deposition in adolescent period is the key factor for determining the bone mineral mass in later life. According to WHO, adolescents are individuals aged between 10-19 years. Adolescence may be divided into three developmental stages based on physical, psychological and social changes (13).

- Early adolescence, 10/13-14/15 years;
- Mid adolescence, 14/15-17 years;
- Late adolescence, between 17-21 years, but variable.

To sustain rapid growth along with many physiological and psychological changes of the adolescent period there are increased requirement of all nutrients. But many socio-economic factors are responsible for inadequate access to food and/or unhealthy dietary patterns which include-

- Poverty and lack of access to food (food insecurity): This is a major cause of food unavailability among the adolescents. In India, the intake of energy, protein, calcium, thiamine and riboflavin among adolescent girls was significantly higher in rural areas than in urban areas, but irrespective of urban or rural population, mean dietary intakes were below the recommended intakes for energy and many nutrients (13). The dietary inadequacy of the adolescent girls and boys make them susceptible to many deficiency disorders like underweight, stunted growth, anaemia and many other specific deficiency disorders (13).

*Figure-7: Poverty and Gender discrimination reduce the food availability of adolescents*
• Gender inequality: This is prevalent in some cultures where parents allocate nutritious foods and other resources differently depending on whether the child is a boy or a girl. Gender discrimination is more prevalent in Asia than in Africa (13).

1.1 IMPORTANCE OF IRON FOR REDUCING THE MAGNITUDE OF ANAEMIA

Anaemia is the world’s second leading cause of disability and is responsible for about 1 million deaths in a year, of which three-quarters occur in Africa and South-east Asia (14). According to WHO anaemia is a condition in which the number of red blood cells (and consequently their oxygen-carrying capacity) is insufficient to meet the body’s physiologic needs (15). WHO classified anaemia as a problem of public health significance in the following manner (Table-1) - (16), (17)

<table>
<thead>
<tr>
<th>Prevalence of anaemia (%)</th>
<th>Category of public health significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤4.9 %</td>
<td>No public health problem</td>
</tr>
<tr>
<td>5.0 to 19.9 %</td>
<td>Mild public health problem</td>
</tr>
<tr>
<td>20 to 39.9 %</td>
<td>Moderate public health problem</td>
</tr>
<tr>
<td>≥40.0%</td>
<td>Severe public health problem</td>
</tr>
</tbody>
</table>

1.1.1 Prevalence of Anaemia

The prevalence of anaemia and severe anaemia globally as well as in South-East Asia Region is as follows (WHO, 2011) (Table-2) (17).
Table-2: The global prevalence of anaemia and severe anaemia, as well as prevalence in South-East Asia Region (WHO, 2011)

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Percentage of population with anaemia</th>
<th>Percentage of population with severe anaemia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In the World</td>
<td>In South East Asia Region (WHO)</td>
</tr>
<tr>
<td>Children (6–59 months)</td>
<td>42.6%</td>
<td>53.8%</td>
</tr>
<tr>
<td>Non-pregnant women (15–49 years)</td>
<td>29.0</td>
<td>41.5%</td>
</tr>
<tr>
<td>Pregnant women (15–49 years)</td>
<td>38.2%</td>
<td>48.7%</td>
</tr>
<tr>
<td>All women of reproductive age (15–49 years)</td>
<td>29.4%</td>
<td>41.9%</td>
</tr>
</tbody>
</table>

Figure-8 (A): Percentage of population with anaemia in the world and in the South East Region

Figure-8 (B): Percentage of population with severe anaemia in the world and in the South East Region
Anaemia is a severe public health problem in India and its neighbouring countries like Nepal, Bhutan, Pakistan and Bangladesh \(^{(14)}\). Based on WHO (2011) estimation of anaemia, the prevalence of anaemia and severe anaemia in India is mentioned below (Table-3) \(^{(17)}\) –

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Specification for prevalence of anaemia in India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children aged 6–59 months</td>
<td>Mean blood haemoglobin concentration (g/L) 106</td>
</tr>
<tr>
<td></td>
<td>Percentage of children with blood haemoglobin Concentration &lt;110 g/L 59</td>
</tr>
<tr>
<td></td>
<td>Percentage of children with blood haemoglobin concentration &lt;70 g/L 1.8</td>
</tr>
<tr>
<td></td>
<td>Level of public health significance Severe</td>
</tr>
<tr>
<td>Non-pregnant women aged 15–49 years</td>
<td>Mean blood haemoglobin concentration (g/L) 119</td>
</tr>
<tr>
<td></td>
<td>Percentage of children with blood haemoglobin concentration &lt;120 g/L 48</td>
</tr>
<tr>
<td></td>
<td>Percentage of children with blood haemoglobin concentration &lt;80 g/L 2.5</td>
</tr>
<tr>
<td></td>
<td>Level of public health significance Severe</td>
</tr>
<tr>
<td>Pregnant women aged 15–49 years</td>
<td>Mean blood haemoglobin concentration (g/L) 108</td>
</tr>
<tr>
<td></td>
<td>Percentage of children with blood haemoglobin concentration &lt;110 g/L 54</td>
</tr>
<tr>
<td></td>
<td>Percentage of children with blood haemoglobin concentration &lt;70 g/L 1.3</td>
</tr>
<tr>
<td></td>
<td>Level of public health significance Severe</td>
</tr>
<tr>
<td>All women of reproductive age (15–49 years)</td>
<td>Mean blood haemoglobin concentration (g/L) 118</td>
</tr>
<tr>
<td></td>
<td>Percentage of women with anaemia (blood haemoglobin concentration &lt;120 g/L for non-pregnant women and &lt;110 g/L for pregnant women) 48</td>
</tr>
<tr>
<td></td>
<td>Percentage of women with severe anaemia (blood haemoglobin concentration &lt;80 g/L for non-pregnant women and &lt;70 g/L for pregnant women) 2.4</td>
</tr>
<tr>
<td></td>
<td>Level of public health significance Severe</td>
</tr>
</tbody>
</table>

**1.1.2. Causes of Iron Deficiency Anaemia**

The main causes of iron deficiency anaemia are –

1. Low bioavailability of iron consumed
2. Inadequate intake of iron compared to the iron requirement.
3. Increased need for iron during the rapid growth period of infancy and early childhood, adolescents, pregnancy, lactation etc. \(^{(18)}\)
4. Micronutrient inadequacy like deficiencies of vitamin A, vitamin B\textsubscript{12}, folic acid, riboflavin and copper.

The causes of dietary iron inadequacy, the primary cause of anaemia, are as follows –

- Poor purchasing capacity of the poverty-stricken people
- Illiteracy of the community
- Poor standard of living
- Ignorance about the nutritive value of locally available, cheap, nutritious foodstuffs
- Religious and cultural taboos regarding foods
- Superstitions and myths about diet
- Large family size \textsuperscript{19}

1.1.3. Adverse Effects of Anaemia

Adverse Effects of Anaemia in Adults include—

i. Reduced physical development causing reduced work output and decreased work capacity \textsuperscript{14}.

ii. Poor pregnancy outcome and increased risk of infant and maternal mortality. Globally 20% of maternal deaths directly results from anaemia whereas another 50% of maternal mortality is associated with anaemia \textsuperscript{19}.

![Figure-9: Signs and Symptoms of Anaemia](image-url)
iii. The cognitive development as well as growth and behaviour of preschool and school children are impaired. Reduced cognitive performance leads to poor concentration, disturbance in perception and poor learning ability \(^{(14)}\), \(^{(20)}\).

iv. Anaemia reduces immunity and increases the frequency of infections in all age groups, which in turn further decreases the body iron stores and aggravates the situation of malnutrition \(^{(20)}\).

1.1.4 Food-Based Approaches to Prevent Iron Deficiency Anaemia

- Improving the availability of the micronutrient rich foodstuffs throughout the year.
- Ensuring access of these foods to the households particularly to the vulnerable groups
- Change in the feeding practice
- Eradicating the superstitions, taboos and myths regarding low-cost, nutritious foods \(^{(21)}\).

1.1.5 Sources and RDA of Iron

Cereals, millets, pulses and green leafy vegetables are the rich sources of iron. Among the vegetables, cauliflower greens (40mg/100g), among cereal-products, rice flakes (20mg/100g) and among pulses, Bengal gram (10mg/100g) and gingelly seeds (9mg/100g) are very good sources of iron. The animal sources of iron includes crab muscles (21mg/100g), Ribbon fish (14mg/100g), herring (9mg/100g), sheep liver (6mg/100g) etc \(^{(22)}\).

The daily requirement of iron is mentioned in Table-4 \(^{(23)}\).

<table>
<thead>
<tr>
<th>Group</th>
<th>RDA of Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>17 mg/day</td>
</tr>
<tr>
<td>Women</td>
<td>21 mg/day</td>
</tr>
<tr>
<td>Pregnant woman</td>
<td>35 mg/day</td>
</tr>
<tr>
<td>Lactating women</td>
<td>21 mg/day</td>
</tr>
<tr>
<td>Infants</td>
<td></td>
</tr>
<tr>
<td>0-6 months</td>
<td>46mcg/Kg/day</td>
</tr>
<tr>
<td>6-12 months</td>
<td>5 mg/day</td>
</tr>
<tr>
<td>Children</td>
<td></td>
</tr>
<tr>
<td>1-3 years</td>
<td>09 mg/day</td>
</tr>
<tr>
<td>4-6 years</td>
<td>13 mg/day</td>
</tr>
<tr>
<td>7-9 years</td>
<td>16 mg/day</td>
</tr>
<tr>
<td>Boys</td>
<td></td>
</tr>
<tr>
<td>10-12 years</td>
<td>21 mg/day</td>
</tr>
<tr>
<td>13-15 years</td>
<td>32 mg/day</td>
</tr>
<tr>
<td>16-17 years</td>
<td>28 mg/day</td>
</tr>
<tr>
<td>Girls</td>
<td></td>
</tr>
<tr>
<td>10-12 years</td>
<td>27 mg/day</td>
</tr>
<tr>
<td>13-15 years</td>
<td>27 mg/day</td>
</tr>
<tr>
<td>16-17 years</td>
<td>26 mg/day</td>
</tr>
</tbody>
</table>
1.2 IMPORTANCE OF CALCIUM FOR MAINTAINING BONE HEALTH

Daily intake of adequate calcium is essential for human beings. Calcium makes up between 1.5-2% of the body weight, accounting for 1200-1600g of the typical adult male body. Almost 99% of this calcium is found in the hard tissues of the body, namely the bones and teeth. The rest is distributed in the blood and soft tissues, such as muscles, the liver and the heart (22).

1.2.1 Need and RDA for Calcium

Formation and maturity of the bones and teeth are the primary functions of the calcium. Though present in small quantity, non-skeletal calcium is responsible for performing many other important roles like neuromuscular excitation, blood coagulation, membrane permeability etc. Calcium is required by an adult for replacing Ca lost from the body through urine, stools, bile and sweat. The calcium loss is around 700mg/day in an adult. Additional Ca is required during growth periods for skeletal development, during lactation to compensate for Ca in milk secreted and during old age to prevent excessive bone resorption (23). The daily requirement of calcium is mentioned in Table-5 (23).

<table>
<thead>
<tr>
<th>Group</th>
<th>RDA of calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult men and women</td>
<td>600 mg/day</td>
</tr>
<tr>
<td>Pregnant and lactating women</td>
<td>1200 mg/day</td>
</tr>
<tr>
<td>Post-menopausal women</td>
<td>800 mg/day</td>
</tr>
<tr>
<td>Infants</td>
<td>500 mg/day</td>
</tr>
<tr>
<td>1 to 9 years boys and girls</td>
<td>600 mg/day</td>
</tr>
<tr>
<td>10 to 18 years boys and girls</td>
<td>800 mg/day</td>
</tr>
</tbody>
</table>

Since milk is a rich source of calcium, the daily calcium intake is fairly high, around 1g or more, in those consuming plenty of milk, as in the Western communities. But in developing countries like India where intake of dairy products is substantially low, most dietary calcium comes from cereals (23). However, cereals contain only moderate amount of calcium, so the daily calcium intake of most Indians, particularly those from lower and middle socio-economic classes, lies in a low range of 300-600mg/day. Other rich sources of Ca among plant foods include the millet ragi and the green leafy vegetables. There is
evidence of widespread calcium depletion, as indicated by bone density measurements, particularly in women after repeated pregnancy and lactation (23).

1.2.2 Symptoms of Calcium Deficiency

Deficiency of calcium is responsible for developing many symptoms, as described below—

a) Muscle cramping, one of the first signs of calcium deficiency, generally occur at night, especially in the legs.

b) Symptoms of moderate calcium deficiency include joint pains, heart palpitations, increased cholesterol levels, slow pulse rates, insomnia, impaired growth, excessive irritability, dry skin, brittle nails, yellowish teeth etc.

c) Osteoporosis and frequent bone fractures are the results of chronic calcium deficiency (24).

Osteoporosis afflicts the entire skeletal system. In addition to fractures, osteoporosis causes shrinkage of vertebrae, height loss, hunched backs, and bone pain (25). Repeated
bone fractures as well as poor and slow recovery from it, causes pain and invites movement disability which is a major problem of old age. Osteoporosis-related morbidity and mortality, as well as health care costs, have significant public health concern\(^{(26)}\).

The effective strategies essential to maintain good bone health and prevent osteoporosis include achieving higher peak bone mass (PBM) in early adulthood, maintaining the bone mass gained and reducing the loss. Regular intake of a balanced diet, containing an adequate amount of calcium, magnesium, potassium and vitamin D throughout the life is essential for maintaining good skeletal health\(^{(27)}, (28)\).

In our country, a large section of the population remains below the poverty line. Their diet is usually devoid of milk, resulting in dietary calcium inadequacy, and thus, skeletal problems are frequently observed among them. In this scenario, it is needed to develop a low-cost, calcium rich supplementary product and distribute it among the poverty-stricken people, which may be helpful to ensure adequate calcium intake.

### 1.3. IMPORTANCE OF DIETARY MAGNESIUM

Magnesium (Mg) is important for proper functioning of the nerves and the heart and it aids in many enzymatic reactions. Most of the magnesium in the body is found in bones which contain 60% of the body’s magnesium\(^{(20)}\).

#### 1.3.1. Sources of Magnesium\(^{(20)}\)

As magnesium is found in the plant pigment chlorophyll, so plant foods like green vegetables, wheat bran, whole grains, beans, nuts, legumes, seeds, and broccoli etc. are rich sources of magnesium. Animal products like milk and meats supply some magnesium. Hard water, which contains a high mineral content, and coffee are the two good sources of magnesium.

#### 1.3.2. Daily Requirements for Magnesium

The adult RDA for magnesium is about 340mg/day for men and about 310mg/day for women\(^{(23)}\). About 30% of the dietary magnesium is absorbed from the small intestine and
widely distributed to all metabolically active tissue \(^{(29)}\). Ageing, stress and various diseases increase the magnesium requirement \(^{(30)}\).

### 1.3.3. Functions of Magnesium \(^{(20), (29)}\)

1. Magnesium serves a structural role in bones to provide rigidity.
2. Magnesium helps in muscle relaxation after contraction.
3. It resists tooth decay by stabilising calcium in tooth enamel.
4. Over 300 enzymes use magnesium.
5. It plays a critical role in the synthesis of DNA and protein.
6. Magnesium is required for the synthesis of vitamin D in the liver.
7. Magnesium helps to reduce blood pressure by dilating arteries and preventing heart abnormalities.
8. It is required for the transmembrane transport of potassium and calcium.
9. Magnesium influences both the secretion and action of PTH \(^{(29)}\).

### 1.3.4. Deficiency of Magnesium

Since magnesium is present in most of the common foodstuffs, hence low dietary intake of magnesium is associated with general nutritional insufficiency. It usually results from a combination of poor dietary intake and increased urinary or intestinal losses.

The symptoms of magnesium deficiency include-
- Decreased bone strength and volume
- Poor bone formation and development
- Increased bone resorption.
- Irregular heartbeat, sometimes accompanied by weakness, muscle pain, disorientation, and seizures \(^{(20)}\).

### 1.4. IMPORTANCE OF ZINC FOR MAINTAINING GOOD HEALTH

Zinc is an essential micro-mineral present in our body. Approximately 200 enzymes require zinc as a cofactor for activity. It is a part of many enzymes like carbonic anhydrase, alcohol dehydrogenase, alkaline phosphatase and steroid hormone receptors \(^{(20)}\).
The body has a small reserve of zinc which is mainly located in muscles and bones. In the liver, zinc is incorporated into metalloenzymes, while in blood it is mainly present in the erythrocytes. Zinc is excreted in urine, bile, pancreatic juice and in the milk of the lactating mothers (29).

1.4.1 Functions of Zinc (20)

Adequate zinc intake is necessary to support many bodily functions, such as:

- DNA synthesis and function
- Protein metabolism, wound healing, and growth
- Immune function
- Development of sexual organs and bones
- Storage, release, and function of insulin
- Maintaining of cell membrane structure and function
- Prevention of oxidative damage to cells (Zinc being a component of the enzyme superoxide dismutase, acts as an antioxidant)
- Reducing the risk of developing certain forms of cancer.

1.4.2 RDA and Sources of Zinc

For the Indian adults, RDA for zinc is 12mg for men and 10mg for women (23). Protein-rich foods are rich in zinc. Animal foods supply almost half of zinc intake. Other sources of zinc are fortified breakfast cereals, wheat germ, and some cheeses. Approximately 30% zinc is absorbed from the animal foods. Zinc found in animal foods is better absorbed than that in plant foods due to the presence of phytates in the latter source, which form an unabsorbable salt of zinc. The forms generally used in multivitamin and mineral supplements (zinc oxide), although not as well-absorbed as the zinc found naturally in foods, still fulfils zinc requirements to a certain extent (20).

1.4.3 Zinc Deficiency

Zinc deficiency is a major public health problem in the poorer nations of the world, now recognised among the South Asian developing economics. Prevalence of zinc deficiency in
developing countries is very common, and 61% of the population is at an increased risk of low dietary zinc intake \(^{(31)}\).

1.4.3.1 Causes \(^{(32)}\)
- Low dietary intake
- Low bioavailability
- Unhygienic conditions
- Recurrent infections
- Poor socioeconomic status
- Inadequate monitoring and surveillance as well as a lack of public awareness.

1.4.3.2 Symptoms

Zinc deficiency is characterised by
- Growth retardation
- Poor wound healing capacity
- Poor sexual development
- Acne-like skin rash
- Hair loss
- Diarrhoea
- Anorexia
- Reduced sense of taste and smell
- Low learning capacity.

The high mortality rate among children resulting from infections like diarrhoea, pneumonia, and malaria has been reported to be associated with inadequate zinc intake \(^{(20)}, (29)\).

1.4.3.3 Current Strategies for Combating Zinc Deficiency

Supplementation, fortification and dietary diversification are the most viable strategies for enhancing zinc status among various population groups \(^{(32)}\).
1.4.3.4 Zinc Deficiency in India

Zinc deficiency is prevalent among preschool and school children as well as pregnant and lactating women in South Asian developing countries like India, Pakistan, Bangladesh, Sri Lanka, and Nepal. Diarrhoea has been established as a leading cause to intensify zinc deficiency (31).

In India, recent epidemiological studies have confirmed high prevalence of zinc deficiency among children belonging to lower socioeconomic groups in five major Indian states, reporting an overall zinc deficiency of 43.8% (cutoff level ≤65 μg/dL), with the highest in Orissa (51.3%), followed by Uttar Pradesh (48.1%), Gujarat (44.2%), Madhya Pradesh (38.9%), and Karnataka (36.2%) (31).

A recent study on the Zinc status of the adolescent girls (10-16 years) revealed that low plasma zinc concentration and poor cognitive performance in 45% of the adolescent girls (n=630) in India, signifying the need to adopt dietary zinc intake for normal health (Kawade, R., 2012) (33). Another study by Pathak P. et. al. (2008) stated that nearly 65% of the pregnant women from Haryana suffered from zinc deficiency because of low dietary intake (34). Similarly, a community-based cross-sectional survey on 288 nulliparous non-pregnant women from Haryana showed a high prevalence of zinc deficiency (41%) (35).

1.5 ROLE OF GOOD SODIUM-POTASSIUM RATIO IN MAINTAINING HEALTH

Sodium (Na+) is the principal extracellular cation whereas potassium (K+) is the main intracellular cation.

Since sodium is widely distributed in plant and animal foods and common salt (NaCl), hyponatraemia (sodium deficiency) is not so common in people. Hyponatraemia usually occurs when sodium loss or water retention occurs such as in case of prolonged diarrhoea or vomiting (29).

Symptoms of hyponatraemia reflect neurological dysfunction resulting from cerebral over-hydration induced by hypo-osmolality.
On the other hand, potassium performs many of the same functions as sodium, such as water balance and nerve impulse transmission. It is the principal cation of the intracellular fluids, which contains 95% of the K$^+$ in the body. Approximately 90% of the potassium consumed is absorbed. Low blood potassium is a life-threatening problem. Symptoms often include a loss of appetite, muscle cramps, confusion, and constipation. Eventually, the heart beats irregularly, decreasing its capacity to pump blood (20).

Unprocessed foods are rich sources of potassium. This includes fruits, vegetables, milk, whole grains, potatoes, dried beans, tomatoes, orange juice, meat, coffee. The Adequate Intake for potassium for adults is 4.7g/day (20).

Higher potassium intake is associated with lower blood pressure values. A diet low in sodium and high in potassium reduces the risk of hypertension and stroke (20).

Dietary sodium intake influences blood pressure level in population and should be limited so as to reduce the risk of coronary heart disease and both forms of stroke. Current evidence suggests that an intake of not more than 70 mmol or 1.7 g of sodium/day is beneficial in reducing blood pressure, which can be achieved by restricting daily salt (sodium chloride) intake to less than 5 g / day. Adequate dietary intake of potassium lowers blood pressure and is protective against stroke and cardiac arrhythmias. Potassium intake should be at a level which will keep the sodium to potassium ratio close to 1.0, i.e. a daily potassium intake level of 70-80 mmol per day. This may be achieved through adequate daily consumption of fruits and vegetables (36).

The diet of the most Indians, particularly those from the poorer communities in rural and tribal areas are rich in common salt which supplies excessive amount sodium. But such diets are usually inadequate in potassium-rich foods like fruits and green leafy vegetables which lead to dietary potassium inadequacy. These type of high sodium, low potassium diet increases the risk of developing hypertension which in long term invites many other cardiac ailments.
1.6 NEED FOR DEVELOPING LOW COST, NUTRITIOUS, SUPPLEMENTARY PRODUCT IN OUR COUNTRY

India is the second most populous country in the world, next to china, with over 1.21 billion people (2011 census), contributing to 17.5% of the world's total population \(^{(37)}\). \(^{(38)}\)

In 2011-12, India had 270 million people below the poverty line, which constitutes about 21.92% of the citizens. The percentage of persons below the poverty line was 25.7% (2166.58 lakhs) in rural areas and 13.7% (531.25 lakhs) in urban areas of the country. For 2011-12, for rural areas the national poverty line is estimated at Rs. 816 per capita per month and Rs. 1,000 per capita per month in urban areas \(^{(39)}\).

The poverty line would vary from State to State because of inter-state price differences. For 2011-12, the state specific poverty line is estimated Rs. 783 per capita per month in rural areas and Rs. 981 per capita per month in urban areas of West Bengal. In this state, 19.98% (i.e. 184.98 lakhs) people live below the poverty line, which includes 141.14 lakhs rural population and 43.83 lakhs urban population. The percentage of people below the poverty line have been estimated to be 22.52% in rural areas and 14.66% in urban areas \(^{(39)}\).

In our country, a large section of the population subsists on an inadequate as well as poor quality intake of cereal-based diet, mostly devoid of animal foods and fruits, having a dietary inadequacy of vegetables and fatty foods. Such a diet is usually deficient in energy, protein, fat, iron, calcium, magnesium, zinc, potassium and vitamins but high in sodium content. It is not possible for them to incorporate any high-cost food in their diet on a regular basis. Hence, to improve the overall health and nutritional status of the Indian citizens and to overcome the problem of malnutrition and age-related disorders, development and distribution of low-cost, nutritious supplementary foods is essential.

There are many health drinks available in the market but all are high-cost foods which are out of reach of the poor. For the betterment of the poorer section of the community, it is an urgent need to develop a low-cost, nutritious, supplementary food by...
using locally available foodstuffs and to distribute it among the “at risk” groups. The newly developed food should be-

- based on easily available foodstuffs
- easy to prepare
- easy to incorporate in many recipes
- well accepted by the common people
- cost-effective
- easy to transport and distribute among the vulnerable people.
- easily consumed by different age groups
- able to provide an adequate amount of all the macronutrients.

So, being a researcher in the field of nutrition it is my social responsibility to do research towards developing low-cost nutritious supplementary food items.

For the research work, three unconventional but easily available foodstuffs, i.e. egg shell, cauliflower leaves and pumpkin seeds, were selected in order to formulate a new low cost nutritious supplementary food. Since cauliflower leaves and pumpkin seeds are abundantly available in season and are considered as waste products in the vegetable markets, they can be collected at free of cost. The egg shell is a common kitchen waste of almost all non-vegetarian households which can also be easily procured. Along with these three zero-cost foods, some other locally available, nutritious foodstuff as well as common spices were also used in the preparation of the supplementary product.

The foodstuffs used as ingredients of the supplementary product include—

A. Rice flakes: Rice flakes is an easily available, commonly consumed rice product. It is used as a source of energy (346Kcal/100g), carbohydrate (77.3g/100g) & iron (20mg/100g). It is a good source of magnesium (101mg / 100g) and potassium (154mg / 100g) as well.[40]
B. **Bengal gram, roasted:** It is a low cost, widely consumed, easily digestible, nutritious pulse. It is selected as a source of energy (369Kcal / 100g), protein (22.5g / 100g), carbohydrate (58.1g / 100g) and iron (9.5mg / 100g). It is a rich source of both potassium (808mg / 100g) and zinc (6.1 mg / 100g) as well as a good source of magnesium (119mg / 100g) also (40).

![Bengal gram, roasted](image)

C. **Groundnut, roasted:** Groundnut is a low cost, tasteful, widely used, nutritious nut. It is used as a source of energy (570Kcal / 100g), protein (26.2g / 100g) and fat (39.8g / 100g). It also provides a good amount of zinc (3.9mg / 100g) (40).

D. **Gingelly seeds:** Gingelly seed is a tasteful, commonly used, highly nutritious nut. It is used as a source of energy (563Kcal / 100g), protein (18.3g / 100g), fat (43.3g / 100g),
calcium (1450 mg/ 100g) & iron (9.3mg / 100g). It is a very rich in zinc content (12.2 mg / 100g) as well (40).

E. Cauliflower leaves: Cauliflower (Brassica oleracea) leaves are low-cost, nutritious, underutilised green leafy vegetables that can be explored to overcome nutritional disorders. Since cauliflower is grown extensively in different parts of India, its leaves are widely available in season but are wasted due to the ignorance of common people. 100g of fresh cauliflower leaves contain 80g moisture, 5.9g protein, 1.3g fat, 7.6g carbohydrate, 2g crude fibre and 66Kcal of energy, 626 mg calcium & 40mg iron. These leaves can be dried and stored for the lean period (40).

Wani TA et. al. (2011) prepared dry cauliflower leaf powder (CLP) from cauliflower leaves. 100g CLP provided 2.41g moisture, 26.54 g protein, 43.11mg β-carotene, 60.38mg Iron, 1.55mg copper, 5.86mg manganese and 5.10 mg zinc (41).

Mohankumar, J. B. et al. (2004) reported that the feeding of cauliflower green preparations to the anaemic girls (20-22 years of age) caused significant (P<0.05) rise in the haemoglobin levels (42). So cauliflower leaves can be used as a valuable source of iron.

F. Pumpkin seeds: Pumpkin (Cucurbita maxima) is a most widely grown and commonly consumed vegetable in many parts of the world, including India. The pumpkin seeds are also highly nutritious but just thrown away in the garbage due to ignorance (43).

According to ICMR, 100g of edible portion of pumpkin seeds contain 8.3g moisture, 24.3g protein, 47.2g fat, 15.6g carbohydrate, and 4.7g total minerals. It supplies 50 mg calcium, 830mg phosphorus and 5.5mg iron. The energy value of pumpkin seed is 584Kcal/ 100g (43).

Pumpkin seed kernel contains 66% unsaturated fatty acids, consisting of 13% oleic acid and 53% linoleic acid. 27% saturated fatty acids are present in the seeds, comprising of 16% palmitic acid and 11% stearic acid. The relatively high iodine value indicates a preponderance of unsaturated fatty acids (14). Pumpkin seed is rich in
choline (63mg/100g), which helps in brain development. Pumpkin seed kernel is rich in minerals, especially P, Mg & K \(^{(43)}\).

The seed kernel flour contains considerable amounts of phosphorus, potassium, magnesium, manganese and calcium. It may be inferred that pumpkin seed flour can be potentially used to improve the nutritive value of the product \(^{(43)}\).

Chung, KH et. al (2013) analyses the detail chemical composition of 11 types of nuts and seeds which showed that pumpkin seeds contained a higher amount of almost all the amino acids compared to other nuts and seeds \(^{(44)}\).

According to the study of Procida G et. al. (2013) the nutraceutical properties of the pumpkin seed oil was confirmed by the presence of high content of \(\alpha\)- and \(\gamma\)-tocopherol and carotenoids in it \(^{(45)}\).

**G. Egg shell:**

It is a source of bio-available calcium \(^{(46)}\). The calcium bioavailability of chicken egg shell is 93.80\% \(^{(47)}\). An average eggshell contains about 35.1 – 35.4% calcium \(^{(48)}\). Clinical and experimental studies showed that eggshell powder had positive effects on bone and cartilage and it was suitable for the prevention and treatment of osteoporosis \(^{(49)}\). The eggshell powder is, in the case of casein-based diets, as good a source of calcium as CaCO\(_3\) and, in the case of soya protein-based diets, better than CaCO\(_3\) for growing piglets.

As the piglet model is considered to be representative for humans, the chicken eggshell powder is also a promising source of calcium for human nutrition \(^{(50)}\).

**H. Some common spices:** Some common spices like cumin seeds, turmeric powder, omum and black salt were added to the product to make the product more nutritious and tasteful. These spices are rich in minerals. Calcium content of 100g each of cumin seeds and omum is 1080mg and 1525mg respectively. Turmeric is a very rich source of iron, providing 67.8mg iron /100g. Cumin seeds (11.7mg /100g) and omum (12.5mg /100g) also supply a good amount of iron \(^{(40)}\).